The Journal of Animal & Plant Sciences, 26(1): 2016, Page: 149-155
ISSN: 1018-7081

INHERITANCE STUDY OF DIFFERENT AGRONOMIC TRAITS IN MUNG × MASH INTERSPECIFIC RECOMBINANT GENOTYPES

G. Abbas[1*], M. Ahsan[2], M. Saleem[2] and R. Ahmad[3]

[1]Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan
[2] Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan
[3]Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan

Corresponding author's email: gabbas_niab@yahoo.com

ABSTRACT

Inheritance study for various agronomic traits was first time conducted in 5 x 5 mungbean × mashbean interspecific recombinant genotypes. Highly significant general and specific combining ability (GCA & SCA) effects were observed among parents and their hybrids for days to flowering, days to maturity, clusters per plant and pods per plant however, pod length, 100-seed weight and seed yield per plant had significant GCA but non-significant SCA effects. The GCA/SCA ratios for all traits except 100-seed weight were less than unity indicating the preponderance of non-additive gene action. GCA/SCA ratio was more than unity for 100-seed weight showing the preponderance of additive gene action. Heterosis breeding for the improvement of all traits while, recombination breeding for 100-seed weight were suggested. The genotype MMH 4224 was observed to be good general combiner for seed yield and their related trait i.e. clusters per plant, pods per plant and pod length. The best specific cross combinations for the improvement of days to flower and maturity, plant height and clusters per plant were MMH 4224 × MMH 7124, MMH 7124 × MMH 4255 and MMH 1115 × MMH 2112. Special consideration must be given to cross combination MMH 7124 × MMH 4255 to improve clusters per plant in mungbean.

Key words: Interspecific recombinants, diallel analysis, gene action, heterosis/recombination breeding.

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) and mashbean (*Vigna mungo* L. Happer) are widely grown cultivated pulse crops. They are thought to be domesticated in India (Tomooka *et al*., 2006). Both these crops have considerable importance because of their use as supplementary crop in the cereal based cropping systems. Average seed yield of mungbean and mashbean is very low because of low varietal potential and are mainly grown on marginal lands with low inputs and poor management practices. Mungbean production has been affected by various stresses and the severity of these stresses is largely due to varying weather conditions that prevails throughout the year, thus lowering mungbean yield at farmer's field and keeping it below the potential yield or economic level (Ullah *et al*., 2013).

Evaluation of breeding potential of parent's lines to assess the genetic components of variation is necessary. For this purpose many biometrical techniques have been extensively used in crop improvement programs. Diallel analysis (Griffing, 1956) is one of the most commonly used biometrical techniques for the assessment of the nature of gene action to adopt an appropriate breeding strategy for desired improvement in any crop. In this technique progeny performance can be statistically partitioned into different components on the basis of general combining ability (GCA) and specific combining ability (SCA) effects (Glover *et al*., 2005). This technique had already been used in mungbean (Khattak *et al.*, 2002a) and has been observed very useful for the identification of good combiners for hybrid seed production in tomato (Pratta *et al*., 2003; Chishti *et al*., 2008); wheat (Inamullah *et al*., 2006) and in rice (Saleem *et al*., 2010). In literature only few reports on the mode of gene action and inheritance pattern of seed yield and its component traits in mungbean are available. Positive GCA and SCA effects are desirable for earliness while days to maturity needs negative effects because early maturity is more desirable in mungbean. Mungbean × mashbean interspecific hybridization was performed with the aim to improve the amino acid concentration of mungbean as it is deficient in some essential amino acids as compared to black gram (Poehlman, 1991). Keeping in view, the present study was extended to assess the inheritance pattern and gene action of different morphological and economic traits and to formulate an effective breeding strategy for the improvement of seed yield and its component traits in mungbean × mashbean interspecific recombinant genotypes. According to our knowledge, this study is a new report and has not been presented so far in Pakistan.

