academicJournals

Vol. 8(26), pp. 3340-3347, 11 July, 2013
DOI: 10.5897/AJAR12.2129
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

Stability analysis and G × E interaction in Mungbean (*Vigna radiate* L. Wilczek): A review

Anamika Nath[1]*, P. N. Harer[1] and Utpal Dey[2]

[1]Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist-Ahmednagar, Maharashtra, India.
[2]Department of Plant Pathology, MarathwadaKrishi Vidyapeeth, Parbhani, Maharashtra,India.

Accepted 1 July, 2013

Plants generally showed variation in their response to changing environment. Stability analysis has become one of the important tools for plant breeders in predicting the response of various genotypes over changing environments. It is imperative to have stable performing cultivars across environment to realize higher seed yield. The interaction of genotype with the environment has an important bearing in breeding improved varieties. Genotype × environment (G × E) interaction has a masking effect on the performance of a genotype and hence the relative ranking of the genotypes do not remain the same over different environments. Adaptability of genotypes to environmental fluctuation is important for the stable crop production over the environments. Several methods such as regression analysis, multivariate clustering analysis, multiplicate formulations such as additive main effects and multiplicative interaction besides nonparametric method may be used for the G × E interaction. Among all, the model is widely used for stability parameters. The genotypes with high mean ($\bar{X}$), regression coefficient (bi) close to unity and less/no deviation from regression (S^2di) is found to be stable. The overall aim of this review is to emphasize the importance of G × E interaction and stability analysis in Mungbean for increasing the global Mungbean production.

Key words: Mungbean, stability analysis, genotype × environment (G × E) interaction, different sowing dates, stable genotypes.

INTRODUCTION

Mungbean [*Vigna radiata* (L.)] is an important pulse crop of *kharif* season. The climate change may cause unpredictable drought and heat stress. So it is necessary to have stable genotypes. Understanding the stability performance and utilizing it in Mungbean breeding programmes will be beneficial. It is indigenous to India and has potentials as drought tolerant crop. However, productivity of Mungbean is very low which is attributed to moisture stress conditions and fluctuations in the sowing dates, leading to epiphytic conditions of pest and diseases. Productivity of the population is the function of its adaptability. Significant achievement in crop production may be possible by breeding varieties for their stability for yield and yield components (Singh et al., 2009a; Lal et al., 2010).

Plant breeding is said to be the management of genetic variability. Plant breeders look for greater variability in crop plants for evolving strains which give maximum yield over the environments and show consistent performance.

It is imperative that most adaptable varieties should be developed to improve the productivity of this crop in view of climate change.

Hence, it is necessary to study the performance of Mungbean genotypes sown on different dates along with its stability. Literature on this aspect has been reviewed and presented.

*Corresponding author. E-mail: anamikanath87@gmail.com.

GENOTYPE AND ENVIRONMENT (G × E) INTERACTIONS

Environment is the sum total of physical, chemical and biological factors. G × E interactions have major importance to plant breeder in developing improved varieties. Low levels of interactions are useful for some characters so as to maximize the stable of performance over a number of environments. However, for some situation, high interactions are beneficial and can be explored. There is no direct measurement for genetic variability. However, the same can be inferred from the phenotype, which is a linear function of genotypes, environment and their interaction. Phenotype usually gets changed when a genotype is grown over varying environments. It has been shown that, interactions are widely present irrespective of nature of material. This sets limits to the expected progress. The interactions of genetic and non genetic factors on phenotypic expression is called G × E interaction which is widely present and substantially contributes to the non realization of expected gain from selection (Comstock and Moll, 1963). A population which can adjust its genotypic or phenotypic state in response to environmental fluctuations in such a way that it gives high and stable economic returns, can be termed as “well buffered” (Singh and Singh, 1980).

Stable genotypes are particularly of great importance in the country like India, where the crops are grown as a risk under varied environmental conditions. G × E interaction certainly plays an important role in the evaluation and execution of breeding programmes. Allard and Bradshaw (1964) have critically reviewed this phenomenon and brought out its implications in applied plant breeding. Thus, G × E interaction is important in the expression of quantitative characters, which are controlled by polygenic systems and largely influenced by environmental fluctuations.

The process of identification of stable genotype is difficult because of G × E interaction. Although the plant breeders have observed genetic differences for adaptability, they have been unable to fully exploit these differences in breeding stable genotypes. This has been largely due to the problem of defining and measuring phenotypic stability. Various attempts were made to characterize the behaviors of genotypes in response to varying environments. Statistical approach of Finlay and Wilkinson (1963) has proved considerably useful to measure the phenotypic stability in the performance of genotype. They considered linear regression slope (bi) as a measure of stability. This regression analysis proposed by Finlay and Wilkinson (1963) was improved upon by Eberhart and Russell (1966). They introduced one more parameter, deviation from regression (S^2di) which accounts for unpredictable irregularities in the response of genotypes to varying environments.

Mechanism of stability falls into four general categories as follows:

1. Genetic heterogeneity
2. Yield component compensation,
3. Stress tolerance and
4. Capacity to recover rapidly from stress.

