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Genetic Variability, Correlation and Path Analysis in Mungbean (*Vigna radiata* L)

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Abstract: An experiment was conducted at the Regional Agricultural Research Station (RARS), BARI, Rahmatpur, and Barisal during the period from January, 2013 to April, 2013 to study on the variability, heritability, genetic advance and interrelationship via correlation co–efficient and path co–efficient analysis among the important eight characters in relation to seed yield. Significant variation was observed among the studied 54 mungbean genotypes for all characters. Different genotypes were found superior for different characters. Among the genotypes, ACC–12810002 for plant height (71.80 cm), TPK–2558–97 for days to 50% flowering (48.67 days as minimum), BC–6960–88 and VO–1558 (B–G) for days to pod maturity (89.00 days as minimum), VC–6149 (B–12) for pod length (17.30 cm), ACC–12810006 for pods plant^{-1} (31.73), ACC–12890073 for seeds pod^{-1} (17.60), VC–6960–88 for 100–seed weight (5.63 g) and GK–40 for seed yield (1846.00 kg ha^{-1}) were found to be the superior genotypes. Including seed yield, all the characters, except seeds pod^{-1} exhibited high heritability accompanied by medium to high genetic advance as percent of mean. These characters also showed medium to high GCV and PCV. However seeds pod^{-1} showed moderate heritability and genetic advance as present of mean. In all these case significant genotypic correlation co–efficient were found to be higher than their corresponding phenotypic ones. The character 100–seed weight showed significant positive relationship with seed yield. Path co–efficient analysis suggested that pods plant^{-1} contributed maximum direct effects having positive on seed yield. Plant height, pod length and 100–seed weight had also positive direct effect on seed yield. Thus selection based on pods plant^{-1}, days to first flowering, plant height and 100–seed weight might be effective for improving seed yield in mungbean.

Key words: Mungbean, Heritability, Genotypic and phenotypic variances, Genetic advance, path analysis

Introduction

Mungbean is one of the most important pulse crops grown in Bangladesh for its high digestibility, good flavour, high protein content and absence of any flatulence effects which are common to many pulse (Ahmed *et al*., 1978). This crop covers about 5% of the total acreage under pulses and contributes approximately 4% in the total production in Bangladesh. It ranks 5th in acreage, 6th in production, 3rd in protein (%) content and 1st in respect of price among all pulses. The mungbean is an annual, semi–erect to erect or sometimes twining deep rooted herb, 25–100cm tall (Ahmed *et al*., 1995). At maturity, the pods are glabrous or have short hairs, 5 to 14 cm long and 4 to 6 mm wide having 6 to 20 seeds pod^{-1}. Seeds are nearly round or oblong. Seed coat color is green, yellow, brown, black or mottled. Seed luster is either glossy or dull. Dull seeds are coated with a layer of the pod the pod inner membrane which may be translucid or pigmented. Cultivation of mungbean can improve the physical, chemical and biological properties of soil and through biological nitrogen fixation from the atmosphere. It is essential to evaluate the characters properly and the genetic information on yield and yield contributing characters for the improvement of seed yield. However, it is difficult to know what proportion of the observed variability is for genetic effect. For rapid and efficient plant breeding programme, knowledge of relationship among yield and yield contributing characters is necessary. Such the facts, correlation coefficients between characters, which help in construction of selection indices is also very important. Correlation between characters may be misleading due to complex interrelations and may not provide the exact picture of influence of one character over others. Splitting correlation into direct and indirect effects, therefore, would provide more meaningful interpretation. Thus correlation in combination with path coefficient analysis is required to assess quantitatively direct and indirect influences of yield attributing characters. It is also important to study the genetic parameters, like genotypic and phenotypic coefficient of variations for the most influencing traits for improving the seed yield. When many characters affecting a given character, splitting the total correlation in to direct effects as devised by Rahman *et al*. (1982) would give a more meaningful interpretation to the causes of association. Therefore, path coefficient analysis is used to measure the causes of association and quantify the direct and indirect influence of one character upon another (Dewey, 1959). So, the genetic variability can offer opportunity for the effective selection for a high yielding desirable plant. Considering the above facts, the present study was therefore, under taken to evaluate the field performance and to selection indices via GCV, PCV and their relative efficiencies in relation to correlation coefficient and path analysis