MATERIALS AND METHODS

The present study was conducted at Nuclear Institute for Agriculture and Biology, Faisalabad and the experimental material comprised of five mungbean × mashbean interspecific elite recombinant genotypes viz. MMH 1115, MMH 2112, MMH 4224, MMH 4255 and MMH 7124. In these genotypes the concentration of some essential and non essential amino acids was improved as compared to their parent female mungbean cultivars which were involved in interspecific hybridization. The genotypes were dibbled in two rows keeping row to row distance of 30 cm and plant to plant distance of 10 cm and were crossed in 5 × 5 diallel fashion (Griffing, 1956) in spring season during 2013 under field and in tunnel conditions. Recommended agronomic practices were applied to raise healthy mungbean crop. At maturity the F_0 seeds were collected cross wise and used for inheritance study. In 2013 summer season, five parental lines alongwith their 10 direct F_1 and 10 reciprocal F_1 crosses were grown in pots under controlled conditions in glass house following Randomized Complete Block Design. Five pots were used for each genotype per replication and four seeds were sown in each pot and a total of fifteen pots were maintained for each genotype. After germination three plants per pot having plant to plant distance of 10 cm were maintained by manual thinning. The data for days to flower were recorded when a genotype flowered 50% and days to maturity when 90% of pods turned brown/black. The data for other agronomic traits i.e. plant height (cm), number of clusters per plant, number of pods per plant and seed yield per plant (g) were recorded on three plants per genotype per replication and then averaged to per plant basis. Seeds per pod and pod length (cm) were recorded on 10 pods selected at random from each genotype. Hundred seed weight (g) was recorded for each genotype by counting and weighing 100 seeds. Mean data were used for analysis of variance following Steel *et al*. (1997) for each character by using Mstat C Software. General combining ability referred as GCA and specific combining ability referred as SCA. Diallel analysis was performed following Model-1, Method-1 of Griffing (1956). Combining ability effects in relation to selection of desired parents and hybrids were distributed, and negative effects were desirable for days to flowering, days to maturity and plant height, while positive values were desirable for clusters per plant, pods per plant, pod length, seeds per pod, 100-seed weight and seed yield per plant.

RESULTS AND DISCUSSION

Analysis of variance showed highly significant differences among genotypes for days to maturity and significant differences for all other remaining traits under study (Table 1) which is a pre-requisite for the improvement of any cop plant as selection efficiency for yield improvement depends upon the amount of genetic variability present for different yield contributing traits (Khan *et al*., 2004 and Yirman *et al*., 2009). Considerable range of genetic variability was reported previously by various research workers (Malik *et al*., 2007 and Tabasum *et al*., 2010) in mungbean and Sharma *et al*. (2012) in mashbean. These results suggested that genetic variability exist for above mentioned traits which can be exploited in breeding programme for the improvement of these traits. But in mungbean × mashbean recombinant genotypes no such information is readily available in literature; hence the present study will help to understand the nature of variation and inheritance pattern in mungbean × mashbean interspecific recombinant. General (GCA) and Specific Combining (SCA) ability differences were highly significant for days to flowering and maturity, clusters per plant and pods per plant (Table 1). GCA differences were also highly significant for 100-seed weight and seed yield per plant, but these traits had non-significant specific combining ability differences. Plant height and seeds per pod had non-significant GCA and SCA differences while pod length had significant GCA and non-significant SCA differences. These results are in accordance with the findings of Ghaviami and Rezai (2000) and Patil *et al.* (2011) who observed significant GCA and SCA differences for most of the traits in mungbean. Barelli *et al.* (2000) and Atnaf *et al.* (2013) observed significant GCA differences for 100-seed weight and seed yield per plant in common bean. Significant GCA and SCA effects were also observed by Patil *et al*. (2011) for most of the traits in mungbean. He also reported non-additive type of gene action for a number of traits in mungbean.

GCA and SCA ratio was less than unity for all the traits except 100-seed weight (Table 1) which showed the influence of non-additive gene action for most of the traits. Whereas hundred seed weight might be influenced by recessive gene action. Hence, heterosis breeding is recommended for traits controlled by non-additive gene action and recombination/backcross breeding for traits governed by recessive gene action. These results are in conformity with the earlier reports (Zubair *et al*., 2007; Vidigal *et al*., 2008; Rehman *et al*., 2009; Singh *et al*., 2010; Rehman *et al*., 2010). Hundred seed weigh had GCA/SCA ratio greater than unity (1) which showed the preponderance of additive type of gene action. The results are contradicted with Vidigal *et al*. (2008) who reported the importance of dominant gene action. This contradiction may be due to the difference in genetic material or seasonal variation which affects gene expression in mungbean (Khattak *et al*., 2002a and 2002b). The role of environment on the expression of genes for most of the traits in mungbean was also reported by Abbas *et al*. (2005); Sadiq *et al*. (2006) and Makeen *et al*. (2007). Hence heterosis breeding can be used for the improvement of all the traits under study except 100-seed weight which can also be improved through recombination/backcross breeding as this is the only traits that was observed to be controlled by additive type of gene action.