STATISTICS AND GENETICS OF G × E INTERACTIONS

The evaluation of G × E interaction gives an idea of stability of the population. Jinks and Mather (1955) reported the relationship of stability to genic balance in the development or developmental homeostasis which is produced by selective action. They stated that there is no property of stability that requires its interpretation as an innate consequence of heterozygosity *per se*. At the most such effect can only be of minor importance in the control of stability. Jones (1958) attributed stability to the homeostatic effect of genetic heterogeneity and suggested that such stability permits double crosses to produce high yields over many years. Plaisted and Peterson (1959) developed a method to characterize the stability of yield performance when several varieties were tested at number of locations within one year. A combined analysis was computed for each pair of varieties, n (n-1)/2 pairs for ‘n’ varieties and estimate of σ^2v was obtained from each variety. The variety with the smallest mean value would be one that contributes the least to variety × location interactions and thus would be considered as the most stable genotype in the tests. Finlay and Wilkinson (1963) utilized technique to compare the performance of a set of cultivars grown at many sites for each variety. Varietal mean yield over all environments and regression coefficients were used to classify the cultivars specially adopted at poor, better yielding environments and for general adaptability. They have indicated average phenotypic stability by a regression coefficient of unit (bi = 1). A cultivar with bi < 1 has above average stability, bi > 1 has below average stability and bi = 0 has absolute phenotypic stability which means a constant gain in all environments. The ideal cultivar is one that possesses genetic potential in highest yielding environment and maximum phenotypic stability. Eberhart and Russell (1966) observed that the corn hybrids with a regression coefficient less than 1.00 usually had mean yields that were below average. Accordingly they suggested that a desired variety should have high mean, regression coefficient equal to 1.00 and variance due to regression as small as possible. Thus they modified the regression technique, which enables partitioning of G × E interaction of each variety into two parts (bi), the variation due to response of variety to varying environmental indices (sum of squares due to regression) and the unexplainable deviation from the regression on the environmental index. They defined both the linear (bi) and non linear (S^2di) components as stability parameters. They compared two types of crosses in maize. They reported that hybrid × year interactions was significantly greater for single crosses than for three way or double crosses. They further stated that some single crosses may show as much or more phenotypic stability than most stable three way or double crosses. The approach of Finlay and Wilkinson (1963) and Eberhart and Russell (1966) are purely statistical and component of these analysis have not been related to the parameters in biometrical genetic model, Perkins and Jinks (1968) performed the second approach which was based on fitting of model which specify the contribution of genetic, environmental and G × E interaction to generation mean and variances allowing for the contribution of additive, dominance and epistatic gene effects to the genetic and interaction components. Knight (1970) reviewed the regression analysis developed by Finlay and Wilkinson (1963) to investigate G × E interactions to assess genotypes for their adoption to a range of environments. The conclusions were extended to consider variation in several environmental factors. Tai (1971) presented a method of genotypic stability based on principle structure relationship analysis where a G × E interaction of a particular variety is partitioned into two components *viz.,* the linear response to environment effects (α) and a deviation from linear response. Bains and Gupta (1972) proposed that, if the linear regression of above average genotypes upon the environmental means is less than 1.0 with comparatively small deviation mean square, an agreeable compromise between the two definitions of Finlay and Wilkinson (1963) and Eberhart and Russell (1966) is essential.

STABILITY PARAMETERS FOR INDIVIDUAL CHARACTERS

Finlay and Wilkinson (1963) considered linear regression slope (bi) and emphasized the need of both 'bi' and deviation from regression 'S^2di' as measure of stability. Further, Eberhart and Russell (1966) showed the need of both regression coefficient (linear) (bi) and deviation from regression (S^2di) (nonlinear) in evaluating genotypes for phenotypic stability by measuring G × E interactions. The performance of a genotype and its suitability for different environments was judged using these parameters, that is, mean, bi and S^2di. A stable variety is defined as a variety with high mean, bi is equal to unity and S^2di not deviating from zero. Further the suitability of genotypes for different environments was considered as stated subsequently. The genotype having mean yield greater than the grand mean (population mean) and S^2di low or non-significant and:

1. 'bi' approaching to unity were regarded as having general adaptability or average stability.
2. 'bi' significantly greater than unity is considered as better adaptable to rich or favourable environment (below average stability).
3. 'bi' significantly less than unity and or having lower magnitude than unity are considered as better adaptable to poor or unfavourable environment (above average stability).

The genotypes with significant S^2di components are considered as highly unpredictable. In some cases relative 'bi' values were also considered to decide specific adaptability. Eberhart and Russell (1966) method was preferred because of its explicit nature.