Materials and Methods

The experiment was conducted at the research field of PBD, RARS, BARI, Rahmatpur, and Barisal during the period from January, 2013 to April, 2013. The RARS, Rahmatpur, Barisal lies at the $22^0$42" North latitude and 90^o23" East longitude at an elevation of 4 meter above the sea level. It belongs to the Non–calcarious Grey Floodplain Soils (Non saline, Ganges Tidal Alluvium) under AEZ 13. The experimental materials comprised of 54 local and exotic summer mungbean germplasm. All the genotypes were obtained from the Pulse Research Centre, BARI, Rahmatpur, and Barisal. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The size of unit plot was 2.4 m × 2 m. The distances of 40 cm between rows, 75 cm between plots and 1 m between replications. The experimental field was prepared by repeated ploughing followed by laddering. After ploughing and laddering all the stubble and uprooted weeds were removed from the field. Before final land preparation, Urea, TSP and Mop fertilizers were applied at the rate of 20, 50 and 30 kg ha^{-1}, respectively as basal dose. Seeds were shown on the 15 February, 2013. Various intercultural operations were also done for better growth of seedlings. Five randomly selected plants were harvested $plot^{-1}$ when color of almost all the pods become black or brown. Pods of each plant were kept separately in paper bags and sung dried. Threshing was done by hand and strict care was taken to avoid mechanical mixture of seeds. Data on different parameters such as plant height, days to first flowering, days to total pod maturity, pod length, pods $plant^{-1}$, seeds pod^{-1}, 100–seed weight and seed yield were recorded from each plot. The obtained data were statistically analyzed in MSTAT–C computer program by RCBD. The analyses of variance for various crop characters were done following the principle of F–statistics. To test the differences between of genotypes, Duncan's Multiple Range Test (DMRT) was performed following the method described by Steel and Torrie (1960) by M–STATC computer program. Pearson's correlation coefficients were calculated to determine the relationships between yield and yield components. Path coefficient analysis was used as determined by Dewey (1959) to partition the correlation coefficients and to determine the direct and indirect effects.

Results and Discussion

Mean performance of genotypes on morpho–physiology, yield and yield attributing

Plant height: Table 1 indicated that variation among the genotypes in respect of plant height was highly significant. The genotypes showed wide range of variability. The highest plant height (71.80 cm) was found in ACC=12810002 followed by VC 3828 A (71.07cm) and lowest plant height (49.93 cm) in GK–26. In 1968 Chowdhury *et al*., while working with 16 Indian and 5 Japanese varieties of mungbean found significant variation for this trait between the varieties. Later on many researchers such as Ram *et al. (*1997) and Dhananjay *et al. (*2009) also found similar results while they studied a number of mungbean genotypes.

Days to 50% flowering: From the significant mean square value (Table 1), it was revealed that a considerable variability existed among the genotypes for days to first flowering. It was also suggested by DMRT. The earliest first flowering genotype was TPK–2558–97 (48.67 days) and highest days to first flowering (54.33 days) required in ACC–12870020. The significant variation in this character was reported by Sharma after studying 15 mungbean crosses and their six parents in 1999. Earlier similar results were also observed by Shweta (2011) for this character.

Days to pod maturity: From the significant mean square value (Table 1), it was revealed that a considerable variability existed among the genotypes for days to pod maturity. It was also suggested by DMRT. The genotype GK–57 was the most late maturing one which took 90.67 days and the earliest pod maturing genotype was VO–1558 (B–G) and VC 6960–88 (89.00 days). The significant variation in respect of days to pod maturity was reported by Vikas *et al. (*1998) and Shweta (2011) for this character.

Pod length: The variation in the trait pod length among the genotypes was found significant as shown by the genotype mean square value (Table 1). This significant variation was also revealed by DMRT. The genotype VC–6149 (B–12) had the longest pod (17.3 cm) and VC–1658 A had the shortest pod length (7.37 cm). The significant variation is this character was reported earlier by Shweta (2011).

Number of pods $plant^{-1}$: Significant genotype mean square value (Table 1) suggested that there was a considerable variation among the genotypes for number of pods/plant. The mean performances of the genotypes were tested by DMRT which also showed the presence of variation among the genotypes for this trait. The highest number of pods/plant (22.75) in ACC–12840014 followed by ACC–12890073 (20.80) and lowest (2.92) in GK–40. The significant variation in this character was reported by Ram *et al*. (1997) studied 30 genotypes of green gram.

Number of seeds pod^{-1}: The significant mean square, presented in Table 1, showed that there was significant variation among the genotypes in respect of this trait. Test by DMRT also indicated the presence of significant variation. The highest number of seeds (12.05) in VC–6371–93 followed by VC–1209 A (11.67) and the lowest (7.05) GK–40. Significant variation of this character in 60 mungbean genotypes was reported by Ram *et al*. (1997). Similar results have been reported earlier by Shweta (2011).

Hundred–seed weight: The analysis of variance for this character showed significant differences among the genotypes (Table 1). The genotype GK–65 produced the highest 100–seed weight (65.10 g) followed by the genotype GK–6 (62.00 g) and GK–63 (62.00 g). On the other hand, the genotype VC–1719–A and VC–3828–A produced the lowest seed weight (27.00g) followed by VC–6173 (B–6) and GK–48 (29.00g). Similar results have also been reported by Sharma (1999).