General Combining Ability (GCA) Effects: Estimates of GCA effects of the parents are given in Table 2. Mung and mash interspecific recombinants genotypes MMH 4224 and MMH 2112 were good general combiners for days to flower as both the parents showed highly significant and desirable negative GCA effects (-0.61). The parents MMH 7124 and MMH 4255 were not good general combiners because they had undesirable positive and highly significant GCA effect (0.69 and 0.63) respectively. GCA/SCA ratio was less than unity for this trait, hence heterosis breeding is being recommended. The results are in confirmation with Khattak *et al*. (2001); hence these parents can be used to reduce number of days taken to flowering and when the numbers of days taken to flowering reduce it will expand reproductive phase which greatly help to increase crop productivity. MMH 4224, MMH 1115 and MMH 2112 showed significant and desirable negative GCA effects for days to maturity with values of -0.61, -0.18 and -0.81 respectively. These parents are good general combiners and can be used to improve days to 90% maturity. MMH 2112 was best general combiner for the improvement in days to maturity (decreased maturity period). Decreased in maturity period positively help to develop short duration varieties of mungbean which is the need of the day to fit mungbean in Rice-Wheat copping system in Pakistan (Ali *et al*., 2012). Positive GCA effects were recorded for days to mature in the parent MMH 7124 (1.09) followed by MMH 4255 (0.52). These parents cannot be used for improvement of said trait. For plant height, all the parents showed non-significant GCA effects. The results are in accordance with the findings of Khattak *et al.* (2002b). Saleem *et al*., 2013 also observed negative GCA effects for plant height in tomato. MMH 7124, MMH 4255 and MMH 1115 had desirable negative but non-significant GCA effects for this trait; hence no parents can be used to shorten the plant height in mungbean which is also an important trait for the development of short stature and lodging resistant genotypes. The results are in accordance with Zubair *et al*. (2007) who also reported negative GCA effects for plant height in mungbean but contradict with Atnaf *et al*. (2012) and Yadav and Lavanya (2011) who reported significant GCA effects for plant height.

For clusters per plant, MMH 4224 and MMH 4255 were good general combiners; they had significant and desirable positive GCA effects with values of 0.46 and 0.26 respectively. All the remaining three parents were observed to be not good general combiners as they showed significant but undesirable negative GCA effects hence cannot be used for the improvement of this trait. Parents MMH 4224 and MMH 4255 were good general combiners for pods per plant as they showed significant and desirable positive GCA effects with the values of 1.02, and 0.55, respectively. The results are in accordance with the findings of Zubair *et al.* (2007) who observed highest GCA effects for number of seeds per pod in mungbean. Hence number of pods per plant which is an important yield contributing traits (Abbas *et al*., 2005) can be improved with the use of above mentioned parents as general combiners. Only one parent MMH 4224 had significant and desirable positive GCA effects for pod length, hence this parent can be used for the improvement of this trait. While the parent MMH 1115 had positive and undesirable negative GCA effects, hence cannot be used for the improvement of pod length. None of the parent proved to be good general combiner for seeds per pod due to non-significant GCA effects. The results are in contradict with the earlier findings of Atnaf *et al*. (2007) and Zubair *et al*. (2007) who observed significant GCA effects for seeds per pod. This might be due to the difference in material and seasonal variations that affects gene expression (Khattak *et al*., 2002a and 2002b). Parent MMH 7124 was observed to be good general combiner for 100-seed weight as it showed significant and desirable positive GCA effects (0.45) and can be used to improve this trait. The parent MMH 4224 was good general combiners for seed yield per plant as it showed highly significant and desirable positive GCA effects (0.29) and can be used to improve this trait. The results are in accordance with the earlier research work of Zubair *et al*. (2007) who also identified some parents as good general combiners for the improvement of seed yield in mungbean.