STABILITY STUDIES IN MUNGBEAN

Joshi (1972, 1969) evaluated the stability of six Mungbean varieties for the seed yield and reported the presence of G × E interaction for all the genotypes studied. The varieties D-2-15 and local had the average stability, D-45-6 showed below average stability, while 12-2, T 6-3, T 5-7 showed above average stability. Choudhary and Haque (1977) studied stability analysis of nine green gram genotypes. None of the genotype was found to be ideally stable one. However, genotype No. 122 had showed average stability and higher grain yield than the other genotypes. Reddy (1980) indicated presence of G × E interaction for pods/plant and seed yield in green gram. Imrie and Butler (1982) carried out stability analysis on 30 genotypes of Mungbean at two locations in each of two years. They reported high G × E interaction for seed yield followed by days at harvest, plant height and days to flower. Krishnaswamy and Ratnaswamy (1982) found the existence of interaction for green gram seed yield. Further, they found significant G × E (linear) and pooled deviation for seed yield and the proportion of linear component of genotype environment interaction. Reddy and Sreeramulu (1984) performed stability analysis of 11 green gram varieties over 3 locations for 2 years. The G × E interaction of the first order were not significant but the second order interaction, genotype × site × year displayed significance at 1% level for the characters viz., mean seed yield and number of pods/plant. Variety PIMS 4 gave the highest mean seed yield and the highest number of pods/plant. PIMS 1, the variety with the second highest mean seed yield and third in ranking for pods/plant was the most stable for both the characters. Miah and Corangal (1986) studied stability of seed yield for ten genotypes of Mungbean under eight different growing conditions. The genotypes EGMG-7743 and CES-55 were most stable, while M-350, CES-1-D-21, CES-IFS were suited for favourable environment and MG-50-10A (Y), CE-51 suited for unfavourable environment. Pathak and Lal (1987) studied stability under four environments with six pure lines of Mungbean. They found high G × E interaction for plant height, whereas number of branches and number of clusters were least affected by the interaction. Further, they revealed that linear component of G × E interaction was significant for plant height, number of clusters/plant, yield/plant and non-linear components of interaction was significant for clusters/plant and yield/plant. Srinivas et al. (1987) found VC-2742-6, the most stable of Mungbean line where as VC-2745-25 was the highest yielder when the stability parameters of all traits were considered together. Patil and Narkhede (1989) evaluated sixteen genotypes of green gram over four environments for stability in pod length and seed/pod exhibited presence of G × E interaction for all the genotypes. The genotypes RM-76-40, J-781 for pod length and J-781 and S-8 for seeds/pod were found to be stable. The genotype RM-75-25-6-10 was found to be most stable and average in response and performance for both the characters. The linear and non-linear component of G × E interaction was found significant for pod length and seeds/pod. George et al. (1989) conducted an experiment "Adaptation and Environmental sensitivity of Mungbean genotypes evaluated in the international Mungbean nursery". They observed a very high positive linear relationship between the regression coefficient and the average yield of cultivars, indicating that high yielding cultivars were less stable across environments. They observed VC-1973A was a high yielding and widely adopted cultivar. Pathak et al. (1990) performed stability analysis for forty-nine genotypes of Mungbean comprising of seven parents and their twenty one F_1s and F_2s. They reported presence of G × E interaction for all the seven characters under study. Six F_1s and 16 F_2s showed stability for seed yield. The crosses of stable parents for seed yield were also stable. They further reported significance of linear component of G × E for the character seed yield, while significant non-linear components of G × E interaction for number of days to flowering, days to maturity and seed yield. Reddy et al. (1990) studied stability analysis of yield for eleven genotypes of green gram in different seasons showed that genotype PIMS 88-4 was stable for plant height and RGG-88-4 reported above average response for plant height. Pusa-115 and ML-267 were most stable genotypes for clusters/plant while UPM-89-3-4 suitable in poor environment. For pods/plant PDM-54 genotype was stable. All genotypes were found unstable for seed yield. However, Pusa 54 and UPM-79-1-12 were suitable for seed yield/plant. Further pooled deviation for the characters plant height, number of clusters/plant, number of pods/plant and seed yield/plant was found highly significant. Gupta et al. (1991) carried out stability analysis of 33 genotypes of Mungbean in 6 environments for seven characters *viz*., days to maturity, plant height, number of branches/plant, number of pods/plant, seeds/pod, 100 seed weight and seed yield/plant. The analysis of variance for stability revealed significant differences among genotypes, environment and G × E interaction for all the characters studied. They observed significant linear and non linear components of G × E interaction, but the magnitude of former was higher than later in all the characters. Naidu and Satyanarayana (1991a) evaluated stability of 20 genotypes of Mungbean in 6 environments for 6 characters. They noted that both linear and non-linear components of G × E interaction were significant, for all the characters, however, former being greater in magnitude, suggested possibility of prediction across the environment. The genotypes ML-267, PDM-54, K-851 and PDM-84-145 were found high yielding and average stable. The genotype LGG-407, LGG-410, LGG-426 showed below average stability while LGG-403, LGG-450, Pusa-105 showed above average stability. Naidu and Satyanarayana (1991b) reported presence of G × E interaction for seed yield and its component characters of green gram. They observed that genotype with high mean values were responsive to favourable environment. Abeysiriwardena et al. (1991) in their experiment on analysis at multi environmental yield trials for testing adaptability of crop genotypes reported that adaptability is the ability of a crop variety to perform well over diverse environments. Patil and Narkhede (1992) conducted stability analysis with 16 genotypes of Mungbean grown under four seasons. The analysis of variance for plant height, days to flower, days to maturity, indicated significance of genotypes, environments and environment (linear) suggesting variability in genotypes and considerable influence of differential environments on plant height, days to flower and days to maturity. Two genotypes RM-75-25-6-10 and RM-75-29-3 were found most stable and exhibited high seed yield. The linear and non-linear (pooled deviation) components of G × E interactions were highly significant for all these characters. Kasno (1992) studied the adaptability and yield stability of several Mungbean genotypes on 12 sites. Among the recommended varieties tested, only Manyar showed stable yield and had higher yield than mean yield over sites and varieties. Line VC 3-300A showed best performance and stable yield. Therefore, it was suggested for release as a new Mungbean variety. Sarma et al. (1993) tested ten promising genotypes of greengram during the summer seasons of 1989, 1990 and 1991. The genotype AAU 34 gave the highest seed yield with bi value around unity and deviation from regression is zero, indicating its stable performance and suitability for all the environments. Genotype AAU 39 suitable for poor environments for seeds per pod because of its high mean and low regression value. Dobhal and Gautam (1994b) while working on 12 promising lines of adzuki bean (*Vigna angularis*) reported that among all the genotypes the line EC 108080 had the highest mean values for pod length and unit regression coefficient. Thus indicating that this line would perform consistently well in fluctuating environmental conditions.