Table 1. Mean performances of 54 genotypes for morpho–physiological, yield and yield attributes of mungbean

Genotypes/varieties	Plant height (cm)	Days to 50% flowering	Days to pod maturity	Pod length (cm)	Pod plant^{-1}	Seed pod^{-1}	100 seed weight (g)	Yield (kg ha^{-1})
GK–40	52.40 mno	51.00 c–i	90.00 bc	8.23 k–s	22.87 f–l	10.00 c	4.967 b–h	1846.00 a
GK–67	52.83 k–o	50.67 d–i	89.33 de	7.80 p–w	24.57 e–g	10.40 c	3.967 no	1565.00 b
VC–6773 (B–G)	54.13 i–o	51.33 b–i	89.67 cd	8.57 i–n	24.13 f–h	10.71 c	4.00 m–o	647.10 qr
ACC–12810004	64.80 a–h	51.33 b–i	90.00 bc	8.63 h–m	24.53 e–g	10.89 c	4.40 h–o	432.00 v
VO–1319 (A–G)	68.50 a–e	51.67 a–h	89.67 cd	8.53 i–n	23.13 f–j	10.02 c	3.97 no	233.60 x
VC–6372 (45–8–1)	67.20 a–f	52.00 a–h	89.33 de	8.80 g–k	22.20 g–n	10.93 c	3.90 op	301.70 w
ACC–12890078	60.93 b–n	52.67 a–f	90.00 bc	7.83 o–w	20.33 k–r	9.737 c	3.40 p	784.20 op
VC–6367 (55–97)	62.80 a–l	53.00 a–e	89.67 cd	9.73 de	20.27 k–s	9.407 c	4.33 i–o	531.40 tu
ACC–12870020	58.33 e–o	54.33 a	90.33 ab	8.57 i–n	21.67 h–n	9.070 c	5.10 a–f	417.00 v
GK–57	51.33 no	52.67 a–f	90.67 a	9.53 d–f	19.73 m–t	10.93 c	5.17 a–e	310.60 w
GK–37	62.07 a–m	51.67 a–h	89.33 de	8.30 j–r	18.07 p–v	12.40 bc	4.73 d–j	531.00 tu
ACC–12910110	58.83 d–o	51.67 a–h	89.67 cd	9.37 e–g	17.07 tuv	10.73 c	4.40 h–o	835.90 m–o
vc–1160	64.33 a–h	51.67 a–h	89.67 cd	9.47 ef	17.67 q–v	9.690 c	4.43 g–o	134.10 y
GK–6	62.87 a–k	51.00 c–i	89.67 cd	8.93 f–j	16.80 uv	10.97 c	5.27 a–d	354.10 w
VC–6173 (B–32)	64.00 a–i	50.33 e–i	90.00 bc	8.97 f–i	17.13 t–v	9.473 c	4.97 b–h	518.60 tu
ACC–12890083	65.67 a–g	51.67 a–h	89.67 cd	8.47 i–o	17.73 q–v	10.33 c	5.17 a–e	894.60 k–m
ACC–12840014	64.40 a–h	50.67 d–i	90.00 bc	8.07 l–v	17.80 q–v	10.60 c	5.37 a–c	795.40 op
VC–6144 (B–12)	59.33 c–o	52.00 a–h	90.33 ab	8.96 f–i	17.53 s–v	10.73 c	4.77 c–i	316.70 w
VC–6173 (B–6)	58.53 e–o	53.00 a–e	89.33 de	9.23 e–h	18.20 p–v	10.95 c	4.13 j–o	547.00 tu
ACC–12890073	52.73 l–o	51.00 c–i	90.33 ab	8.36 i–q	18.13 p–v	17.60 a	4.60 e–m	1011.0 i
GK–26	49.93 o	51.67 a–h	90.67 a	9.80 de	18.20 p–v	10.53 c	4.30 i–o	842.60 mno
VC–6960–88	56.83 g–o	50.67 d–i	89.00 e	10.1 d	18.07 p–v	10.07 c	5.63 a	851.60 mno
VC–1658 A	59.60 c–o	50.33 e–i	89.67 cd	7.37 wx	17.87 q–v	11.53 c	5.30 a–d	1025.00 i
GK–63	55.00 h–o	50.33 e–i	89.67 cd	8.70 h–l	15.80 v	10.40 c	4.43 g–o	1594.00 b
GK–65	57.00 f–o	52.33 a–g	90.67 a	8.27 k–r	17.00 tuv	11.20 c	4.70 d–k	939.50 jk
VC–6371–93	63.07 a–j	51.33 b–i	89.67 cd	8.42 i–p	22.00 g–n	10.00 c	5.06 a–f	936.20 jkl
VO–1547 (A–G)	62.07 a–m	50.00 f–i	90.00 bc	7.47 t–x	23.00 f–k	11.00 c	4.60 e–m	1133.00 h
