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Genetic variation and correlation studies between micronutrient (Fe and Zn), protein content and yield attributing traits in mungbean (*Vigna. radiata* L.)

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ABSTRACT

Mungbean can effectively contribute in alleviation of iron, zinc and protein malnutrition as it is a source of micronutrients and protein. To improve this cultivars have to be developed which are rich in micronutrients and protein. But in general more focus is given to quantitative traits such as yield. Breeding mungbean for enhanced grain nutrients is still in its start-up phase. The present study was carried out to access genetic variation for both quantitative as qualitative traits. The correlation between important traits such as yield and Fe, Zn, protein content was calculated. A positive correlation was found between iron and zinc content (r = 0.47) whereas no significant correlation with grain yield was observed indicating no compromise of yield for improving quality. Breeding a cultivar which is nutritionally improved along with high yield is therefore possible. A few promising cultivars with high micronutrients, protein and yield were identified. These cultivars can be used in specific breeding programs aiming at nutrient-rich high yielding cultivars.

Key words: Correlation, Iron, Mungbean, Protein, Quality traits, Quantitative traits.

INTRODUCTION

Mungbean or greengram (*Vigna radiata* L.) is one of the most important food legumes of the genus *Vigna*. Especially for the vegetarian population, it is a good source of protein, carbohydrates, vitamins and minerals (Amarteifio and Moholo, 1998). Proteins of grain legumes are rich in lysine and threonine but poor in methionine and tryptophan. On a dry-weight basis mungbean contains 25 to 28% protein, 1.0 to 1.5% fats, 3.5 to 4.5% fibre, 4.5 to 5.5% ash and 60 to 65% carbohydrate (Singh *et al.*, 2014). In order to increase the nutritional value of meal grain legumes should be eaten together with cereals. Regular consumption of pulses is an excellent method to overcome malnutrition, especially among growing children, pregnant women and nursing mothers.

In developing countries cereal grains and food legumes are the primary source of calcium, iron and zinc but their intake nowadays is not high enough. Studies have shown that in developing nations 26% of the population is anaemic, while this is 10% and 11% in Europe and the US respectively. Studies by Rosado *et al.* (2007) have shown that anaemia is mainly caused by iron deficiency. Forty per cent of iron intake is coming from legumes and cereals. Besides iron, zinc is also an essential micronutrient for normal growth, appetite and immunity. It is an essential component of more than one hundred enzymes involved in digestion, metabolism and wound healing (Stauffer, 1999). While iron deficiency has long been considered a major nutritional problem, zinc deficiency has only recently been recognized as a public health problem (Ranum, 1999).

To start a breeding program for improving mungbean variation is required for yield but also for iron and zinc content and other quantitative traits. Knowledge regarding the availability of such variation, the genetic background causing differences and response to different environmental conditions is important. The majority of the breeding research had its emphasis on yield and resistance against biotic and abiotic stress while little attention has been paid to nutritional value. It is known that concentrations of micronutrients vary in tissue or seed between cultivars and that this variation is partially genetically determined. Literature shows comparable ranges of mineral concentration in most leguminous crop seeds like in common bean, peas, chickpeas, lentils etc. (Haq *et al.*, 2007; Thavarajah *et al.*, 2010). Taunk *et al.* (2012) identified genetic diversity in mungbean for iron and zinc content using RAPD polymorphism among 16 mungbean genotypes. Similarly, molecular diversity among 21 mungbean genotypes varying in micronutrient (Fe, Zn) content was assessed by Aneja *et al.* (2012) using SRAP markers. In the light of such variation in related leguminous crops a study was done to search for variation in mungbean (*V. radiata* L.). As for the producers

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(farmers) quantitative traits such as yield are of more importance thus the correlation was studied between some of these quantitative traits, micronutrient and protein content. Correlations among the variables were estimated to know the association among the variables. As mungbean contains low levels of iron and zinc in cultivated genotypes and it is important to assess genetic variability for iron and zinc among available germplasm for incorporating this trait into commercial cultivars. Thus the overall objective of this study is to obtain better yielding cultivars with a considerable content of micronutrients and proteins so. The availability of such cultivars will improve the status of the people depending on mungbean as the major source of protein and micronutrients.

MATERIALS AND METHODS

Plant material: The experimental material comprised ninety two elite mungbean cultivars along with three controls i.e. high yielding and disease resistant cultivars (MH-215, MH-318 and MH-421 Appendix I). These cultivars were provided by the Pulses Section, Department of Plant Breeding, CCS HAU, Hisar (India).

Field trials and experimental design: The material was grown in two different years (July to September 2007 and 2008) at the university experimental farms of Hisar. Hisar is geographically situated at latitude 29°10’N, longitude 75°46’E and altitude 215.2 m above sea level and falls in the semi-tropical region of the Western Zone of India. The overall weather data during the course of experiment (2007, 2008 like temperature (maximum/minimum), relative humidity, rainfall, bright sunshine hours) was collected with help of the meteorological observatory of the Department of Meteorology, CCS HAU, Hisar (Fig A, B).