Jahagirdar et al. (1994) studied stability analysis of six promising genotypes of Mungbean at four locations for seed yield and its components. They observed that BM-112 and BM-114 were stable to favourable and unfavourable environments respectively. BM-4 was better for unfavourable environments. For pods/plant, the promising culture BM-4 had shown specific adaptation to unfavourable environments. However, cultures PM-2 and PM-1 exhibited high mean value and shown above average stability to unfavourable environments. BM-4 can be exploited for better performance during *kharif* season. Muduli and Hati (1994) in their experiment on stability analysis for seed yield in green gram and black gram reported that, in green gram the variety Dhauli proved to be the best and most adaptable to the entire environment, better adaptation to poor environments. Experiment conducted by Mishra (1994) on 11 genotypes of rice bean revealed that the genotype SRBS 74 had high mean for grain yield with regression value close to unity and less deviation from regression hence it is stable for different environmental condition. However the genotypes SRBS 23, SRBS 50 and SRBS 60 showed unstable in performance as they had high deviation from regression. Kandaswami (1995) evaluated phenotypic stability for Mungbean seed yield in sodic soil. Pooled analysis of variance indicated significant differences among genotypes and environments. Moreover, G × E interaction was highly significant indicating differential performance of genotype under varied environmental conditions. The genotype SSRC-9 showed higher yield and stability for yield performance. The genotype SSRC-7 and Co-5 had high yield stability, better adapted to rich environments. SSRC-6 showed average yield, high stability and better adapted to poor environments. Patil and Narkhede (1995) derived information on G × E interaction and stability from data of 3 yield components in 16 greengram genotypes. Pooled analysis of variance revealed high G × E interaction for 100 seed weight, pods/plant and seed yield. Regression analysis indicated that genotypes RM-76-42 and RM-75-6-10 were suitable for better management conditions and RM-77-38 and RM-75-29-3 appeared suitable for poor environmental conditions. Renganayaki (1995) evaluated ten promising genotypes of Mungbean for yield and its components for three years. He observed significant G × E interaction for all the characters studied. Non-predictable component of clusters/plant and predictable component (linear) for grain yield indicated that the genotypes responded non-linearly to the change of environments. Stability parameters revealed that among the genotypes studied, CO-4 exhibited high mean grain yield, number of clusters/plant, length of pod and number of seeds. Durate and Zimmermann (1995) found correlation among yield stability parameters in French bean. According to him stability statistics was divided into four groups. He concluded that (i) there were highly significant correlation between stability statistics and (ii) mean yields were positively correlated with stability statistics. Kalpande et al. (1996) carried out stability analysis for seed yield and its components of Mungbean genotypes. They found that mean differences among the genotypes were significant for most of the characters studied. The non-linear components of G × E interaction were significant for all the characters studied and played a large role in determining seed yield. Stability parameters revealed that TAP-7, JLM-4 and TAM-9201 have high yield potential with stable performance. Phule M-2-70 was recommended for poor environment and TARM-18 was considered suitable for favourable environments. Anwari and Soehendi (1997) performed yield and stability analysis of 20 Mungbean promising lines at four locations. They found significant genotype and location interaction. Genotype IPBM 79-9-82 and C-301213 showed high yield and adaptive for non productive environment. The genotypes V-3476 and MLG-166 were high yielding and wider adaptability while the VC-2754, MLG-936, MLG-944 and Merak showed adaptive for productive environment and high yield. Stability analysis in black gram by Manivannan et al. (1997) revealed that among the 8 genotypes studied, Vamban 1 recorded bi value of 0.35 hence considered below average responsive to environment and genotype CO 5 recorded bi value of 1.02 which is considered as average responsive to environment. Hence Vamban 1 may be recommended to any environment because of its predictable performance to environment and high yield. Khairnar (1998) carried out stability analysis of twenty promising progenies of greengram. He observed significant G × E interaction for all the characters .Nine progenies 1, 2, 4, 5, 7 (KDM-1 × WGG-37), 11, 16 (JLM-5 × WGG-37) 18 and 19 (BM-4 × PM-2) revealed wider adaptability for yield. Six Mungbean and two Mungbean mutant lines as well as two Mungbean varieties Merak and Walet were tested in seven locations by Sumanggono et al. (1998). The result showed that there were no differences on the yield of Mungbean mutant lines with that of the control plants. In the rainy season, Mungbean line No. CR-879-2-1-2 and Walet variety had a good adaptation to less favourable environment, whereas mutant line of No. 19-PSJ-90 had a good adaptation to favourable environment. Line No. VC-1973-A had a good adaptation to less favourable environment in dry season. The stability analysis of ten genotypes of Mungbean was carried out by Manivannan et al. (1999a). They found ML-131 and ML-5 were the most stable genotypes and also recorded high seed yield. Manivannan et al. (1999b) studied 110 genotypes of Mungbean for G × E interaction for seed yield over three environments. Thirty six genotypes showed stability for seed yield and recorded average responsiveness to environments. Genotypes LM-154 and PLS-311 recorded high mean seed yield, average responsiveness to environment and stability. They could be used in breeding programmes to obtain high yielding, stable genotypes. The studies