ACC–12890071	67.33 a–e	49.67 g–i	89.67 cd	7.70 r–w	21.73 h–n	10.33 c	5.30 a–d	1396.00 d
ACC–12810002	71.80 a	52.00 a–h	90.00 bc	8.10 l–u	25.07 def	9.670 c	5.00 b–h	836.90 mno
GK–63	53.00 j–o	52.00 a–h	89.67 cd	7.71 q–w	21.20 i–o	10.00 c	4.80 c–i	1010.00 i
VC–1719–A	63.80 a–i	52.67 a–f	89.67 cd	13.2 c	15.87 v	9.801 c	4.10 k–o	1414.00 d
ACC–12890032	68.00 a–e	52.00 a–h	90.00 bc	7.58 s–x	15.47 v	10.13 c	5.47 ab	1487.00 c
VC–1209 A	62.53 a–l	54.00 ab	89.67 cd	7.85 o–w	17.63 r–v	10.07 c	1.40 r	824.00 nop
VO–1100 (B–G)	59.73 c–o	53.67 a–c	89.33 de	7.99 m–w	18.00 q–v	10.27 c	4.63 e–l	1247.00 fg
ACC–12890098	65.00 a–h	53.33 a–d	90.33 ab	13.99 b	30.07 ab	14.80 b	4.03 l–o	830.90 mno
VC–1137 A	68.93 a–d	52.00 a–h	90.67 a	7.72 q–w	30.87 ab	10.60 c	4.50 f–o	1220.00 g
ACC–12810006	65.20 a–h	51.67 a–h	90.33 ab	7.77 p–w	31.73 a	11.47 c	4.90 b–i	688.20 q
ACC12890055	69.13 a–d	51.00 c–i	90.33 ab	8.13 l–t	26.80 c–e	11.07 c	5.03 a–g	789.00 op
GK–48	68.93 a–d	51.33 b–i	89.67 cd	7.59 s–x	24.60 e–g	9.800 c	4.50 f–o	801.80 op
VO–1558 (B–G)	63.93 a–i	52.67 a–f	89.00 e	8.13 l–t	20.73 j–p	11.00 c	5.03 a–g	611.60 rs
VO–1207 (A–G)	67.00 a–g	51.67 a–h	89.33 de	8.57 i–n	24.27 e–h	10.13 c	4.10 k–o	1417.00 d
VC–6149 (B–12)	58.60 e–o	51.67 a–h	89.67 cd	17.3 a	23.60 f–i	10.20 c	4.70 d–k	1005.00 i
ACC=12890081	69.53 a–c	51.33 b–i	90.00 bc	8.02 m–w	22.87 f–l	9.600 c	4.40 h–o	757.00 p
VO–1154 (A–G_	66.67 a–g	49.67 g–i	90.33 ab	7.43 vwx	24.67 e–g	10.40 c	4.53 f–n	988.90 ij
VO–1139 (B–G)	67.33 a–e	49.33 hi	89.67 cd	9.25 e–h	22.00 g–n	11.27 c	5.06 a–f	840.90 mno
TPK–2558–97	59.53 c–o	48.67 i	89.67 cd	7.47 t–x	28.87 bc	9.530 c	4.10 k–o	534.90 tu
VC–3828 A	71.07 ab	51.33 b–i	89.33 de	7.96 n–w	18.93 o–u	9.202 c	4.86 b–i	1145.00 h
VO–1352 (A–G)	64.40 a–h	53.00 a–e	90.00 bc	7.98 m–w	22.33 g–m	10.27 c	5.03 a–g	925.50 jkl
VO–1586 (A–G)	64.87 a–h	50.67 d–i	90.00 bc	8.16 k–s	27.40 cd	10.00 c	4.30 i–o	502.50 u
VC–6144 C	64.07 a–i	51.00 c–i	90.67 a	7.95 n–w	19.47 n–tu	10.07 c	3.96 no	1331.00 e
ACC–12890084	66.80 a–g	53.00 a–e	89.33 de	7.45 u–x	20.40 j–q	10.73 c	4.83 c–i	971.80 ij
GK–36	65.60 a–g	53.00 a–e	90.00 bc	6.99 x	20.20 l–s	10.67 c	5.00 b–h	1296.00 ef
BARI Mungbean–6	52.07 m–o	50.00 f–i	90.33 ab	8.430 i–p	21.00 i–o	9.870 c	5.20 a–e	872.70 lmn
Barisal (Check)	58.52 e–o	51.67 a–h	89.63 cd	8.130 l–t	21.73 h–n	10.47 c	2.30 q	576.30 st
$LSD_{0.05}$	**8.13**	**2.29**	**0.501**	**0.536**	**2.24**	**2.67**	**0.504**	**59.42**
Level of sign.	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability.