Data for some of the agronomic traits were taken at different time points like days to 50% flowering was when the first flower makes its appearance and days to maturity is when most (90%) of the pods on the plant became dark brown in colour. About two weeks before harvesting, the severity of mungbean yellow mosaic virus (MYMV) damage was scored on a scale from 1 to 9. (Singh *et al.*, 1992). For yellow mosaic virus symptoms a score 1 stands for a completely resistant plant and 9 for a completely susceptible plant. At harvest five random plants were selected from each cultivar from each block and yield and quality parameters were measured. These includes plant height (cm), number of branches per plant, number of pods, MYMV severity, seed yield per plant (g), protein (%), iron (ppm) and zinc (ppm).

Statistical procedure: The mean values of yield and its components from the five random plants of each cultivar from each replication were subjected to statistical analysis. The data for each trait were subjected to analysis of variance of the randomized complete block design described by Panse and Sukhatme (1989).

$$Y_{ijk} = \mu \pm R_i \pm G_j \pm e_{ijk}$$

Where, Y_{ijk} is kth observation on jth G cultivar of ith R replication; μ is overall general mean of the population; R_i is the effect of ith replication (i= 1, 2, 3); G_j is the effect of jth cultivar (i.e. j – 1, 2, 3…..92) and e_{ij} is random error.

For protein content, mineral micronutrient concentration (iron and zinc) and yield, Pearson (1973) coefficients were calculated. Before calculating, the data recorded in percentage were subjected to angular transformation and the transformed data was subjected to statistical analysis.

Heritability was calculated according to the formula of Hanson *et al.* (1956): h^2= ó^{2}g/ ó^{2}p, where genetic variance ó^2 g = (MSg- MSe)/k, where k is number of replication, variance due to error ó^{2}e = MSe and ó^2 p = ó^2 g ± ó^2 e. genotypic correlation were computed using genotypic variance and genotypic co-variances obtained from the analysis of variance and co-variance in a manner used for heritability estimation as described by Becker (1975). To estimate the inter-relationships among the variables and their contribution to yield performance the data was subjected to correlation coefficient and path coefficient analysis (Dewey and Lu, 1959).

Genetic diversity was studied following Mahalanobis’s (1936) generalized distance (D^2) extended by Rao (1952). Clustering of genotypes was done according to Tocher’s method (Rao, 1952) and Principal Component Analysis for graphical representation of the genotypes. Selection of parents from the highly divergent clusters is expected to manifest high heterosis and also wide variability in genetic architecture.

Mineral and protein analysis: A subsample of 2 g seeds were picked at random from the bulk seed harvest of each cultivar and washed with sterile water and then dried in an oven for 2 days at 45°C before grinding. Mineral analysis was then implemented on powdered sample using atomic absorption spectroscopy (AAS). Sample preparation for AAS involved digesting of 1 g flour with nitric/per-chloric acid (5 ml of a 2:1 mixture of 65% nitric acid (HNO_3) and 70% per-chloric acid ($HClO_4$)) for 2 h followed by a heat treatment for 2 h and re-suspension in 25 ml of de-ionized water. The resulting samples were analysed in a AAS-800 with acetylene flame (Lindsay and Norvell, 1978). While total nitrogen was determined in the dry seeds by Kjeldahl method using KjelTech (KEL PLUS Classic DX) nutrient analyser as per association of official Analytical Chemists. Protein content was estimated by multiplying total nitrogen content with a factor of 6.25 (Altschul, 1958). The data of mineral micronutrient and protein means along with their standard error are presented in appendix I.

RESULTS AND DISCUSSION

Iron and zinc are needed for a healthy development of humans. Molecular breeding efforts should aim at

Appendix I:

List of 92 cultivars of mungbean varieties with their origin, zinc, iron and protein content and seed yield per plant.