on G × E interaction of 10 green gram genotypes during five years found significant by Venkateswarlu (1999). The genotype MGG-295 and LGG-407 appeared to be most desirable with high yield, unit regression coefficient and non-significant deviation from regression. Raje and Rao (2001) carried out stability analysis of two hundred germplasm lines of Mungbean for 100 seed weight in 4 diverse environments. They observed significant variance due to genotype, environment and G × E interaction. The genotypes 169, 126, 98, 42, 63, 70, 74, 174, 106, 164, 93, 138, 16, 38, 66, 60 and 59 had higher stability for 100 seed weight among all the genotypes tested. Gomashe (2003) carried out stability analysis for twenty genotypes of Mungbean. He observed significant G × E interaction for all the characters except primary branches/plant. Genotypes TARM-18, AKM-8802, PM-9377 and Kopargaon were found suitable for earliness flowering having average stability over all types of environment. Genotype Vaibhav, TARM-18 and PM-9377 recorded average stability for seed yield/plant (g) and found suitable for the entire environment. Raje and Rao (2004) evaluated two hundred germplasm lines of Mungbean along with 6 commercial cultivars over four diverse environments. The genotypes showing above and below average stability along with higher mean value were PLM-566, PLM-84, K-851, PLM-117, PS-105, PLM-94, IC-2593-5M, PLM-648, IC-669-3, IC-9121-5, PLM-427, PLM-30, PLM-182, PLM-477, PLM-156, Pusabaisakhi, PLM-237, PLM-588 and PLM-303-2. These genotypes will be useful in breeding programmes to obtain stable and high yielding cultivars of Mungbean. Rao et al*.* (2004) evaluated ten Mungbean genotypes at five locations to study their stability. The genotype MGG-347 was considered as the most stable among all the genotypes and its performance could be predicted over the environments. Swamy and Reddy (2004) carried out stability analysis of fifty Mungbean genotypes under three environments. The genotypes LGG-460 was stable for seed yield per plant under average environmental conditions, whereas, CO-5, LGG-427 and LGG-470 were suitable for poor environmental condition. Tarakanoar and Ruzgas (2006) proposed AMMI (additive main effect and multiplicative interaction) model for analyzing the G × E interaction (GEI) and the phenotypic stability of promising lines of grain wheat. This model is widely used in analyzing GEI and it is effective because it captures a large portion of GEI sum of squares. Berger et al*.* (2007) have done their experiment on chickpea and observed that multi-environment trials (METs) are typically used in plant breeding programmes to evaluate material across a range of sites representing target environments for the crop. A key concept in G × E analysis is genotype stability and by definition, genotypes exhibiting a high degree of G × E interaction are unstable across sites. Abbas et al. (2008) studied stability and wider adaptability of elite lines of Mungbean (*V. radiata*) at four locations in Punjab province during 2004. They observed that G × E interaction was highly significant and was cross over in type. Mean seed yield performance of five environments revealed the superiority of genotype NM-1 by producing significantly higher yield (1383 kg/ha). They also found that NM-1 and NM-10-12-1 responded better to favourable conditions showing high regression coefficient (bi) value. Negative regression values of M-6 and M-1 may be an indicator of better response to poor environment yet showing low seed yield. They suggested that NM 20-4 had stable performance under different locations. Gauch et al. (2008) suggested that statistical methods for effective analysis of yield trials have received considerable development. The multilocation yield trials are the most important in varietal identification, especially for testing a number of genotypes in a number of environments. Singh et al. (2009b) studied the role of genotype and environmental interactions in expression of various characters and stability of mungbean genotypes in different environments. While working in 80 genotypes of Mungbean in 3 environments, they observed that the genotypes showed considerable differential interaction with different environments. Manzoor and Shah (2009) while evaluating 12 elite chickpea genotypes along with two check which are grown in four diverse locations, observed that maximum mean seed yield over the locations was produced by the CC-119/00 (1.229 t ha) and the highest mean seed yield producing locations was NIAB (1.412 ha^{-1}). They also reported that genotypes CC-119/00, CC-117/00, CM-256/99, CH-38/00 and K-70022 were most stable and adapted to the diverse environmental conditions. Abeytilakarathna (2010) while evaluating 10 promising Mungbean lines in 3 environments for 2 years using AMMI (additive main effects and multiplication interactions) along with mean deviation from maximum plot yield, reported that, Mungbean line with above grand mean yield having the lowest mean deviation (D) and IPCAs scores which are class to zero, are selected as the most adoptable promising lines in the multi-location trial. Karale (2010) evaluated 20 Mungbean genotypes at four environments to study stability performance and yield stability. He found linear component of G×E interaction was significant for all the characters except pod clusters per plant and seeds per pod, where pooled deviation were significant for the characters, plant height, primary branches per plant and 1000 seed weight (g). He also observed that Vaibhav, AKM-9907 and PM-2 found average stability for seed yield per plant. Akhtar et al. (2010) conducted an experiment with fifteen genotypes of Mungbean which were tested at five locations in Pakistan in kharif 2006, to study their yield stability. They observed that the partitioning of G × E interaction into linear and non-linear components indicated that both predictable and unpredictable components stated the interaction. They found CGM-504, exhibited the stable performance over all five locations.