Parent MMH 4224 and MMH 1115 produced the highest GCA effects for most of the traits under study followed by MMH 4255. MMH 4224 and MMH 2112 were observed best general combiners for days to flower and maturity. MMH 4224 and MMH 4255 were best general combiners for number of clusters and pods per plant. The results are in accordance with the findings of Singh *et al*. (2006) and Narasimulu *et al*. (2014) who also observed significant GCA effects for number of clusters and pods per plant; hence these two very important yield contributing traits can be improved with the use of best general combiners in breeding programme. MMH 4224 was best general combiner for all desirable traits under study except seeds per pod and 100-seed weight followed by MMH 4255 which was good general combiner for clusters per plant and pods per plant. All traits except plant height and seeds per pod can be improved by using any parent as a general combiner.

Specific Combining Ability (SCA) Effects: Estimates of SCA effects are presented in Table 2. Significant and negative desirable SCA effects were observed for days to 50% flowering in cross combination MMH 7124×MMH 2112 (-1.06) and MMH 4255×MMH 1115 (-0.83). Hence these hybrids can be used in heterosis breeding to reduce the number of days taken to flowering and to extend the reproductive phase that greatly help to increase crop productivity. The results are in accordance with the findings of Mishra *et al*. (2008) and Patil *et al*. (2011) who also reported significant specific combining ability effects for most of the traits in mungbean. Crosses MMH 4224×MMH 7124 and MMH 7124×MMH 4255 showed undesirable significant positive SCA effects of value 1.94 and 1.71 respectively but the former had significant and negative desirable GCA effect for female parent and the latter had the same for male parent. So these hybrids can be used in recombination breeding. MMH 1115×MMH 2112 had significant but undesirable SCA effects (0.91). MMH 4224×MMH 2112 had non-significant SCA effects but both the parents had desirable negative GCA effects so this hybrid can be used in recombination breeding with pedigree method of selection. For days to maturity, crosses MMH 4224×MMH 2112, MMH 7124×MMH 1115, MMH 7124×MMH 2112 and MMH 4255×MMH 2112 showed significant and desirable negative SCA effects with values of -0.49, -1.65, -1.52 and -0.95 respectively and recommended for heterosis breeding. These four cross combinations can be successfully used to develop mungbean varieties with short maturity period which is a very important aspect to fit mungbean in Rice-Wheat cropping system (Ali *et al*., 2012). The results are not in line with the earlier findings of Mishra *et al*. (2008) and Yadav and Lavanya (2001) who observed positive and significant SCA effects for most of the traits including days to maturity in mungbean. This is might be due to the difference in material and seasonal variation that affects gene expression (Khattak *et al*., 2002a and 2002b). Undesirable significant and positive SCA effects were recorded in cross MMH 4224×MMH 7124 (female parent also had significant and desirable negative GCA effects), and MMH 1115×MMH 2112 (both parents also had significant and desirable negative GCA effects). So, these hybrids can be used in recombination breeding for days to mature. Cross MMH 7124×MMH 4255 had significant but undesirable positive SCA effects (1.65). Cross MMH 4224×MMH 1115 had non-significant SCA effects with desirable negative GCA effects for both the parents. The best progeny might be derived from crosses with genotypes having greatest GCA effects (Arunga *et al*., 2010). Hence, this cross can be use for further progeny testing to identify superior segregants. Undesirable significant and positive SCA effects were observed for plant height in two cross combinations MMH 7124×MMH 4255 and MMH 1115×MMH 2112 with values of 3.17 and 2.59 respectively. Hence none of the parent can be used to reduce plant height in mungbean. The results are in accordance with the earlier findings of Zubair *et al*. (2007); Yadav and Lavanya (2011) and Farag and Afia (2012) who also reported undesirable positive and significant SCA effects for the said trait. Highest significant SCA effects were observed for clusters per plant in all crosses except one. Crosses MMH 7124×MMH 4255 (0.27), MMH 7124×MMH 1115 (0.24) and MMH 7124×MMH 2112 (0.54) showed desirable significant and positive SCA effects for clusters per plant. Whereas crosses MMH 4224×MMH 7124 (-0.21), MMH 4224×MMH 1115 (-0.36), MMH 4224×MMH 2112 (-0.06), MMH 4255×MMH 2112 (-0.09) and MMH 1115×MMH 2112 (-0.29) showed significant but negative SCA effects. Hence, these hybrids having desirable and positive SCA effects can be used in heterosis breeding for the improvement of clusters per plant which is an important yield contributing trait (Abbas *et al*., 2005). For pods per plant, only cross MMH 4224×MMH 4255 showed significant and positive SCA effects with value of 1.58 and can be used specifically for the improvement of this character. Hence special consideration must be given to this specific cross combination to enhance number of pods per plant which is very important yield contributing trait after clusters per plant. These results are in accordance with Yadav and Lavanya (2011) who reported positive and significant SCA effects for clusters and pods per plant. The parents of this hybrid also had positively significant GCA effects. Therefore, selection of superior plants should be postponed to later generation for cultivar development with more number of pods per plant which is an important yield contributing trait (Begum *et al*., 2013). The best progeny might be derived from crosses with genotypes having greatest GCA effects (Arunga *et al*., 2010). For pod length, all crosses showed non-significant SCA effects. Cross MMH 4224×MMH 1115 had non-significant SCA effects but significant GCA effects for female parent (MMH 4224) and can be useful in identification of superior segregants in later generations. All crosses showed non-significant SCA effects for seeds per pod and 100-seed weight. The results are in conflict with Farag and Afia (2012) who reported significant and positive SCA effects for 100-seed weight. This confliction might be due to the difference in material and seasonal variations that affect gen action in mungbean. Therefore, no cross can be used for the improvement of these traits. For seed yield per plant, cross MMH 4224×MMH 7124 had significant SCA effects. Hence this cross must be specially considered for the improvement of seed yield in mungbean.

