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Genetic Architecture of Synchronous Pods Maturation and Yield Related Traits in Mungbean [*Vigna radiata (L.)* Wilczek]

Javed IQBAL[1]* Muhammad AHSAN[1] Muhammad SALEEM[1] Asghar ALI[2]
[1] Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad, Pakistan
[2] Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

*Corresponding author:
Email: raijavediqbalpbg@gmail.com

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Abstract

The mode of inheritance of days to flowering and pods maturation at different phases, synchrony in pods maturation and yield related characters in mungbean were examined in F1, F2, BC1, and BC2 generations of two crosses by utilizing four parents who differed for each character through generation mean and variance analyses. Digenic epistatic interactions were engaged in both the crosses for all the traits studied except for days to ninety percent pods maturity, degree of indetermination of pod maturity from first flower to first pod maturity (DDd_3) and seed yield in NM-2006 × AUM-9 cross, where additive and dominant gene effects were prominent. Genetic variance analysis revealed the preeminence of additive and environmental components for the inheritance of investigated characters with the primacy of only additive genetic component. Narrow sense heritability estimates both in F2 and infinity generation also showed the pre-pondrance of only additive gene action for the inheritance of all the studied traits in both the crosses. Intercrossing of F2 plants with earliness, synchronized pods maturation with high yielding ability and eventually selection in the latter generations of segregating populations are recommended for the exploitation of the complex inherited traits and particularly for developing green gram lines with higher seed yield and improved synchrony in pod maturity.

Keywords: *Degree of indetermination; Gene action; Synchronous maturity; yield*.

INTRODUCTION

Green gram commonly known as mungbean is an important eco-friendly food grain leguminous crop of dry land [1]. It is a tropical and subtropical crop and requires a warm temperature of 30 to 35°C.Presence of high levels of proteins, amino acids, oligosaccharides and polyphenols in mungbean are thought to be the main contributors to the anti-oxidant, anti-microbial, anti-inflammatory, and anti-tumor activities and are involved in the regulation of lipid metabolism [2,3]. Due to the presence of alkaloids, coumarin and phytosterin components in its seed and soup, it helps to improve the physiological metabolism of humans and animals. Mungbean seeds are free from anti-nutritional factors such as trypsin inhibitor, phytohemagglutinsand tannin [4]. Green gram is a short duration legume crop therefore has less water requirement as compared to summer crops. Moreover, it is drought resistant that can withstand adverse environmental conditions, and hence successfully be grown in rain fed areas [5]. A large part of the cultivated area for mungbean is almost fixed,as no other crop is as economical as mungbean, but the area could be increased by planting green gram as an intercrop or grown on available fallow lands after wheat harvest in April/May [6, 7]. A crop with such a promise is still unable to find major areas in the country. A huge gap exists between experimental and national average yield in Pakistan. Due to intensive research and engagement of skilled manpower high yielding varieties have been developed in wheat, cotton, sugarcane and rice etc. Since farmers are fore seeking economic returns tilted towards more income generating crops. Pulses are still unable to snatch that position due to various biotic (insect, pest and disease) and abiotic (salinity, drought and grown on less productive soils with minimum inputs etc.) stresses. Similarly there are also linked some negative plant attributes, which are affecting the crop in adverse manner. Among them non-uniform pod maturation is one of the focal issue in mungbean cultivation, it involves time factor, which result in increased cost of production. Mungbean has long flowering period in consecutive flushes [8, 9].to non-uniform pod maturation extra picking becomes pre-requisite to get normal yield. This negatively linked plant attribute effect the farmer's economy by virtue of increasing the cost of production of mungbean crop. Not only lower yield but also asynchrony in pod maturity is a major problem in mungbean cultivation that is time consuming and costly practice of hand picking pods. It has been observed that only about 65% of pods can be harvested in the first picking at 70-75 days after sowing (DAS), 18% in the second at 75-80 DAS and 17% in the third at 90-95 DAS [10]. Plants in which maximum flowering was witnessed within two to three weeks after flowering gave higher pod yields in mungbean and groundnut [11]**.**Keeping in view the importance of synchronous pod maturity present investigation was mainly designed to find the genetic background and the inheritance pattern of yield and pod maturity related traits.