Ten genotypes of Mungbean were sown on four different sowing dates in a Randomized Block Design with three replications with a view to estimate G × E interaction for seed yield and to assess the seed yield potential of different genotypes of Mungbean under different sowing dates and to identify genotypes suitable for different predictable environments. The G × E interaction and both variance due to genotypes and environments were significant. On the basis of these parameters the genotype AKM-9911 exhibited stable performance for seed yield per plant (g), the genotypes Vaibhav and PM-2 showed average stability for seed yield per plot (kg) and found suitable for all types of environment. Considering the stability performance, the genotypes Vaibhav and PM-2 would be suitable to grow under different environments for seed yield. Above average stability was exhibited by very few genotypes, that is, Vaibhav and AKM-8802 (Nath, 2012).

ANALYSIS OF VARIANCE FOR STABILITY

The pooled analysis of variance for phenotypic stability found that, the mean differences due to genotypes were statistically significant for all the characters except plant height (cm) when tested against G × E interaction and pooled deviation. The environmental means also varied considerably for all the traits, except protein content when tested against G × E interactions, pooled deviation and pooled error. The highly significant G × E interaction observed for all the characters except for primary branches, pod length and protein content indicated that, genotypes showed varied responses to different environments (Nath, 2012). Previously, Akhtar et al. (2010), Patel et al. (2009), Singh et al. (2009b), Abbas et al. (2008), Swamy and Reddy (2004), Raje and Rao (2004), Muhammad and Ghafoor (2001), Khairnar (1998), Kalpande et al. (1996), Renganayaki (1995), Patil and Narkhede (1995), Patil and Narkhede (1992), Naidu and Satyanarayana (1991a), Gupta et al. (1991), Pathak et al. (1990), and Imrie and Butler (1982) observed significant differences among genotypes, environment and G × E interaction for most of the characters they studied in Mungbean.

REFERENCES

AkhtarLH, Muhammad K, Muhammad A, Tariq A (2010). Stability analysis for grain yield in mungbean (Vigna radiata L. Wilczyek) grown in different agro-climatic regions. Emir. J. Food Agric. 22(6): 490-497.

Abbas G, Babar MA, Shah TM, Haq MA (2008). Stability analysis for seed yield in Mungbean. J. Agric. Res. 46(3):223-228.

Abeytilakarathna PD (2010). Statistical analysis for stability and adaptability testing of mungbean (*Vigna radiate* L.) genotypes. Electr. J. Plant. Breed. 1(3):244-249.

Abeysiriwardena DS, Deze Burs GR, Rase PE Jr (1991). Analysis of multi environmental yield trails for testing adaptability of crop genotypes. Tope. Agriculturist 147:85-97.

Ahmednagar, Maharashtra (India).

Allard RW, Bradshaw AD (1964). Implications of genotype × environment interaction in applied plant breeding. Crop Sci. 4:503-508.

Anwari M, Soehendi R (1997). Evaluation of yield and stability of mungbean promising lines. Research results of legumes and root crops during 1996-97 periods. Malang (Indonesia). Baitkabi. pp. 52-61.