V.No	Varieties	Origin	Mean value of			
			Zn ± S.Emg/100g	**Fe ± S.E**mg/100g	**Protein ± S.E**%	**SYP ± S.E**g
1	2KM-107	-	2.107± 0.009	3.877± 0.484	28.067± 0.030	4.812± 1.389
2	2KM-111	Ludhiana	3.270± 0.031	4.667± 0.447	26.227± 0.056	3.383±0.818
3	2KM-112	IARI	2.680± 0.210	4.467± 0.592	21.360± 0.248	2.070±0.709
4	2KM-114	IARI	3.653± 0.035	4.437± 0.066	23.497± 0.092	3.989±1.461
5	2KM-115	Sri Ganganagar	2.033± 0.041	2.760± 0.211	26.173± 0.050	7.554±2.072
6	2KM-116	Ludhiana	2.333± 0.127	3.510± 0.012	21.780± 0.127	5.458±1.056
7	2KM-117	Varanasi	2.917± 0.018	4.000± 0.632	23.327± 0.161	4.701±0.963
8	2KM135	Sri Ganganagar	2.947± 0.041	3.243± 0.100	27.127± 0.066	3.943±0.891
9	2KM-138	Hisar	2.040± 0.477	2.393± 0.185	28.090± 0.040	6.586±2.280
10	2KM-139	Hisar	1.757± 0.144	2.917± 0.079	27.133± 0.049	2.164±0.545
11	2KM-151	Pant Nagar	2.040± 0.231	4.017± 0.181	26.273± 0.062	5.159±1.047
12	2KM-155	Ludhiana	2.943± 0.288	4.537± 0.872	27.133± 0.049	4.145±0.563
13	2KM-161	Ludhiana	1.820± 0.288	3.053± 0.028	26.153± 0.069	2.862±1.110
14	2KMH-52	Hisar	2.510± 0.012	3.703± 0.057	23.653± 0.064	4.602±0.793
15	AMP-36-10	Hisar	2.443± 0.299	2.653± 0.274	23.610± 0.012	5.679±2.099
16	AMP-36-18	Hisar	2.350± 0.062	2.680± 0.121	22.670± 0.046	9.585±3.089
17	AMP-36-4	Hisar	2.380± 0.076	2.570± 0.111	25.227± 0.111	5.588±1.324
18	ASHA	Hisar	2.363± 0.177	4.117± 0.351	25.370± 0.026	3.422±0.890
19	BDYR-1	Bangladesh	2.503± 0.052	4.527± 0.113	28.550± 0.282	4.363±1.045
20	BDYR-2	Bangladesh	2.490± 0.095	4.660± 0.70	22.670± 0.046	6.441±1.780
21	BG-39	-	2.640± 0.191	6.023± 0.405	26.200± 0.036	2.643±1.026
22	CH1355	-	3.450± 0.131	3.860± 0.061	24.503± 0.012	0.533±0.255
23	CH2103	-	3.130± 0.064	4.620± 0.488	26.250± 0.035	0.565±0.160
24	CoGG902	-	3.133± 0.050	6.750± 2.902	26.217± 0.018	5.091±1.016
25	GANGA-8	Sri Ganganagar	2.837± 0.636	2.390± 0.604	25.383± 0.003	2.934±0.771
26	GP-149	Varanasi	2.853± 0.081	6.017± 1.523	22.367± 0.209	4.255±0.589
27	GP-150	-	3.273± 0.027	3.603± 0.314	24.440± 0.060	4.040±0.812
28	GP-181	Hisar	3.560± 0.040	4.923± 0.369	21.770± 0.059	4.192±1.0101
29	GP-182	Hisar	3.340± 0.036	5.713± 1.988	22.723± 0.018	1.742±0.609
30	GP-196	Hisar	2.743± 0.116	4.440± 0.301	26.263± 0.024	4.437±1.184
31	GP-248	-	2.157± 0.037	3.117± 0.112	27.117± 0.058	5.529±1.469
32	GP-32	-	2.903± 0.369	4.627± 0.470	22.717± 0.024	2.032±0.269
33	GP-68B	-	2.753± 0.035	5.097± 0.871	28.093± 0.069	2.979±0.361
34	GP-69	Hisar	3.287± 0.015	3.260± 0.546	24.513± 0.015	4.756±0.542
35	GP-78	Hisar	3.070± 0.025	4.600± 0.226	30.003± 0.450	5.604±0.232
36	GP-86	Hisar	3.570± 0.032	3.890± 0.767	23.577± 0.035	5.554±0.691
37	GP-86-1	Hisar	3.290± 0.046	4.830± 1.182	24.510± 0.017	4.093±1.251
38	HUM-1	Varanasi	2.010± 0.115	1.597± 0.234	25.327± 0.027	4.545±0.685
39	HUM-7	Varanasi	2.210± 0.017	2.707± 0.250	25.277± 0.129	5.615±1.881
40	IC103196	NBPGR	2.550± 0.035	5.253± 1.840	24.510± 0.017	4.313±1.748
41	IC39574	NBPGR	3.363± 0.059	4.060± 0.464	21.797± 0.056	2.949±0.858
42	IC39595	NBPGR	2.287± 0.018	4.950± 0.955	24.510± 0.012	5.865±1.380
43	KM-92-11	-	3.570± 0.049	9.223± 1.747	22.673± 0.113	6.218±1.387
44	L-24-2	Ludhiana	1.723± 0.241	1.920± 0.142	21.820± 0.035	2.197±0.109
45	LM-10	Ludhiana	2.927± 0.074	3.473± 0.263	24.487± 0.015	4.168±0.675
46	M-1361B	Ludhiana	3.853± 0.043	5.107± 1.112	26.220± 0.046	4.925±0.808
47	M-169	Kanpur	2.057± 0.027	3.833± 0.276	25.390± 0.199	5.033±0.651
48	M-395	Ludhiana	1.607± 0.045	1.757± 0.111	22.670± 0.053	5.401±0.688
49	M-516	Kanpur	1.910± 0.085	2.253± 0.168	21.777± 0.055	6.423±0.960
50	M-605	-	2.257± 0.035	3.007± 0.294	26.297± 0.101	6.031±1.250
51	MH-124	Hisar	1.957± 0.039	3.047± 0.641	23.610± 0.012	6.671±1.612
52	MH-125	Hisar	2.323± 0.184	3.267± 0.135	26.217± 0.018	5.520±0.763
53	MH-215	Hisar	2.433± 0.219	3.283± 0.133	21.057± 0.033	5.723±1.167
54	MH-318	Hisar	3.153± 0.178	5.022± 0.768	23.554± 0.052	7.707±1.600
55	MH-419	Hisar	2.550± 0.136	3.790± 0.583	23.637± 0.058	8.850±0.261