MATERIALS AND METHODS

Selection of parents for hybridization

For the selection of desirable parents a screening trial was performed during autumn (July-September- 2009) season at University of Agriculture, Faisalabad.For the same a triplicate randomized complete block design was exercised. Row length was maintained at 4m, with 30cm distance between the rows. A distance of 10cm was established between plants within the row. Plantation was done with the help of dibbler. One week after germination thinning was performed. One vigorous seedling was kept per hole. Recommended agronomical/cultural practices done were adopted. Plant protective measures were also adopted accordingly. Five random and guarded plants from each genotype within a replication were selected to record data on the following traits.

At screening

Days to first pod maturity: $\mathbf{D_2}$

Days to 90% pods maturity: $\mathbf{D_3}$

Plant height (cm) at first flower initiation: **H1**

Plant height (cm) at 90% pods maturity: **H3**

Degree of indetermination of pod maturity from first pod maturity to 90% pods maturity = $\mathbf{DDd_2}$= D3- D2/D3 × 100

Degree of indetermination of plant height from first flower to 90% pods maturity =

$\mathbf{DDh_2}$ = H3- H1/H3 × 100

A graph was plotted between DDd_2 and DDh_2 taking the DDd_2 at X- axis and DDh_2 at Y- axis [12]

At final evaluation

Days to first flower initiation=$\mathbf{D_1}$

Days to first pod maturity= $\mathbf{D_2}$

Days to 90% pods maturity= $\mathbf{D_3}$

Degree of indetermination of pod maturity from first flower to 90% pods maturity= $\mathbf{DDd_1}$= D3- D1/D3 × 100

Degree of indetermination of pod maturity from first pod maturity to 90% pods maturity = $\mathbf{DDd_2}$= D3- D2/D3 × 100

Degree of indetermination of pod maturity from first flower to first pod maturity=

$\mathbf{DDd_3}$= D2- D1/D2 × 100

By utilizing the selected four parents two cross combinations were made. The basic population of each cross viz., two parents, their F_1, F_2 and back crosses BC_1 (F_1 × male parent) and BC_2 (F_1 × female parent) were developed and planted in a completely randomized block design with three replications on the research area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, during autumn 2010. The parents, F_1 and back crosses were sown in two rows each, F_2 in 20 rows with the row length of 4 meter, and the spacing between rows and plants 30 and 10 cm, respectively. Data were recorded on 30 random plants in each parent and F_1, 50 plants in each back cross and 300 plants in each F_2 population. Analysis of variance was performed [13],generation mean and variance analysis was also carried out [14]. Narrow sense heritability estimates were calculated from the variance components:

$h^2(F_2)$= 0.5D/ (0.5D + E)

h^2 (F .) = D/ (D + E)

where,

D = additive genetic component, E = environment components

RESULTS

Selection of the parents and preliminary analysis of variance

Fifty mungbean genotypes were studied for range of variability regarding degree of indetermination of pod maturity from first pod maturity to 90% pods maturity (DDd_2) and degree of indetermination of plant height from first flower to 90% pods maturity (DDh_2) to earmark parents for hybridization. Creation of genetic variability and exploiting the existing one is paramount importance for initiating a successful breeding program [15,16]. Analysis of variance showed significant diversity among the genotypes for both degrees of indetermination. Accordingly a scattered diagram (Figure 1) was constructed between these two variables. In which the variable DDd_2 was taken at X- axis, while DDh_2 at Y- axis. A visual look at the diagram provided the information that two varieties (AZRI-2006 and NM-2006) fall in the zone where the values of both (DDd_2 and DDh_2) the components were at its minimum. Whilst two genotypes namely 97006 and AUM-9 occupied the spaces where no other genotype reached, curtsey of their maximum DDd_2 and DDh_2 values. Most of the genotypes fall in the zone where the value of DDd_2 ranged from 36- 48 and that of DDh_2 from 40- 50. A total of 38 genotypes resided in this particular patch. A line drawn from the point 38.5 representing generation mean for DDh_2 on Y- axis, which divided the graph into two portions each half contains exactly twenty five genotypes. Resultantly two varieties (AZRI-2006 and NM-2006) demonstrated the minimum values for DDd_2 and DDh_2 and the other two genotypes (97006 and AUM-9) exhibited the opposite for the above said traits were selected for hybridization. Six basic generations (P_1, P_2, F_1, F_2, BC_1 and