Seed yield (kg ha^{-1}): The significant differences in seed yield among the studied genotypes were observed where the highest seed yield (1846.00 kg ha^{-1}) was found in genotype GK–40 followed by the accession GK–63 (1594.00 kg ha^{-1}) and GK–67 (1565.00 kg ha^{-1}) and lowest seed yield (134.10 kg ha^{-1}) in VC–1160 (Table 1). Similarly, many researchers such as Ram *et al. (*1997) and Shweta (2011) also reported significant variations for this character in mungbean.

Evaluation of various genetic characteristics of studied rice

Plant height: The estimates of genotypic and phenotypic variances were 22.87 and 48.14, respectively and the genotypic (GCV) and phenotypic co–efficient of variations (PCV) were 7.70 and 11.77, respectively (Table 2). The differences between the variances and co–efficient indicated that there was a considerable environmental influence on plant height of the genotypes. This was also supported by the environmental variance. High genotypic coefficient of variation for this trait was found by Tejbir *et al*. (2009) in some mungbean cultivars. The high heritability estimate (47.50) associated with considerably high genetic advance (6.79) and genetic advance (GA) as percent of mean (10.94) were detected for this trait. This suggested that selection for plant height may be moderately effective within these genotypes. High heritability for this character was reported earlier by Rahman et al. (1982). They also found high genetic advance for this trait.

Days to 50% flowering: Phenotypic variance was estimated as 0.71 which was much higher than that of the genotypic 2.72. This also indicated that there was high environmental influence upon the expression of flowering. The GCV (1.64), PCV (3.20) and heritability estimated in broad sense (26.24) for this character were also high (Table 2). High heritability in this character was reported by Patil *et al*. (1987) after studying 169 local and exotic genotypes of mungbean. GA as mean and percentage of this character were 0.89 and 1.73, respectively.

Days to pod maturity: The phenotypic and genotypic variation were 0.15 and 0.25, respectively, in this character, indicated that there was less environmental effect on days to pod maturity. The high heritability (61.13) with low GA (0.63) and low GA as percent (0.70) shown in Table 2, revealed that selection for earliness within these genotypes may not be so useful. In 1998 Vikas *et al*., while studying 63 *Vigna radiata* genotypes during Kharif season at 4 locations observed high heritability for this character.

Pod length: The values of genotypic and phenotypic variances were 2.88 and 2.99, respectively and GCV and PCV were 19.54 and 19.91, respectively. Heritability estimates was high (96.32) and although GA was high as percentage (39.50) but the GA of mean (3.43) was found moderate for this character (Table 2). These estimates suggested that selection based on this character was expected to be effective. Reddy *et al*. (1997) studied 70 genotypes of green gram at Tirupati in India and found highest heritability for this character.

Number of pods plant^{-1}: The values of genotypic and phenotypic variances were 14.80 and 16.73, respectively (Table 2) and the genotypic and phenotypic co–efficient of variations were 18.08 and 19.22, respectively. Similar result was also found by Shamsuzzaman *et al. (*1982) who found high GCV and PCV. The heritability estimate was 88.44 and GA as mean and percent were 7.45 and35.02, respectively (Table 2). The high values of these two estimates indicated that on the basis of number of pods plant^{-1} there is enough scope for improvement through selection from these genotypes. High heritability and high genetic advance for this character was reported by Ram *et al. (*1997) and Tejbir *et al. (*2009).

Number of seeds pod^{-1}: The value of genotypic and phenotypic variances were 0.86 and 2.02, respectively (Table 2) and the genotypic and phenotypic co–efficient of variations were 8.43 and 17.75, respectively. Comparatively high environmental variance (22.57) was also noticed. The heritability value (22.57) was moderate for this character. The estimates of GA (0.87) and the GA as percent (8.25) were found considerably low. Contrary to this findings, Sharma (1999) working with 15 mungbean crosses and their six parents detected high heritability and high genetic advance for this character.

Hundred–seed weight: The genotypic and phenotypic variances were 0.49 and 0.59, respectively and the genotypic and phenotypic co–efficient of variations were 15.34 and 16.80, respectively. It seemed that the variances and the co–efficient of variations were quite close. These indicated that a considerable degree of genetic variability prevailed in this character and there was a negligible influence of environment on this trait. Ilhamuddin *et al. (*1989) working with 22 cultivars of mungbean genotypes and found high genotypic and phenotypic variations for this trait. Heritability (83.46) obtained for this trait was the highest among all the characters studied. The value of genetic advance was 1.32 and genetic advance as percent was 28.88.