When all the traits under study were considered, the cross combination MMH 7124×MMH 2112 had greater estimates of desirable negative as well as positive significant SCA effects. The crosses with significant SCA effects indicated presence of non-additive (dominance and epistasis) gene action.

Table 1. Mean squares of preliminary analysis of variance and combining ability analysis for different agronomic traits of Mung × Mash inter-specific recombinant genotypes.

SOV	**Df**	**Days to flower**	**Days to mature**	**Plant height (cm)**	**Clusters/ Plant**	**Pods/ plant**	**Pod length (cm)**	**Seeds /pod**	**100-seed weight (g)**	**Seed yield (g/plant)**
Replications	2	0.693^{ns}	0.360^{ns}	5.760^{ns}	0.213^{ns}	4.053^{ns}	0.520^{ns}	1.693^{ns}	0.099^{ns}	0.405^{ns}
Genotypes	24	18.053*	24.980**	14.608*	2.303*	9.041*	0.487*	1.126*	1.053*	1.068*
GCA	4	4.052**	6.303**	1.777^{ns}	1.168**	6.609**	0.519*	0.474^{ns}	1.083**	0.599**
SCA	10	2.683**	3.279**	8.587^{ns}	0.579**	2.989**	0.065^{ns}	0.305^{ns}	0.149^{ns}	0.346^{ns}
Reciprocal	10	10.139**	14.183**	3.002^{ns}	0.766**	1.600^{ns}	0.177^{ns}	0.406^{ns}	0.261^{ns}	0.269^{ns}
Error	48	0.162	0.064	2.249	0.085	0.853	0.159	0.458	0.192	0.090
σ^2GCA		0.389	0.624	-0.107	0.108	0.603	0.036	0.002	0.089	0.049
σ^2SCA		2.521	3.215	6.334	0.494	2.407	-0.094	-0.153	-0.044	0.236
GCA/SCA		0.154	0.194	-0.017	0.219	0.250	-0.380	-0.011	-2.046	0.207

*, ** = Significant at $P < 0.05$, $P < 0.01$ probability level, respectively; ns: non-significant; df: degree of freedom

GCA = General combining ability; SCA = Specific combining ability, σ^2GCA = variance of GCA, σ^2SCA = variance of SCA, GCA/SCA= Ratio

Table 2. Estimates of general and specific combining ability effects for various agronomic traits among Mung × Mash inter-specific recombinant genotypes.