Table 1. Mean squares for 50 mungbean genotypes for six traits during autumn (kharif) season

Trait	D.F.	Mean Squares
Days to first pod maturity	49	18.78**
Days to 90% pods maturity	49	47.72**
DDd_2	49	53.87**
Plant height at first flower initiation	49	23.16**
Plant height at 90% pods maturity	49	78.94**
DDh_2	49	155.7**

** = P<0.01

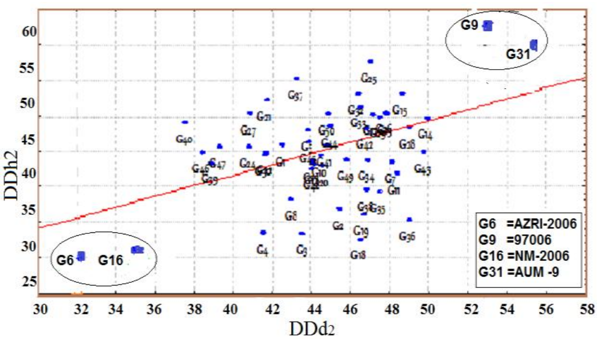

Figure 1. Scattered plot of degree of indetermination of pods maturity from first pod maturity to 90% pods maturity (DDd_2) against degree of indetermination of plant height from first flower to 90% pods maturity (DDh_2)

BC_2) of two crosses were utilized for computing the genetic components of mean for synchronous pod maturity and yield related traits. Three, four and five parameters models were the best fit for all the traits studied in two crosses. The model fitting was based on the χ^2 values. The best fit was the one with non significant χ^2 value along with significant genetic components.

Generation means and partitioned analyses

In a partitioned analysis maximum diversity was observed between the parents for all the characters except DDd_1. Similar genetic behavior could be witnessed from table (Table 2), between parents and hybrids for synchronous pod maturity related traits. Both the back cross generations (BC1 and BC2) showed non- significant differences for degrees of indetermination of pod maturity (DDd_2 and DDd_3) and most of the yield influencing traits in both the crosses. Alike behavior for the said traits were recorded among back crosses (BC1 and BC2) and the F2 generations in both the cross combinations, which revealed complete unanimity for genetic diversity between the said generations. In a comparative study, synchronous pod maturation traits demonstrated maximum genetic dissimilarity between the generations in both the crosses, while the same was nearly reverse for yield relevant traits in the studied crosses of mungbean.

Only additive component was observed for days taken to 90% pods maturity (Table 3) in one cross combination. While additive and dominant genetic components played important role in the inheritance of DDd_3 and seed yield per plant in NM-2006 × AUM-9 cross. For rest of the traits in both the crosses epistatic component (additive × additive, additive × dominant and dominant × dominant) were engaged. A negative sign was also associated with most of the components for the studied traits in both the crosses.

Genetic component of variance and narrow sense heritability estimates

The model incorporation in case of generation variance analysis in the present studies gave the non-significant χ^2 values only at two parameters (DE) model of genetic variances. Additive component of variance was much higher than the corresponding environmental variance for pod maturation traits only in both the cross combination. While for yield relevant traits the said parameters showed nearly similar values. Additive and environmental components ranged from 0.250 – 99.50 and 0.04 – 17.14, respectively for AZRI-2006 × 97006 cross. While the values for the same parameters ranged from 0.160 – 55.17 and 0.090 – 7.70, respectively in NM-2006 × AUM-9 cross.

Minimum narrow sense heritability F_2 generation (h^2_{F2}) was computed for the trait seeds per pod and maximum for seed yield per plant closely chased by degree of indetermination of pod maturity from first flower to first pod maturity (DDd_3) with respective values 71.5, 92.6 and 91.1 for AZRI-2006 × 97006 cross. The value for the same parameter was lowest for pods per plant (67.6) followed by days to first flower (71.1) and highest for seed yield per plant (86.4) followed by degree of indetermination of pod maturity from first pod maturity to 90% pods maturity (83.2) in NM-2006 × AUM-9 cross. A glimpse at the table (Table 4) revealed that narrow sense heritability estimate for infinity generation ($h^2_{F\infty}$) was least for pods per plant tracked by degree of indetermination of pod maturity from first pod maturity to 90% pods maturity(DDd_2) with respective values 83.4 and 74.1 and maximum forseed yield per plant and degree of indetermination of pod maturity from first flower to first pod maturity (DDd_3) with respective values (96.0 and 92.4, respectively) for AZRI-2006 × 97006 cross. Similarly for NM-2006 × AUM-9 cross combination minimum narrow sense heritability for infinity generation was noticed for days to first flower (83.2) and pods per plant (83.4), while extreme for the same was noticed for seed yield per plant (92.7) and DDd_1 (90.8).