Appendix 1 Continue......

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56	MH-421	Hisar	2.725± 0.083	3.803± 0.058	25.325± 0.036	5.939±0.706
57	MH-96-1	Hisar	2.263± 0.098	3.113± 0.227	24.457± 0.035	6.655±1.687
58	MH-98-1	Hisar	2.923± 0.072	7.097± 3.820	25.440± 0.119	4.299±0.774
59	MI-3580	-	2.393± 0.043	4.257± 1.054	27.133± 0.043	6.845±2.003
60	ML-1108	-	2.227± 0.046	3.760± 0.394	23.550± 0.044	4.346±0.645
61	ML-194	Ludhiana	3.050± 0.031	4.407± 1.176	22.640± 0.078	6.909±1.231
62	ML-406	Ludhiana	1.537± 0.290	2.523± 0.361	21.830± 0.036	5.035±1.278
63	ML-5	-	2.413± 0.280	2.780± 0.096	27.153± 0.034	6.812±1.505
64	ML-506	Ludhiana	2.267± 0.026	4.800± 1.481	24.457± 0.035	4.765±1.218
65	ML-515	Ludhiana	3.350± 0.061	5.650± 1.005	22.730± 0.053	1.992±0.467
66	ML-682	Ludhiana	3.189± 0.146	3.303± 0.108	25.627± 0.135	3.463±0.985
67	ML-735	Ludhiana	2.820± 0.080	6.580± 0.206	28.053± 0.034	8.765±1.295
68	ML-759	Ludhiana	1.560± 0.076	2.643± 0.071	25.283± 0.128	2.460±0.671
69	ML-776	Ludhiana	3.323± 0.384	7.270± 1.939	23.587± 0.026	2.926±0.760
70	ML-803	Ludhiana	3.807± 0.414	5.340± 1.158	28.060± 0.032	5.695±0.424
71	ML-818	Ludhiana	3.187± 0.096	4.470± 0.354	29.743± 0.041	2.510±0.242
72	ML-839	Ludhiana	1.827± 0.299	3.237± 0.364	23.600± 0.021	7.571±1.553
73	Muskan	-	2.057± 0.029	2.717± 0.044	24.357± 0.163	4.383±0.760
74	P-105	IIPR Kanpur	2.753± 0.064	3.160± 0.518	26.210± 0.023	2.935±0.588
75	PDM-9249	IIPR Kanpur	1.833± 0.215	2.557± 0.128	25.327± 0.027	4.629±1.413
76	PLM-116	Ludhiana	3.647± 0.095	5.180± 1.061	25.363± 0.038	4.717±1.046
77	PLM-176	Ludhiana	3.533± 0.286	5.073± 0.826	27.140± 0.036	3.550±0.683
78	PLM-18	Ludhiana	3.250± 0.035	4.473± 1.360	25.340± 0.026	1.457±0.759
79	PLM-62	Ludhiana	1.830± 0.099	3.403± 0.255	25.330± 0.026	1.096±0.360
80	PLM-65	Ludhiana	2.713± 0.015	4.387± 0.688	23.603± 0.018	2.983±1.147
81	PM-827	-	2.717± 0.015	6.140± 1.050	21.823± 0.032	5.235±1.490
82	PMB-14	Ludhiana	1.603± 0.243	2.023± 0.052	23.533± 0.058	1.783±0.243
83	SM-99-1	Hisar	2.183± 0.068	4.843± 1.342	21.830± 0.026	7.395±1.210
84	SMH-99-1A	Hisar	3.143± 0.331	3.973± 0.339	28.103± 0.062	3.761±1.049
85	SMH-99-1DB	Hisar	3.110± 0.058	3.910± 0.120	27.133± 0.043	2.977±0.594
86	SMH-99-2	Hisar	2.487± 0.015	3.020± 0.100	25.483± 1.637	3.438±0.702
87	SMH-99-3A	Hisar	1.697± 0.316	3.403± 0.299	25.210± 0.098	4.426±0.966
88	SMH-99-3D	Hisar	1.657± 0.156	2.243± 0.054	21.590± 0.195	14.578±2.632
89	SMH-99-4	Hisar	2.743± 0.138	3.173± 0.097	27.190± 0.038	6.346±1.425
90	SML-668	Ludhiana	2.268± 0.260	4.012± 0.587	23.538± 0.095	8.827±1.983
91	Satya	Hisar	2.468± 0.102	4.060± 0.346	21.132± 0.043	9.537±1.919
92	T-44	-	3.177± 0.032	4.643± 0.527	26.220± 0.021	4.509±1.023