Genetic Efefects	**Sources of variation**	**Days to flower**	**Days to mature**	**Plant height (cm)**	**Clusters/ plant**	**Pods/ plant**	**Pod length (cm)**	**Seeds /pod**	**100-seed weight (g)**	**Seed yield (g/plant)**
General Combining Ability (GCA) Effects	MMH 4224	-0.61**	-0.61**	0.31^{ns}	0.46**	1.02**	0.36**	0.29^{ns}	0.08^{ns}	0.29**
	MMH 7124	0.69**	1.09**	-0.29^{ns}	-0.19*	-0.01^{ns}	0.06^{ns}	0.03^{ns}	0.45**	0.07^{ns}
	MMH 4255	0.63**	0.52**	-0.18^{ns}	0.26**	0.55*	-0.11^{ns}	0.09^{ns}	-0.26*	0.10^{ns}
	MMH 1115	-0.11^{ns}	-0.18*	-0.27^{ns}	-0.26**	-0.98**	-0.24*	-0.14^{ns}	-0.38**	-0.36**
	MMH 2112	-0.61**	-0.81**	0.43^{ns}	-0.28**	-0.58**	-0.07^{ns}	-0.27^{ns}	0.12^{ns}	-0.10^{ns}
Specific Combining Ability (SCA) Effects	MMH 4224 × MMH 7124	1.94**	1.78**	-0.54^{ns}	-0.21**	0.15^{ns}	0.34^{ns}	0.27^{ns}	0.04^{ns}	-0.16**
	MMH 4224 × MMH 4255	-0.49^{ns}	-0.15^{ns}	1.01^{ns}	1.00^{ns}	1.58*	-0.16^{ns}	-0.13^{ns}	0.16^{ns}	0.43^{ns}
	MMH 4224 × MMH 1115	-0.09^{ns}	-0.29^{ns}	-2.43^{ns}	-0.36**	-0.05^{ns}	-0.03^{ns}	-0.06^{ns}	0.34^{ns}	0.05^{ns}
	MMH 4224 × MMH 2112	-0.26^{ns}	-0.49*	0.68^{ns}	-0.06**	0.38^{ns}	0.14^{ns}	0.74^{ns}	-0.16^{ns}	0.12^{ns}
	MMH 7124 × MMH 4255	1.71**	1.65**	3.17*	0.27**	0.78^{ns}	-0.03^{ns}	0.31^{ns}	0.30^{ns}	0.48^{ns}
	MMH 7124 × MMH 1115	-0.56^{ns}	-1.65**	-0.58^{ns}	0.24**	0.81^{ns}	0.11^{ns}	0.21^{ns}	-0.32^{ns}	-0.06^{ns}
	MMH 7124 × MMH 2112	-1.06**	-1.52**	0.67^{ns}	0.54**	0.91^{ns}	-0.06^{ns}	-0.16^{ns}	0.27^{ns}	0.41^{ns}
	MMH 4255 × MMH 1115	-0.83*	-0.42^{ns}	0.54^{ns}	0.00**	-0.59^{ns}	0.11^{ns}	0.14^{ns}	-0.11^{ns}	-0.20^{ns}
	MMH 4255 × MMH 2112	-0.49^{ns}	-0.95**	-0.66^{ns}	-0.09**	0.35^{ns}	0.11^{ns}	-0.23^{ns}	0.08^{ns}	0.15^{ns}
	MMH 1115 × MMH 2112	0.91**	1.41**	2.59*	-0.29**	-1.12^{ns}	-0.09^{ns}	0.01^{ns}	-0.20^{ns}	-0.35^{ns}

In general all the traits except 100 seed weight had GCA/SCA ratio less than unity, which showed that all traits excluding 100 seed weight were under the control of non-additive gene action, so heterosis breeding is ideal for the improvement of these traits. As 100 seed weight had GCA/SCA ratio greater than unity, this showed the involvement of recessive gene action. This trait can be improved through recombination/back cross breeding. The hybrids having desirable positive and significant SCA effects were recommended for heterosis breeding and the hybrids whose parents had desirable significant GCA effects and non- significant SCA effects were recommended for recombination breeding. Hence, it was concluded that all traits with the exception of plant height and seeds per pod can be improved by using one and another parent as a general combiner. Moreover, the cross combination MMH 7124×MMH 2112 had greater estimates of desirable negative as well as positive significant SCA effects.

REFERENCES

Abbas, G., M. S. Sadiq, M. Saleem, S. Haider and M. Saleem (2005). Selection criteria for segregating F_4 generation of mungbean (*Vigna radiata* L. Wilczek). J. Agric. Res. 43: 95-102.

Ali, R.I., T.H. Awan, M. Ahmad, M.U. Saleem and M. Akhtar (2012). Diversification of rice-based cropping system to improve soil fertility, sustainable productivity and economics. J. Anim. Plant Sci. 22: 108-112.