DISCUSSION

In mungbean synchrony in pod maturity is very important as it confirms cost effective single harvesting, contributes in productivity and reduction in diseases [17, 18].The aim of the present investigation was to find the genetics of different reproductive stages (days to first flower, first and 90% pods maturity), synchrony in pod maturity in terms of degree of indeterminations and seed yield related traits. Uniformity in pod maturity with low degree of indetermination could be crucial to cultivate mungbean as a catch crop with no competition with major crops like wheat, rice and cotton also reported that low degree of indetermination of pod maturity was pre-requisite for achieving uniform pod maturity in green gram [17]. In this regard choice of the parent(s) and selection of trait(s) play a pivotal role in determining the extent of gene action. Involvement of epistasis for most of the mentioned traits in the present study betrays the genetic diversity of selected parents. In gram and green gram, both additive and non-additive gene effects have been documented for different traits [19- 21]. The concurrent existence of additive and digenic interaction [i], dominant and other epistatic components for various characters divulged the impact of same genes contributing towards each genetic component.

The consistency in significance of additive [d] component for all the traits in both generation means and variance analysis clearly reflect the engagement of additive genetic effect and likelihoods of genetic improvement of all the studied traits, though the same may be practiced in early or later generations as per the significance of other genetic components. Under such circumstances, additive variance is affected by the presence of [i] and [j]. The presence of [i] often inflates the variance of F_2 and its subsequent generations, while [j] increases it when positive and decreases it when negative. The incongruity in both the analyses may arise due to difference in the estimation precision of the two analyses. The generation mean analysis is comparatively more robust than the generation variance analysis. Pedigree selection method involving numerous crosses could be employed for the improvement of characters where only additive and positive interaction [i] effects are important. In present study crop maturity period could be minimized by adopting the said procedure. Non-additive gene action for seed yield in cowpea was also observed [22]. An additive genetic effect for grain yield per plant was also witnessed in mungbean [23]. Genotypic × environmental interaction and its involvement in the inheritance were also reported in wheat [24]. Narrow sense heritability estimates also reflects the engagement of additive gene action for the onward transmission of synchronous pod maturation and yield related traits to the further progenies.

High narrow and broad sense heritability for days to first pod maturity was observed in green gram [25]. Similarly engagement of higher heritability estimates for seed yield was noticed in mungbean [26]. Additive genetic

Table 2. Mean squares with partioned generation variances for various traits in two crosses of mungbean