Seed yield: The values of genotypic and phenotypic variances were 144236.11 and 145583.59, respectively (Table 2) and the GCV and PCV were 43.96 and 44.17, respectively. Ahmed *et al. (*1978) studied 70 local, exotic and mutant strains of mungbean found highest co–efficient of variation in respect of yield plant^{-1}. Ilhamuddin *et al. (*1989) and reported highest coefficient of variation in yield plant^{-1} of 22 mungbean cultivars. The heritability value for this trait was found high (99.07). GA was 778.73 and genetic advance as percent was 90.14. These estimates suggested that depending on yield, there was much scope for selection from these genotypes.

Table 2. Estimation of genetic parameters for studied characters of 54 Mungbean genotypes

Characters	Genotypic variance	Phenotypic variance	Heritability (%)	GCV (%)	PCV (%)	GA	GA (%)
50% Flowering	0.71	2.72	26.24	1.64	3.20	0.89	1.73
Days to pod maturity	0.15	0.25	61.13	0.43	0.55	0.63	0.70
Plant height (cm)	22.87	48.14	47.50	7.70	11.17	6.79	10.94
Pod plant^{-1}	14.80	16.73	88.44	18.08	19.22	7.45	35.02
Seed pod^{-1}	0.80	3.53	22.57	8.43	17.75	0.87	8.25
100 seed weight (g)	0.49	0.59	83.46	15.34	16.80	1.32	28.88
Pod length (cm)	2.88	2.99	96.32	19.54	19.91	3.43	39.50
Yield (kg ha^{-1})	144236.11	145583.59	99.07	43.96	44.17	778.73	90.14

Estimation of genotypic and phenotypic co–relation co–efficient

Plant height: Among the correlations of plant height with pods plant^{-1}, 100–seed weight and seed yield were found positive concerning both genotypic and phenotypic correlation coefficient (Table 3) which indicated that plant height have significant contribution to increase these 3 traits i.e., with the increase of plant height these 3 characters were found to increase. Likewise, this trait showed negative association with days to 50% flowering, days to pod maturity, seeds pod^{-1} and pod length in case of genotypic correlation while days to pod maturity, seeds pod^{-1}, pod length and seed yield showed negative correlation regarding phenotypic correlation coefficient. This suggested that with the increase of plant height, pod length and 100–seed weight decreases or vice–versa. Significant positive correlation between plant height and seed yield have been reported by Rahman *et al*. (1982) in 9 varieties.

Days to 50% flowering: Days to 50% flowering showed negative correlation among the whole studied traits except seeds pod and pod length regarding genotypic correlation while plant height, seeds pod^{-1} and pod length showed positive correlation via phenotypic techniques depending days to 50% flowering where days to maturity, pods plant^{-1}**,** 100–seed weight and seed yield were negative correlation depending days to 50% flowering in this study.

Days to pod maturity: Days to pod maturity had positive significant genotypic relationship with pods plant^{-1}, seeds pod^{-1} and 100–seed weight except that all the traits such as 50% flowering, plant height, pod length and seed yield were negative while plant height, pod length and seed yield had negative and days to 50% flowering, pods plant^{-1}, seeds pod^{-1} and 100–seed weight had positive in respect of phenotypic correlation coefficient (Table 3). Similarly, Rahman *et al. (*1982) and Kousar *et al. (*2007) observed days to pod maturity were positively correlated with plant height, pod length and 100–seed weight.

Pod length: Pod length showed either or both genotypic and phenotypic significant negative correlation with most of the studied traits except days to 50% flowering and seeds pod^{-1} (Table 3). This result revealed that longer plant height caused shorter pod length and with the increase of pod length and pods plant^{-1} has decreased. Pod length showed positive significant association with 100–seed weight both genotypic and phenotypic. This indicated that seed weight have increased with the increase of pod length. In the study, pod length showed very low positive relationship with seed yield. On the other hand, Rahman *et al. (*1982) while working with 9 varieties of mungbean found positive correlation between seed yield and pod length.

Number of pods plan^{t-1}: Number of pods plant^{-1} was found to show both genotypic and phenotypic significant positive correlation with days to pod maturity, plant height and seeds pod^{-1} (Table 3). The results revealed that number of pods plant^{-1} increased with the increase of plant height and ultimately number of seeds plant^{-1}. It also showed significant negative association wither or both genotypic and phenotypic with pod days to 50% flowering, 100–seed weight, pod length and seed yield. The negative association indicated that decrease of increase of pod length and also the seed weight was inversely proportional to the increase or decrease of number of pods plant^{-1}. Similar results were also reported by Rahman (1982) in 9 varieties; Kousar *et al. (*2007) in 639 genotypes of mungbean.