Bains KS, Gupta VR (1972). Stability of yield and yield components in bread wheat. Indian J. Genet. pp. 306-312.

Berger JD, Specijers J, Sapra RL, Sood UC (2007). Genotype by environment interaction and chickpea improvement.In: chickpea breeding and management. CAB International. pp. 617-629.

Choudhary SK, Haque MN (1977). Stability performance of some greengram varieties. Indian J. agric. Sci. 47(6):303-304.

Comstock RE, Moll RH (1963). Genotype × environment interaction. Statistical genetics and plant breeding NAS-NRG-Publ. 982:174-196.

Dobhal VK, Gautam NK (1994b). Phenotypic stability in adzuki bean (*Vigna angularis*). Indian J. Agric. Sci. 64(3):179-181.

Durate JB, Zimmermann Deo MJ (1995). Correlation among yield stability parameters in common bean (*Phaseolus vulgaris* L.). Crop Sci. 35(3):905-912.

Eberhart SA, Russell WA (1966). Stability parameters for comparing varieties. Crop Sci. 6:36-40.

Finlay KW, Wilkinson GN (1963). The analysis of adaptation in a plant breeding programme Aust. J. Agric. Res. 14:742-754.

Gauch HG, Jr. Piepho HP, Annichiarico P (2008). Statistical analysis at yield trials by AMMI and GGE further consideration. Crop Sci. 48:866-899.

George CJ, Fernandez Chen HK, Crighton Miller J (1989). Adaptation and environmental sensitivity of mungbean genotypes evaluated in the International Mungbean Nursery. Euphytica. 41(3):253-261.

Gomashe SS (2003). Stability for seed yield and its components in mungbean. Thesis submitted to Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra (India).

Gupta RK, Tomer YS, Battan KR, Singh VR (1991). Stability analysis in mungbean. Indian J. Agric. Res. 25(3):154-160.

Imrie BC, Butler KL (1982). An analysis of variability and genotype x environment interaction in mungbean [*Vigna radiate* (L.)Wilczek] in South Eastern Queensland. Aust. J. agric. Res. 33:523-530.

Jahagirdar JE, Makne VG, Khapre PR, Ghodke MK (1994). Stability analysis in summer Mungbean. J. Maharashtra Agric. Univ. 19(2):283-284.

Jinks JL, Mather K (1955). Stability in development of heterozygotes and homozygotes. Proc. Royal Soc. (London) Series, B. 143:561-578.

Jones DF (1958). Heterosis and homeostasis in evaluation and applied genetics. Am. Nat. 42:32-328.

Joshi SN (1969). Variety x environmental interaction in varietal test of greengram (*Phaseolus aureus* Roxb.). Indian J. Agric. Sci. 39:1010-1012.

Joshi SN (1972). Stability parameters for comparing greengram (*Phaseolus aureus* Roxb.) varieties. Madras. Agric. J. 59:195-197.

Kalpande HV, Patil JG, Deshmukh RB (1996). Stability analysis for seed yield and its components in greengram. J. Soil. Crops. 6(2):173-176.

Kandaswami M (1995). Phenotypic stability for seed yield in greengram (*Vigna radiate* L.) in sodic soil. Madras Agric. J. 82(3):211-213.

Karale SN (2010). Stability for yield and its components in Mungbean (*Vigna radiate* (L.) Wilczek.). M.Sc. (Agric) Thesis submitted to MPKV, Rahuri, Dist. Ahmednagar, Maharashtra.

Kasno A (1992). Adaptability and yield stability of several Mungbean genotypes. Report research results of Malang Research Institute for food crops, during 1991, Malang (Indonesia) BPTP. pp. 205-213.

Khairnar MN (1998). Variaiblity and stability for yield and its components in Mungbean [*Vigna radiate* (L.)Wilczek]. M.Sc. (Agri.)

Knight R (1970). The measurement and interpretation of genotype – environment interactions. Euphytica. 19:225-233.

Krishnaswamy S, Ratnaswamy R (1982).Multilocation performance of greengram cultivars in Tamil Nadu. Madras Agric. J. 69:777-779.

Lal HA, Muhammad K, Muhammad A, Tariq A (2010). Stability analysis for grain yield in Mungbean (*Vigna radiata* L. Wilczyek) grown in different agro-climatic regions. Emir. J. Food Agric. 22(6):490-497.

Manivannan N, Murugesan S, Ramamoorthi N, Nadarajan N (1997). Phenotypic stability for seed yield in black gram. Madras Agric. J. 84(11,12):652-653.

Manivannan N, Sethuraman K, Nandrajan N (1999a). Phenotypic stability for seed yield in Mungbean. Indian J. Pulses Res. 12(1):105-106.

Manivannan N, Sethuraman K, Vishwanathan P, Dhankodi CV (1999b). Genotype x environment integration in Mungbean. Indian J. Pulses Res. 12(1):30-33.

Manzoor BA, Shah TM (2009). Stability analysis of elite chickpea genotypes tested under diverse environments. Australian J. Crop Sci. 3(5):249-256.