Traits	Cross Combination	Generations	P_1 vs.P_2	P's vs. F_1	B_1 vs. B_2	B's vs. F_2	Error
D.F		5	1	1	1	1	10
Days to first flower initiation	AZRI-2006 ×97006	167.07**	305.3**	0.720$_{NS}$	3.920$_{NS}$	2.982 $_{NS}$	1.059
	NM-2006 × AUM-9	15.745**	61.44**	0.569$_{NS}$	3.081*	1.693*	0.241
Days taken to first pod maturity	AZRI-2006 ×97006	186.1**	682.6**	42.32**	198.3**	1.356$_{NS}$	0.637
	NM-2006 × AUM-9	18.648**	52.22**	12.34**	13.85**	3.855$_{NS}$	7.176
Days taken to 90% pods maturity	AZRI-2006 ×97006	225.7**	965.2**	1.561*	156.0**	1.460$_{NS}$	1.431
	NM-2006 × AUM-9	26.369**	102.5**	2.570$_{NS}$	26.67**	0.000$_{NS}$	4.000
DDd_1	AZRI-2006 ×97006	133.02**	355.7**	0.642$_{NS}$	47.94**	0.656$_{NS}$	3.460
	NM-2006 × AUM-9	7.123**	5.141$_{NS}$	0.076$_{NS}$	25.23**	1.820$_{NS}$	1.249
DDd_2	AZRI-2006 ×97006	139.8**	387.8**	0.349**	33.42**	0.670$_{NS}$	1.000
	NM-2006 × AUM-9	18.61**	5.005**	0.640 ^{NS}	2.33 $_{NS}$	14.71**	0.505
DDd_3	AZRI-2006 ×97006	37.58**	101.1**	0.748$_{NS}$	0.833$_{NS}$	0.200$_{NS}$	3.240
	NM-2006 × AUM-9	12.25**	28.63**	0.165$_{NS}$	2.27 $_{NS}$	10.29**	0.740
Pods per plant	AZRI-2006 ×97006	13.12**	56.42**	2.000$_{NS}$	0.690$_{NS}$	2.112$_{NS}$	1.228
	NM-2006 × AUM-9	333.5**	184.8**	11.68**	11.62**	0.012$_{NS}$	0.470
Seeds per pod	AZRI-2006 ×97006	0.424*	1.307**	0.222$_{NS}$	0.030$_{NS}$	0.257$_{NS}$	0.122
	NM-2006 × AUM-9	1.880**	4.507*	0.889**	0.260$_{NS}$	0.669**	0.476
100-seed wt.	AZRI-2006 ×97006	0.176*	0.674*	0.066**	0.011$_{NS}$	0.000$_{NS}$	0.004
	NM-2006 × AUM-9	0.161*	0.330*	0.169**	0.002$_{NS}$	0.006 ^{NS}	0.051
Pod clusters per plant	AZRI-2006 ×97006	133.0**	5.801**	0.681**	1.283*	0.017$_{NS}$	0.025
	NM-2006 × AUM-9	1.730**	5.607**	0.642**	1.354**	0.631**	0.019
Seed yield per plant	AZRI-2006 ×97006	0.532*	0.620*	1.887*	0.060$_{NS}$	0.093$_{NS}$	0.160
	NM-2006 × AUM-9	2.632**	8.965**	1.811*	2.251**	0.001$_{NS}$	0.003

NS = Non-significant, * = P<0.05 and ** = P<0.01

Table 3. Estimates of gene effects with standard error and χ² values of the fitted models for pods maturity and yield related traits in two crosses of mungbean

Traits	Cross Combination	m (±SE)	[d] (±SE)	[h] (±SE)	[i] (±SE)	[j] (±SE)	[l] (±SE)	χ2 (d.f)
Days to first flower initiation	AZRI-2006 ×97006	39.1±1.5	7.10±0.4		6.99±1.1	6.45±1.3	-8.72±1.0	0.38 (1)
	NM-2006 × AUM-9	31.4±0.6	3.20±0.3	3.82±0.8	4.37±0.7	-4.62±0.5		0.27 (1)
Days taken to first pod maturity	AZRI-2006 ×97006	60.4±0.9	10.7±0.3	9.84±1.1	5.25±0.9	-22.1±0.8		0.80 (1)
	NM-2006 × AUM-9	61.4±0.3	2.95±0.3		2.89±0.4			2.49 (3)
Days taken to 90% pods maturity	AZRI-2006 ×97006	87.4±0.3	12.7±0.4		-1.28±0.5	-22.9±1.1		1.64 (2)
	NM-2006 × AUM-9	84.1±0.2	4.23±0.3					3.60 (4)
DDd_1	AZRI-2006 ×97006	37.3±0.4	1.09±0.4		-3.20±0.6	-9.31±1.2		0.34 (2)
	NM-2006 × AUM-9	44.2±0.3	0.93±0.3	3.12±1.4		-4.99±0.8	-2.92±1.4	3.22 (1)
DDd_2	AZRI-2006 ×97006	57.9±1.5	2.02±0.5	-8.73±2.0	-7.23±1.6	-5.63±1.3		0.02 (1)
	NM-2006 × AUM-9	61.2±0.4			-3.99±0.5	-3.79±0.6	-3.83±0.6	3.89 (2)
DDd_3	AZRI-2006 ×97006	31.2±1.2	2.36±0.3	-12.1±1.5	-6.32±1.3			3.73 (2)
	NM-2006 × AUM-9	27.3±0.3	2.27±0.3	4.08±0.6				0.01 (3)
Pods per plant	AZRI-2006 ×97006	33.4±0.3	3.07±0.3		1.47±0.39	-3.70 ±0.8		2.50 (2)
	NM-2006 × AUM-9	28.2±0.9	5.55±0.3	-21.9±1.4		-2.80 ±0.7	19.6±0.7	0.03 (1)
Seeds per pod	AZRI-2006 ×97006	7.50±0.3	0.41±0.1	1.43±0.4	1.08±0.28			2.50 (2)
	NM-2006 × AUM-9	5.50±0.2	0.87±0.1	3.33±0.3	2.67±0.20	-0.50 ±0.2		0.60 (1)
100-see'8d wt.	AZRI-2006 ×97006	5.93±0.1	0.34±0.1	0.73±0.1		-0.30 ±0.1	-0.60±0.1	0.01 (1)
	NM-2006 × AUM-9	5.75±0.1	0.23±0.1	1.16±0.1		-0.30 ±0.1	-0.90±0.1	1.90 (1)
Pod clusters per plant	AZRI-2006 ×97006	10.1±0.1	0.98±0.1			-1.90±0.2	-0.59±0.1	1.50 (2)
	NM-2006 × AUM-9	10.6±0.2	0.98±0.1	-1.14±0.3	-0.57±0.20	-1.91±0.2		0.20 (1)
Seed yield per plant	AZRI-2006 ×97006	13.2±0.2	0.31±0.1	1.60±0.3	0.56±0.20			0.70 (2)
	NM-2006 × AUM-9	13.8±0.1	1.20±0.1	-0.96±0.1				0.06 (3)