Anonymous. (2013). Economic Survey, Economic Affairs Division, Govt. Pakistan., Islamabad.

Arunga, E. E., R. H. A. Van and J. O. Owuoche (2010). Diallel analysis of snap bean (*Phaseolus vulgaris* L.) varieties for important traits. Afr. J. Agric. Res. 5: 1951-1957.

Atnaf, M., H. Mohammed and H. Zelleke (2013). Inheritance of primary yield component traits of common beans (*Phaseolus vulgaris* L.): Number of seeds per pod and 1000 seed weight in an 8 x 8 diallel cross population. Int. J. Biol. Bimol. Agric. Bitechnol. Eng. 5: 42-46.

Barelli, M. A. A., V. C. M. Goncalves, A.T. Amaral, F.S.P. Vidigal and C.A. Scalpm (2000). Diallel analysis of the combining ability of common bean (*Phaseolus vulgaris* L.) cultivar. Brazilian Archives Biol. Tech. 43: 409-414.

Begum, S., M. Noor, H. Rahman, G. Hassan, Durrishawar, H. Ullah, Alia and F. Ali (2013). Heritability estimates and correlation among flowering and yield related traits in mungbean genotypes. British. J. Appl. Sci. Technol. 3: 472-481.

Chishti, S. A. S., A. A. Khan, B. Sadia and I. A. Khan (2008). Analysis of combining ability for yield, yield components and quality characters in tomato. J. Agric. Res. 46: 325-331.

Farag, H.I.A. and S.A. Afia. 2012. Analysis of gene action in diallel crosses among some faba bean (*Vicia faba* L.) genotypes under maryout conditions. Ann. Agric. Sci. 25: 37-46.

Ghaviami, F. and A. Rezai (2000). Variation and relation of morphological traits in mungbean. Ind. J. Agric. Sci. 31: 147-158.

Glover, M.A., D.B. Willmot, L.L. Darrah, E.H. Bruce, and X. Zhu (2005). Diallel analyses of agronomic traits using Chinese and US maize germplasm. Crop Sci. 45: 1096-1102.

Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci. 9: 463-493.

Inamullah., A. Habib, M. Fida, S. U. Din, H. Ghulam and G. Rahmani (2006). Diallel analysis of the inheritance pattern of agronomic traits of bread wheat. Pakistan J. Bot. 38: 1169-1175.

Khan, M.D., I.H. Khalil, M.A. Khan and Ikramullah (2004). Genetic divergence and association for yield and related traits in mash bean. Sarhad J. Agric. 20: 555–61.

Khattak, G. S. S., M. A. Haq, M. Ashraf and P. Srinives (2001). Combining ability in mungbean (*Vigna radiata* (L.) Wilczek) II traits related to indetermination. Korean J. Crop. Sci. 46: 424-427.

Khattak, G. S. S., M. A. Haq, M. Ashraf and M. Hassan (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. Genet. Breed. 56: 1-7.

Khattak, G. S. S., M. A. Haq, M. Ashraf, A. Jabbar and R. Zamir (2002b). Genetic architecture of secondary components in mungbean (*Vigna radiata* (L.) Wilczek). Breed. Sci. 52: 235-241.

Makeen, K., A. Garad, J. Arif and K.S Archana (2007). Genetic variability and correlation studies on yield and its components in mungbean (*Vigna radiata* (L.) Wilczek). J. Agron. 6: 216-218.

Malik, M. F. A., M. Ashraf, A.S. Qureshi and J. A. Ghafoor (2007). Assessment of genetic variability, correlation and path analysis for yield and its components in soybean. Pakistan J. Bot. 39: 405-413.

Mishra, T. K., R. R. Panda, D. Bastia and L. K. Bose (2008). Combining ability analysis of quantitative traits in rice Bean (*Vigna umbellata* (Thunb)). Emirates J. Food Agric. 20: 51-56.

Patil, A.B., N.C. Desai, P.N. Mule and V. Khandelwal (2011). Combining ability for yield and components characters in mungbean (*Vigna radiata* (L.) Wilczek). Leg. Res. 34: 190-195.

Pratta, G., R. Zorzoli and L.A. Picardi (2003). Diallel analysis of production traits among domestic, exotic and mutant germplasm of lycopersicum. Gen. Mol. Res. 2: 206-213.