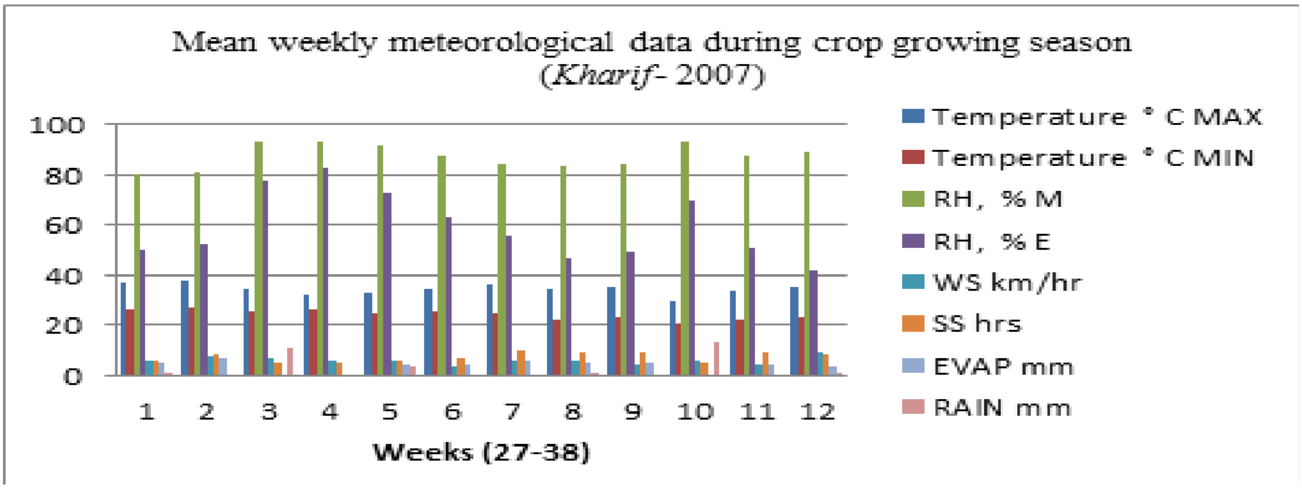


Fig A: Mean weekly meteorological data during crop growing season (*Kharif* -2007) recorded at the experimental station, CCS HAU, Hisar.

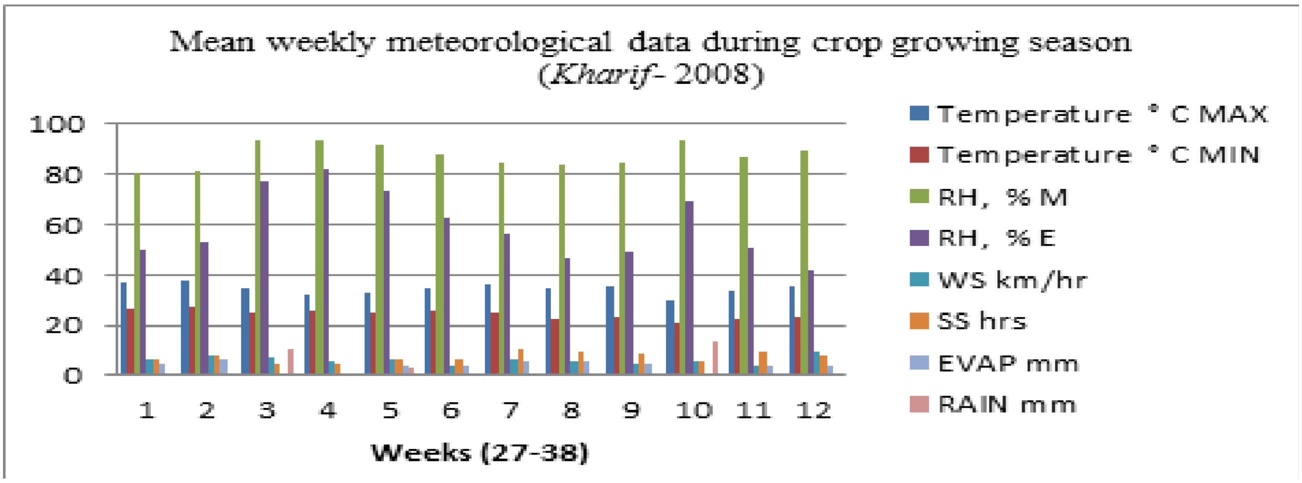


Fig B: Mean weekly meteorological data during crop growing season (*Kharif* -2008) recorded at the experimental station, CCS HAU, Hisar.