Number of seeds pod^{-1}: In case of number of seeds pod^{-1} significant positive relationship with plant days to 50% flowering, days to maturity, pods plant^{-1}, 100–seed weight and pod length regarding both genotypic and phenotypic procedure while plant height and seed yield had negative correlation in genotypic and phenotypic correlation coefficient which suggested that with the increase of number of pods plant^{-1}, number of seeds were increased. Similar results were also reported by Rahman *et al. (*1982) in 9 varieties, Kousar *et al. (*2007) in a large number of genotypes.

Hundred–seed weight: The significant positive association both genotypic and phenotypic of 100–seed weight was found only with the days to pod maturity, plant height and seed yield. This indicated that the increase of seed weight is directly related to the increase of plant height, days to pod maturity as well as greater seed yield. However, the characters 50% flowering, pods plant^{-1} and pod length were also correlated with 100–seed weight but the nature of the relationship was negative. This suggested that the 100–seed weight have decreased with the increase of days to 50% flowering, pods plant^{-1}, and pod length. Similar results were also reported by Rahman *et al. (*1982) in 9 varieties and Vikas *et al. (*1999) in 63 genotypes.

Seed yield: It is evident from the Table 3 that only 100–seed weight had positive correlation in both genotypic and phenotypic techniques on seed yield which indicated the increase of 100–seed weight is directly related to greater seed yield. Rest of the studied traits had negative nature on seed yield in genotypic and phenotypic procedure. This suggested that the seed yield significantly decreased in increasing all the traits except 100–seed weight which results are supported by the findings of Rahman *et al. (*1982) in 9 varieties and Vikas *et al. (*1999) in 63 genotypes.

Table 3. Genotypic and phenotypic correlation coefficients among the studied characters of 54 Mungbean varieties

Characters	Days to pod maturity	Plant height (cm)	Pods plant^{-1}	Seeds pod^{-1}	100 seed weight (g)	Pod length (cm)	Yield (kg ha^{-1})
Genotypic (Rg)							
50% Flowering	–0.022	–0.044	–0.183	0.011	–0.268*	0.194	–0.146
Days to pod maturity		–0.142	0.210	0.229	0.109	–0.023	–0.019
Plant height (cm)			0.289*	–0.199	0.043	–0.147	–0.078
Pod plant^{-1}				0.061	–0.102	–0.007	–0.053
Seed pod^{-1}					0.053	0.108	–0.008
100 seed weight (g)						–0.035	0.105
Pod length (cm)							–0.064
Phenotypic (Rp)							
50% Flowering	–0.002	0.020	–0.152	0.003	–0.255	0.173	–0.134
Days to pod maturity		–0.125	0.209	0.186	0.072	–0.022	–0.013
Plant height (cm)			0.269*	–0.183	0.054	–0.141	–0.074
Pod plant^{-1}				0.054	–0.095	–0.005	–0.053
Seed pod^{-1}					0.020	0.138	–0.007
100 seed weight (g)						–0.032	0.103
Pod length (cm)							–0.063