m = mean, [d] = additive, [h] = dominance, [i] = additive × additive, [j] = additive × dominance, [l] = dominance × dominance

Table 4. Best fit model following weighted analysis of components of variation, and narrow sense heritability estimates in two crosses of mungbean

Traits	Cross Combination	Variance Components		χ^2 (4df)	Heritability (%age)	
		D (±SE)	**E** (±SE)		$h^2_{(F2)}$	$h^2_{(F\infty)}$
Days to first flower initiation	AZRI-2006 × 97006	63.00±9.01	10.80±1.58	1.608	74.5	85.4
	NM-2006 × AUM-9	15.98±2.47	3.232±0.47	1.046	71.2	83.2
Days taken to first pod maturity	AZRI-2006 × 97006	53.99±5.93	4.260±0.63	3.860	86.4	92.7
	NM-2006 × AUM-9	37.40±4.86	5.128±0.75	1.606	78.4	87.9
Days taken to 90% pods maturity	AZRI-2006 × 97006	97.93l±10.8	7.840±1.16	4.967	86.2	92.6
	NM-2006 × AUM-9	55.17 ±4.79	7.700±1.05	2.163	79.4	88.5
DDd_1	AZRI-2006 × 97006	99.50 ±12.2	11.63±1.71	0.237	81.1	89.5
	NM-2006 × AUM-9	40.71 ±7.05	4.128±0.61	1.127	83.1	90.8
DDd_2	AZRI-2006 × 97006	92.63 ±13.7	17.14±2.50	0.931	73.0	84.4
	NM-2006 × AUM-9	27.79 ±3.69	3.999±0.58	2.813	77.7	87.4
DDd_3	AZRI-2006 × 97006	111.7 ±11.1	5.460±0.81	1.231	91.1	95.3
	NM-2006 × AUM-9	27.09 ±3.23	2.851±0.42	2.105	82.6	90.5
Pods per plant	AZRI-2006 × 97006	63.00 ±9.01	10.80±1.58	1.608	74.5	85.4
	NM-2006 × AUM-9	23.34±3.93	5.592±0.81	1.632	67.6	80.7
Seeds per pod	AZRI-2006 × 97006	2.826 ±0.43	0.562±0.82	2.841	71.5	83.4
	NM-2006 × AUM-9	2.074±0.33	0.433±0.10	2.842	70.5	82.7
100-seed weight.	AZRI-2006 × 97006	0.250 ±0.04	0.045±0.01	3.221	73.5	84.7
	NM-2006 × AUM-9	0.160±0.03	0.037±0.01	3.412	68.2	81.1
Pod clusters per plant	AZRI-2006 × 97006	1.977 ±0.26	0.268±0.04	1.669	78.7	88.1
	NM-2006 × AUM-9	1.177±0.19	0.247±0.04	3.412	70.5	82.7
Seed yield per plant	AZRI-2006 × 97006	3.262 ±0.32	0.137±0.021	0.251	92.6	96.0
	NM-2006 × AUM-9	1.132±0.12	0.089±0.01	5.481	86.4	92.7