developing high yielding cultivars with higher concentrations of iron and zinc. Such legumes fortification experiments along with its intervention in diets will definitely prove helpful in fighting against 'hidden hunger' (Burchi *et al.*, 2011). Thavarajah *et al.* (2011) reported variation for iron content in lentils in the range of 4.1-13.2 mg/100g, for chickpea 4.4-13.5 mg/100g and in common bean up to 10 mg/100g while variability for zinc concentrations ranging from 2 – 6 mg/100g in common bean.

Correlation studies: As yield is a complex multigenic trait that can be broken down into its component traits, thus in order to get the highest possible yield traits like maturity, number of branches and pods per plant traits can't be ignored. Therefore for all the seven yield attributing traits, genotypic and phenotypic correlation coefficients were calculated (Table 1).

In present study the estimates of the genotypic correlation (rG) are generally higher than those of the phenotypic correlation (rP). Number of branches/plant and pods/plant have a high genotypic correlation with seed yield/ plant which shows the reliability of these traits in determining yield potential in mungbean. This indicates that the traits were at least partial under genetic control. Hemavathy *et al.* (2015) in green gram and Ajay *et al.* (2012) in pigeon pea had observed similar results.

2. Genetic diversity: The success of any crop improvement depends on the amount of diversity available in the crop. To know the spectrum of diversity, the assessment of divergence in the cultivar is essential. Knowledge about genetic variability and genetic divergence are of great value as they play a vital role in selecting the right parents for a successful breeding programme.

Table 1: Heritability (in parenthesis), Genotypic (rG), phenotypic correlation (rP) and environmental (rE) correlations among the six agronomic traits in mungbean (*V.radiata* L.)

Traits	**r**	**DM** (0.106)	**PH** (0.452)	**BPP** (0.207)	**PPP** (0.219)	**MYMV** (0.581)	**SYP** (0.243)
DF	G	0.503**	0.087	0.353**	0.075	0.190	-0.217
	P	0.238*	0.076	0.176	-0.032	0.114	-0.094
	E	0.056	0.064	0.094	-0.096	0.023	-0.021
DM	G		-0.030	0.077	0.126	-0.013	-0.095
	P		-0.042	0.067	0.098	-0.011	-0.008
	E		-0.053	0.064	0.086	-0.010	0.032
pH	G			0.401**	0.169	-0.186	0.009
	P			0.199	0.142	-0.132	-0.027
	E			0.095	0.133	-0.053	-0.055
BPP	G				0.418**	0.157	0.242*
	P				0.407**	0.065	0.238*
	E				0.404	0.009	0.237
PPP	G					-0.261*	0.873**
	P					-0.124	0.169
	E					-0.029	0.520
MYMV	G						-0.324**
	P						-0.157
	E						-0.035

DF= Days to 50% flowering, DM= Days to maturity; PH= Plant height (cm); BPP= No. of branches/plant; PPP= No. of pods/plant , MYMV score (1-9); SYP= Seed yield/plant (g). *Significance at 5%; **Significance at 1%

Table 2: Distribution of 92 mungbean cultivars into different clusters

Cluster	**I**	**23**	PMB-14, SMH-991-A, T-44, L-24-2, M-169, MH-318, MH-421, ML-515, ML-776, PDM-9-249, PLM-176, PLM-18, 2KM-151, 2KM-155, 2KM-161, AMP-36-10, AMP-36-4, ASHA, BDYR-2, CH-1355, CH-2103, GP182, GP32
	II	**34**	2KM-111, 2KM-112, 2KM-114, 2KM-116, 2KM-117, 2KM-135, 2KM-139, 2KMH-52, BDYR-1, BG-39, GANGA-8, GP149, GP150, GP248, GP69, GP78, GP861, PLM-62, PLM-65, SMH-991-D, SMH-99-2, SMH993A, HUM7, IC-39574, LM-10, M-1361B, MH-125, MH-98-1, ML-1108, ML-682, ML-759, ML-818, Muskan, P-105
	III	**2**	**GP**181, GP68B
	IV	**5**	SMH-99-3D, PM-827, ML-5, M-395, HUM-1
	V	**28**	MH419, MH961, MI3580, ML194, ML406, ML506. ML735, ML803, ML839, PLM116, SM99-1, SMH99-4, SML-668, MH 2-15, 2KM-107, 2KM-115, 2KM-138, AMP-36-1, CoGG-90, GP196, GP86, IC103196, IC39595, KM-92-11, M-516, M-605, MH-124, MH 215

Clustering pattern of cultivars: Treating the estimated D^2 values as the square of the generalized distance, 92 cultivars were grouped into 5 clusters. Of these five clusters, cluster II had the highest number of cultivars (34) while cluster III is the smallest with only two cultivars (Table 2).