** = Significant at 1% level of probability and * = Significant at 5% level of probability

Estimation of genotypic and phenotypic path analysis

Plant height showed a high direct positive effect (0.5402) on seed yield (Table 4). The indirect positive effect of this trait on seed yield through days to first flowering and number of pods plant^{-1} was considerably high and through days to pod maturity and pod length was low. It also had low negative indirect effect on seed yield through number of seeds pod^{-1} and 100–seed weight. The total positive correlation coefficient (0.553) between plant height and seed yield was largely reflection of positive direct effect of plant height on seed yield. Thus plant height may be considered as a yield contributing trait in these genotypes. In 1982, Rahman *et al.*, while working with 9 varieties found that plant height had direct positive effect on yield. Later on similar results were also reported by Marappa *et al. (*2010) in 30 genotypes of mungbean. A positive direct effect (1.0632) of days to first flowering on seed yield was also observed (Table 4). This trait also showed indirect low positive effect through plant height, pods plant^{-1} and seeds pod^{-1} and low indirect negative effect through days to pod maturity, pod length and 100–seed weight on seed yield. Patil and Deshmukh *(*1988) in a large number 64 of mungbean genotypes also reported the similar results of this trait. But Rahman *et al*. (1982) after studied 9 mungbean varieties found that days to 50% flowering also had direct contribution on yield in mungbean. Days to pod maturity had also little negative direct effect (–0.0311) on seed yield (Table 4). It also showed either positive of negative indirect effects on seed yield through all other characters except days to first flowering. Days to first flowering showed high positive indirect effect in seed yield. Low and negative direct effect of days to pod maturity and also the low indirect effects via other characters resulted the non–significant negative association if it with seed yield. Rahman *et al. (*1982) while working with 9 mungbean varieties observed that Days to pod maturity had direct negative effect in yield. Similar results have also been reported by Yaqoob *et al. (*1997) in 30 genotypes of mungbean. From the result (Table 4) it was revealed that pod length had moderate positive direct effect (0.4750) on seed yield. It also showed both positive and negative low indirect effect on seed yield through other characters except seeds pod^{-1} which showed moderately high negative indirect effects. It indicated that increased pod length made large amount of photosynthetic available for storage in seed. In 1982, Rahman *et al*., after studied 9 varieties of mungbean observed that pod length had direct effect on yield. On the contrary Marappa *et al. (*2010) showed direct high negative effect of pod length on seed yield of 40 genotypes. The highest direct positive effect (1.1556) on seed yield was shown by the pods plant^{-1} (Table 6). Rahman *et al. (*1982) studied 9 mungbean varieties observed that number of pods plant^{-1} had direct contribution on yield. From the Table 4, it was also revealed that positive indirect effects on seed yield through plant height, days to pod maturity and 100–seed weight. Number of pods plant^{-1} had negative indirect effect on seed yield through pod length and number of seeds pod^{-1}. Yaqoob *et al. (*1997) and Marappa *et al*. (2010) found pods plant^{-1} had negative direct effect on yield of 30 genotypes. Thus, number of pods having the highest positive direct effect and indirect positive effect through plant height showed high association with seed yield showing its major contribution to the seed yield. Seeds pod^{-1} showed low direct negative effect (–0.0625) on seed yield (Table 4). Rahman *et al*. (1982) studied 9 mungbean varieties and found that seeds pod^{-1} had negative direct effect on seed yield. Results of the present study showed high positive indirect effect through pods plant^{-1} and low positive indirect effect through plant height, days to pod maturity and pod length on seed yield. Table 4 also showed that the low positive direct effect (0.2365) of 100–seed weight on seed yield. It showed both positive and negative little indirect effect on seed yield 66 through the other traits studied except pods plant^{-1} which showed high negative indirect effect and ultimately lead to non–significant low negative association of seed yield with 100–seed weight. Rahman *et al. (*1982) in 9 mungbean varieties found 100–seed weight had direct effect on yield per plant of mu8ngbean, which was in conformity with the present study. Later on similar results have also been reported by Marappa *et al. (*2010).

Table 4. Genotypic and phenotypic path coefficient analysis showing the direct and indirect effects among the studied characters

Characters	50% Flowering	Days to pod maturity	Plant height (cm)	Pods plant^{-1}	Seeds pod^{-1}	100 seed weight (g)	Pod length (cm)	Yield (kg ha^{-1})
Genotypic (Rg)								
50% Flowering	**–0.0186**	–0.00001	–0.0011	0.0224	–0.0003	–0.0129	–0.0054	–0.146
Days to pod maturity	–0.0004	**–0.0005**	–0.0037	–0.0257	–0.0073	0.0052	0.0006	–0.019
Plant height (cm)	0.0008	0.0001	**0.0265**	–0.0354	0.0064	0.0020	0.0041	–0.078
Pod plant^{-1}	0.0034	–0.0001	0.0076	**–0.1225**	–0.0019	–0.0049	0.0001	–0.053
Seed pod^{-1}	–0.0002	–0.0001	–0.0052	–0.0074	**–0.0321**	0.0025	–0.0030	–0.008
100 seed weight (g)	0.0050	–0.0001	0.0011	0.0124	–0.0017	**0.0482**	0.0009	0.105
Pod length (cm)	–0.0036	0.00001	–0.0039	0.0008	–0.0034	–0.0016	**–0.0282**	–0.064
Phenotypic (Rp)								
50% Flowering	**0.1497**	0.00002	0.0007	0.0166	–0.000002	–0.0134	–0.0043	–0.134
Days to pod maturity	–0.0002	**–0.0105**	–0.0049	–0.0229	–0.0017	0.0038	0.0005	–0.013
Plant height (cm)	0.0029	0.0013	**0.0396**	–0.0295	0.0017	0.0028	0.0035	–0.074
Pod plant^{-1}	–0.0227	–0.0022	0.0106	**–0.1097**	–0.0005	–0.0050	0.0001	–0.053
Seed pod^{-1}	0.0004	–0.0019	–0.0072	–0.0059	**–0.0095**	0.0010	–0.0034	–0.007
100 seed weight (g)	–0.0381	–0.0007	0.0021	0.0104	–0.0001	**0.0527**	0.0008	0.103
Pod length (cm)	0.0259	0.0002	–0.0055	0.0005	–0.0013	–0.0016	**–0.0252**	–0.063

Bold and underlined figures indicate the direct effect; Residual effect = 0.9261 for genotypic and 0.9287 for phenotypic

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