D = additive variance, E = environmental variance, $h^2_{(F2)}$ = narrow sense heritability F2 generation and $h^2_{(F\infty)}$ =narrow ,sense heritability F infinite generation.

variance played a pivotal role in the inheritance of investigated traits, merely due to higher heritability estimates, reiterated the engagement of few major genes and similar genetic effects. The same also got support from the results of both generation means and variance analyses. But presence of epistasis in generation mean analysis portrayed a slightly different prospective. Any protective measure which minimizes experimental error could improve the estimate of heritability of a trait [27].

The complexity observed in the inheritance of most of the traits was merely due to the engagement of epistasis. Additive × additive and additive × dominance non allelic interactions were important. Under such situations improvement of traits through simple selection procedure in early segregating generation may be futile. Engagement of epistatic components for most of the pod maturity, degree of indeterminations and yield related traits reflect that these characters are non-directional and unfixable especially in early segregating generations. The bi-parental approach of hybridization among selected plants in F2 generation could be more effective for accumulation of maximum genes for early and synchronous maturity accompanied with high yield. Under such circumstances adjournment of selection procedure until the achievement of homozygosity may be fruitful, so bulk method of selection after attaining homozygosity for maximum heterozygous loci could be adopted. Bi-parental approach was suggested for curtailing negative epistatic effects in *Linumusitisimum*[28] and for developing synchronous maturing and high yielding lines in mungbean [29].

CONCLUSION

Finally, on the basis of heritability estimates, generation mean and variance analyses it can be concluded that genetic improvement of earliness, synchronous pods maturation and yield related traits is possible in mungbean. The study suggests that the inheritance of mentioned traits is complicated therefore simple selection breeding procedure in early segregating population is futile. Therefore multiple crosses may be attempted by utilizing the segregants with early flowering and maturity accompanied with synchronous pods maturity and high yield and eventually delaying the selection until the later generations so bulk selection method may be adopted after subsequent crossings.

REFERENCES

[1] **Keatinge JDH, Easdown W, Yang R, Chadha M, Shanmugasundaram S, et al., 2011.** Overcoming chronic malnutrition in a future warming world: The key importance of mungbean and vegetable soybean. Euphytica, 180 (1). 129–141.

[2] **Anjum NA, Umar S, Iqbal M, Khan NA, et al., 2011.** Cadmium causes oxidative stress in mungbean by affecting the antioxidant enzyme system and ascorbate-glutathione cycle metabolism. Russian J. Plant Physio, 58 (1): 92-99.

[3] **Kanatt SR, Arjum K, Sharma A,et al., 2011.** Antioxidant and antimicrobial activities of legume hulls. Food Res. Int, 44 (10): 3182-3187.

[4] **Chen X, Sorajjapinun W, Reiwthongchum S, Srinives P, et al., 2003.** Identification of parental mungbean lines for production of hybrid varieties. Chiang Mai University Journal, 2 (2). 97-105.

[5] **Anjum MS, Ahmed ZI,Rauf CA,et al., 2006.** Effect of rhizobium inoculation and nitrogen fertilizer on yield and yield components of mungbean. Int. J. Agric&Biol, 8 (2): 238–240.

[6] **Khattak GSS, Haq MA, Ashraf M, Hassan S,et al., 2002.** Yield and yield components at various flower flushes in mungbean. Breed. Sci, 52 (1): 61–63.

[7] **Khattak GSS, Haq MA, Ashraf M, Hassan S,et al., 2002a.**Detection of epistasis, and estimation of additive and dominance components of genetic variation for determinate growth habit in mungbean (Vigna radiata (L.)Wilczek). J. Genetic and Breeding, 56: 1-7.

[8] **Tah PR. 2009.**Induced synchrony in pod maturity in mungbean {Vigna radiata (L.)Wilczek}. J. Agri. Bio. Sci, 4(1): 41-44.

[9] **Tah PR, Saxena R. 2009.** Induced synchrony in pod maturity in mungbean. Int. J. Agric. Biol, 11 (3): 321–324.

[10] **Rahman MM. 1991.** Factors limiting the expansion of summer pulses. In: Advances in Pulse Research in Bangladesh: Proceedings of the second national workshop on pulses, Gazipur, Bangladesh.