Ninety two mungbean genotypes were grouped into five different clusters using clustering technique. A two dimensional scatter diagram was constructed using first canonical variable on X axis and second canonical variable on Y axis, reflecting the relative position of the genotypes (Figure 1). As per scatter diagram the genotypes were apparently distributed into 5 groups.

From the figure it can be seen that in cluster 1 there is more variability than in clusters 2 and cluster 5. Clusters 1 and 2 mainly comprise of early maturing cultivars. The mungbean cultivars show hardly variation for days to 50% flowering and days to harvest but show considerable variation for traits like pods per plant, plant height and seed yield. Clusters 2 and 5 include cultivars higher in yield and more MYMV resistant.

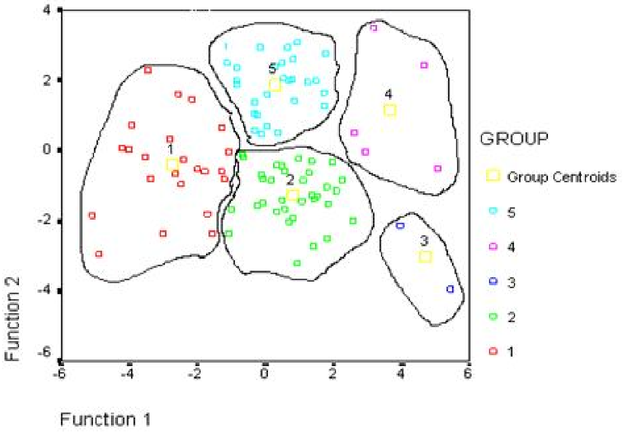


Fig 1: Scatter diagram presenting relationship among 92 mungbean cultivars as revealed by two dimensional plot along with cluster centres.

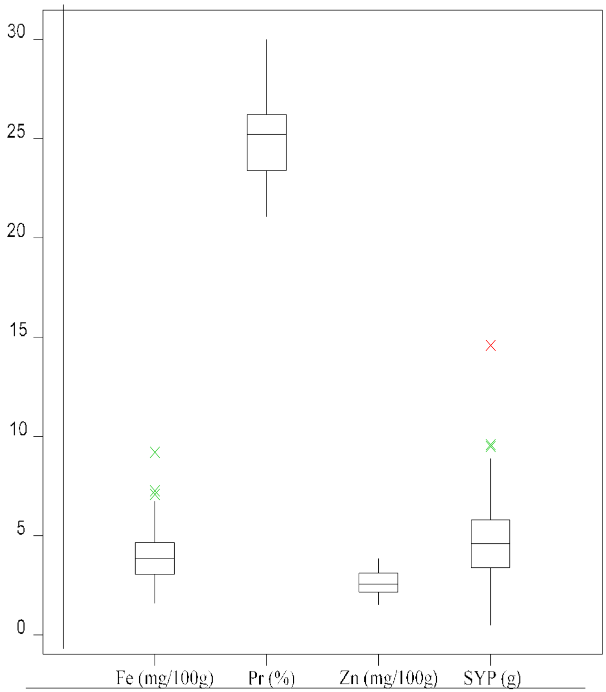
Cluster 3 comprises only of two cultivars which are late maturing, tall, low yielding with maximum branching. Cluster 4 comprises of medium to tall cultivars with high yield and takes about sixty two days (medium) to mature while Cluster 5 comprises dwarf resistant cultivars with high yield. Cluster 1 and cluster 2 comprise mostly of the cultivars having elevated level of micronutrients in them.

Cluster means: Mean values, range, standard deviation and coefficient of variance were calculated for each character (Table 3). Table 4 shows a coefficient of variation and range for four traits i.e., number of branches/plant, number of pods/ plant, plant height and yield/plant. Coefficient of variation shows the degree of variation available in the genotypes for a particular trait. Thus, for these traits coefficient of variation will help in improvement through selection.

Micronutrient content and their correlation with seed yield: Data for micronutrients and protein shows a considerable range for both micronutrients and protein in the mungbean cultivars. The mean concentration (± standard error) of Fe, Zn concentration and protein content in the 92 cultivars of mungbean was determined (Fig. 2). The seed protein content varied from 21.1 % to 30.0 % with a mean of 24.9 ± 0.2, the seed zinc concentration varies from 1.54 mg/kg to 3.85 mg/100g with a mean of 2.63 ± 0.1 and the seed iron concentration ranged from 1.59 mg/100g to 9.29 mg/100g with a mean of 4.03 mg/100g ± 0.1.