Poehlman, J.M. (1991). The mungbean. Oxford and IBH Publishing Company New Delhi, India. 1-343 p

Rehman, A., M.A. Ali, B.M. Atta, M. Saleem, A. Abbas and A. R. Malhi (2009). Genetic studies of yield related traits in mungbean (*Vigna radaiat* (L.) Wilczek). Aust. J. Crop. Sci. 3: 352-360.

Rehman, A., M.A. Ali, M. Saleem and W. Tadesse (2010). Study of heritable variation and genetics of earliness in mungbean (*Vigna radiata* L. Wilczek). Euphytica 176: 331-339.

Sadiq, M.S., M. Saleem, S. Haider and G. Abbas (2006). NIAB MUNG 2006: A high yielding and disease resistant mungbean variety. J. Agric. Res. 44: 97-103.

Saleem, M. Y., J. I. Mirza and M.A. Haq (2010). Combining ability analysis of some morpho-physiological traits in Basmati rice. Pakistan J. Bot. 42: 3113-3123.

Saleem, M.Y., M. Asghar, Q. Iqbal, A. Rehman and M. Akram (2013). Diallel analysis of yield and some yield components in tomato (*Solanum Lycopersicum* L.) Pakistan J. Bot. 45: 1247-1250.

Sharma P., H.S. Sekhon and T.S. Bains (2012). Performance and growth analysis in mashbean genotypes. W. J. Agric. Sci. 8: 303-308.

Singh, I., S.N. Badaya and S.B.S. Tikka (2006). Combining ability for yield over environments in cowpea (*Vigna unguiculata* L. Walp). Ind. J. Crop Science, **1**: 205-206.

Singh, I., M.S. Gill, T.S. Bains and S. Singh (2010). Studies on variability and inheritance of hard seededness in mungbean (*Vigna radiata* (L.) Wilczek). IUP. J. Genet. Evol. 3: 49-52.

Silva P.M, A.T. Junior, R. Rodrigues, G.M. Pereira and A.P. Viana (2004). Genetic control and morpho-agronomic traits in snap bean. Braz. Arch. Biol. Technol. 47: 855-882.

Steel, R.G.D., J. H. Torrie and D. A. Dickey (1997). Principles and procedures of statistics. A biometrical approach, McGraw Hill Book Co, New York, U.S.A.

Tabassum, A., M. Saleem and Irumazi (2010). Genetic variability, trait association and path analysis of yield and yield components in mungbean (*Vigna radiata* (L.) Wilczek). Pakistan J. Bot. 42: 3915-3924.

Tomooka N., A. Kaga, and D. A. Vaughan (2006). The Asian *Vigna* (*Vigna subgenus* Ceratotropis) biodiversity and evolution. Sci. Publi., Enfield, New Jersey, pp 87-126.

Ullah, R., M. I. Lone, K.S. Ullah, S.M. Mehdi and M.A. Qazi (2013). Effect of cropping system and seasonal variations on soil microbial biomass and enzymatic activities in arid soils. J. Anim. Plant Sci., 23: 493-499.

Vidigal, M.C., L. Silverio, H.T. Elias, P.S. Filho, M.V. Kvitschal, V.S. Retuci and C.R. Silva (2008). Combining ability and heterosis in common bean cultivars. Pesq agropec bras. 43: 1143–1150.

Yadav, P.S. and G.R. Lavanya (2011). Estimation of combining ability effects in mungbean (*Vigna radiata* (L.) Wilczek) crosses. Mad. Agric. J. 98: 213-215.

Yirman, T., P. Somta and P. Srinives (2009). Genetic variation in cultivated mungbean germplasm and its implication in breeding for high yield. Faculty of Agriculture at Kamphaeng Saen, Kasetsart University J. Agro. 112: 260-266.

Narasimulu, N., R., N. V. Naidu, K. H. P. Reddy and G. M. Naidu (2014). Combining ability for yield attributes in greengram (*Vigna radiata* (L.) Wilczek). Department of Genetics and Plant Breeding, S.V. Agricultural College, Tirupati - 517 502.

Zubair, M., S. U. Ajmal, M. Munir and M. Anwar (2007). Mode of inheritance and genetic variability of some of the traits in mungbean (*Vigna radiata* (L.) Wilczek). Pakistan J. Bot. 39: 1237-1244.