[11] **Mondal MMA. 2007.** A study of source-sink relation in mungbean. Ph.D Dissertation, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh.

[12] **Rehman A, Ali MA, Ali BM, Saleem M, Abbas A,Mallahi AR,et al., 2009.** Genetic studies of yield related traits in mungbean (Vigna radiata L. Wilczek). Aust. J. Crop Sci, 3(6): 352-360.

[13] **Steel RGD, Torrie JH, Deekey DA, et al.,1997.** Principles and Procedures of Statistics: A Biometrical Approach. 3rd ed. McGraw Hill Book Co., New York, USA.

[14] **Mather K, Jinks JL. 1982.** Biometrical Genetics. 3rd Edition, Chapman and Hall, London, pp. 396.

[15] **Khattak GSS, Ashraf M, Khan MS,et al., 2004a.** Assessment of genetic variation for yield and Yield component in mungbean [Vigna radiate (L.) Wilczek] using generation mean analysis. Pak. J. Bot, 36(3): 583-588.

[16] **Ali MA, Khan IA, Awan SI, Ali S, Niaz S,et al., 2008.** Genetics of fibre quality traits in cotton (Gossypiumhirsutum L.). Aus J Crop Sci, 2 (1): 10-17.

[17] **Khattak GSS, Haq M, Ashraf M,Tahir G,et al., 2001a.**Genetic basis of synchrony in pod maturity in mungbean (Vigna radiata L. Wilczek).Kasetsart J. Nat. Sci, 35: 1–7.

[18] **Khattak GSS, Ashraf M, Saeed I,Alam B, et al., 2006.** A new high yielding mungbean (Vigna radiata L. Wilczek) variety "Ramzan" for the agroclimatic conditions of NWFP. Pakistan J. Bot, 38 (1): 301–310.

[19] **Singh RK, Singh BB, Singh DP,et al., 1993.** Analysis of gene effects for yield and certain yield traits in chickpea. Indian J. Genet, 53 (2): 203-207.

[20] **Ram T. 1997.**Gene action for certain quantitative characters in greengram (Vigna radiata (L.)Wilczek). Indian J. Genet, 57(2): 143-148.

[21] **Khattak GSS, Haq MA, Ashraf M, Jabbar A,Zamir R,et al., 2002b.**Genetic architecture of secondary yield components in mungbean (Vigna radiata (L.)Wilczek). Breed. Sci, 52 (4): 235- 241.

[22] **Dijee B, Kandasamy G, Sakila M, Shunmugavalli N, Bastian D, et al., 2000.** Combining ability for yield and components in cowpea. Research on Crops, 1 (2): 239- 244.

[23] **Joseph J, Santhoshkumar AV. 2000.** Genetic analysis of quantitative characters through biparentalmatings in green gram (Vigna radiata L Wilczek). Research on Crops,1(2): 221-225.

[24] **Deswal RK, Grakh SS, Berwal KK, et al., 1996.**Genetic variability and characters association between grain yield and its components in wheat. Ann Biol. (Ludhiana), 12 (2): 221–224.

[25] **Khattak GSS, Haq MA, Ashraf M, Tahir GR, Marwat UK, et al., 2001.** Detection of epistasis and estimation of additive and dominance components of genetic variation for synchrony in pod maturity in mungbean (*Vigna radiata* L.). Field Crop Res, 72 (3): 211-219.

[26] **Sharma RN. 1999.** Heritability and character association in non-segregating populations of mungbean (Vigna radiata L. Wilczek.) J. Interacedemesia, 3: 5-10.

[27] **Fehr WR. 1987.** Heritability. in principles of cultivar development: Theory and techniques, Vol 1. (Ed. W.P. Fehr), pp. 95-105. Macmillan Pub.Co. New York.

[28] **Sood S, Kalia NR,Bhateria S, Kumar S,et al., 2007.** Detection of genetic components of variation for some biometrical traits in Linumusitatissimum L. in sub-mountain Himalayan region.Euphytica, 155(1-2): 107-115.

[29] **Khattak GSS, Ashraf M, Zamir R,et al., 2004b.**Gene action for synchrony in pod maturity and indeterminate growth habit in mungbean (Vigna radiata (L.)Wilczek). Pak J Bot, 36 (3): 589-594.