Table 3: Range, mean with standard error and coefficient of variance for each character based on the agronomic traits in ninety two cultivars of mungbean (*Vigna radiata* L.)

Traits	**DF**	**DM**	**NBP**	**NPP**	**pH**	**MYMV**	**SYP**
Range	37-51	53-69	1.66-3.8	10.5-66.5	50.7-117	2-9	0.5-14.6
Mean ± S.E	42.1± 0.28	61.8 ± 0.35	2.57 ± 0.04	39.38 ± 1.13	75.76 ± 1.27	5.02 ± 0.16	4.79 ± 0.23
C.V.	6.29	5.48	16.53	27.55	16.08	2.22	45.99



Mean:	4.03	25.23	2.63	4.79
CV:	33.44	8.39	22.88	45.99
h^2:	0.259	0.986	0.727	0.243

Fig 2: Seed yield, protein & Fe and Zn micronutrients content in 92 mungbean (*Vigna radiata* L.) cultivars.

A considerable variation for protein content was found. Out of ninety two cultivars eight (2KM-107, 2KM-138, BDYR-1, GP-68B, ML-818, ML-803, ML-735 and GP-78) have quite high concentrations (> 28%) protein. Among the micronutrients and protein content, a significant positive correlation was found between Fe and Zn (*r* = 0.469). These results imply that a high Fe content can be accompanied by high Zn content. Both these micronutrients exhibit a low but positive correlation with protein content (*r* (Fe) = 0.019; *r* (Zn) = 0.105). This was consistent with findings of Tryphone and Masolla (2010) in common bean and Thavarajah *et al*., (2010), in lentils.

Iron, zinc and seed yield had high values for coefficient of variation (CV) and heritability showing that the selection for these traits will be very effective and reliable. Mobina *et al*. (2014), genetic CV together with heritability provide a reliable indication and estimate of the expected amount of improvement through selection for the traits of interest. The relationships among the few important agronomic traits, protein and mineral content were analysed by Pearson correlation analyses (Table 4). A significant positive correlation was found between seed yield and number of pods (r = 0.656) and a non- significant positive correlation was observed between seed yield and number branches per plant (r = 0.201) indicating no negative effect on yield. Negative associations were seen between seed yield and days to 50% flowering, days to maturity, protein and zinc content.

In our study a non-significant correlation was observed between micronutrient content and yield, making it possible to develop cultivars with high micronutrient concentrations in combination with high yield. The top ten cultivars with a combination of high yield and high micronutrient content are listed in Table 5. These cultivars can be used in cultivar x environment studies, in breeding programs and/or may be the parents in the generation of mapping studies in order to do genetic studies and to find quantitative trait loci (QTL) for Fe/Zn content, protein content and high yield.

Before including micronutrient content in a breeding programme it is important to consider whether micronutrient content is influenced by different environments (Genotype x Environment), and differences in cultural practices. Potential associations with anti-nutritional factors (ANFs) such as tannins, saponins, phytates, lectins etc. These ANFs are the potent inhibitors of iron and zinc (Enneking and Wink, 2000). Therefore these ANF should also be considered while planning experiment. The present study will help in making choices in the conversation of genetic resources and in choosing the best possible cultivars for future breeding programmes.

Table 4: Correlation coefficients between the agronomic traits, protein and micronutrients in 92 cultivars of mungbean (*V. radiata* L.)

	DF	DM	MYMV	NBP	NPP	PH	Protein	SYP	Fe
DF	-								
DM	0.39**	-							
MYMV	0.119*	-0.035	-						
NBP	0.226*	0.069	0.097	-					
NPP	-0.016	0.093	-0.159*	0.441**	-				
PH	0.106	-0.015	-0.136*	0.304**	0.167*	-			
Protein	-0.017	-0.001	-0.031	-0.106	-0.116*	0.058	-		
SYP	-0.143	-0.065	-0.261**	0.201*	0.656**	-0.002	-0.149*	-	
Fe	-0.115	-0.228**	0.067	-0.106	-0.046	-0.135*	0.019	0.022	-
Zn	-0.124	-0.081	0.152*	-0.091	-0.174*	-0.074	0.105	-0.181*	0.469**

*Significance at 5%; **Significance at 1%

Table 5: Selected mungbean cultivars with high micronutrient content and their protein content and yield

Cultivar	Fe (mg/100g)	Zn (mg/100g)	Protein (%)	Yield/plant (g)
KM-92-11	9.22	3.57	22.7	6.2
ML-776	7.27	3.32	23.6	2.9
MH-98-1	7.07	2.92	25.4	4.3
CoGG902	6.75	3.13	26.2	5.1
ML-735	6.58	2.82	28.1	8.8
PM-827	6.14	2.72	21.8	5.2
BG-39	6.02	2.64	26.2	2.6
GP-149	6.02	2.85	22.4	4.3
GP-182	5.71	3.34	22.7	1.7
ML-515	5.65	3.35	22.7	1.9

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