Miah MNI, Corangal VR (1986). Stability of selected Mungbean cultivars evaluated under different growing conditions, Philippine J. Crop Sci. 11:1.

Mishra D (1994). Phenotypic stability for seed yield in rice bean. Indian J. Agric. Sci. 65(12):904-906.

Muduli KC, Hati N (1994).Stability analysis for seed yield in green gram and black gram. Indian J. agric. Sci. 64(3):176-178.

Naidu NV, Satyanarayana A (1991a). Association between mean performance and stability parameters in greengram. Indian J. Agric. Sci. 61(6):420-421.

Naidu NV, Satyanarayana A (1991b). Stability analysis for seed yield its components in Mungbean. Legume Res. 14(4):169-174.

Nath A (2012). Stability analysis in Mungbean.Thesis, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, India.

Patel JD, Naik MR, Chaudhari SB, Vaghela KO, Kodappully VC (2009). Stability analysis for seed yield in green gram (*Vigna radiate* L. Wilczek). Agricultural Science Digest. 29:36-38.

Pathak AP, Lal S (1987). Varietal stability in Mungbean. Farm Sci. J. 2(2):161-164.

Pathak AR, Zaveri PP, Patel JA, Kher HR, Shan, RM (1990). Stability analysis in Mungbean. Indian J. Pulses. Res. 3:13-18.

Patil HS, Narkhede BN (1989). Stability of pod length and seeds per pod in greengram. J. Maharashtra Agric. Univ. 14(2):146-148.

Patil HS, Narkhede BN (1992). Stability of pod length and seeds per pod in greengram. J. Maharashtra agric. Univ. 14(2):146-148.

Patil HS, Narkhede BN (1995). Stability analysis for 100 seed weight, pods per plant and seed yield in greengram [*Vigna radiate* (L.) Wickzek].Legume Research. 18(1):41-44.

Perkins JM, Jinks JL (1968). Environmental and genotype environmental components of variability. 111 multiple lines and crosses. Heredity 23:339-356.

Plaisted RL, Peterson LC (1959). A technique for evaluating the ability of selection to yield consistently in different locations and seasons. Amer. Potato J. 36:381-385.

Raje RS, Rao SK (2001). Stability analysis for hundred seed weight in mungbean [*Vigna radiate* (L.) Wilczek]. Legume Res. 24(4):222-230.

Raje RS, Rao SK (2004). Stability analysis for seed yield in Mungbean (*Vignaradiata*L.). Legume Res. 27(1):11-18.

Rao YK, Durga KK, Murthy SS, Reddy DM (2004). Stability for seed yield in Mungbean. Legume Res. 27(1):77-78.

Reddy PN, Hemantkumar M, Krishanaiah Setty BV (1990). Stability analysis of yield and component characters and correlation of stability in greengram (*Phaeolus radiatus* L.). Indian J. Agric. Sci. 60(11):755-757.

Reddy PRR, Sreeamulu C (1984). G × E interaction and stability of performance in green gram [*Vigna radiate* (L.) Wilczek]. GeneticaIberica. 36(1/2):105-116.

Reddy RR (1980). Combining ability and G x E interaction in green gram [*Vigna radiate* (L.) Wilczek]. Ph.D. Thesis submitted to Andhra Pradesh agric. Univ., Hyderabad.

Renganayaki K (1995). Phenotypic stability in Mungbean. Madras Agric. J. 82(6,7,8):425-427.

Sarma RN, Borthakur AK, Sarma SK (1993). Stability analysis in summer sown green gram (*Phaseolus radiata*). Indian J. Agric. Sci. 63(9):594-596.

Singh SK, Singh IP, Singh BB, Onkar Singh (2009a). 2nd June stability analysis in mungbean [*Vigna radiate* (L.)Wilczek]. Legume Research. P. 32.

Singh SK, Singh IP, Singh BB, Singh O (2009b). Stability analysis in mungbean (*Vigna radiata* (L.) WILCZEK). Legume Res. 32(2):108-112.

Singh SV, Singh RB (1980). Stability of component characters in relation with the stability of yield.Indian J. Genet. 40:93-98.

Srinivas P, Rungsarid-Kaveeta, Atthaphon-Suwannawong (1987). High protein research and development project Kasetsart Univ. Bankok (Thailand). Proceedings of a Research Seminar on High Protein Crops for 1983 and 1984.Bankok (Thailand). pp. 145-168.

Sumanggono AM, Mgiono R, Hakim L (1998). Potential yield stability of some Mungbean lines and mutant line. Summary of scientific meeting of research and development of isotope and radiation application, Book 1 : Agriculture Animal Husbandry and Biology. Jakarta (Indonesia) BATAN. pp. 47-50.

Swamy AA, Reddy G (2004).Stability analysis at yield in Mungbean. Legume Res. 27(2):107-110.

Tai GCC (1971). Genotypic stability analysis and its application to potato regional trails. Crop Sci. 11:184-190.

Tarakanoar P, Ruzgar V (2006). Additive mean effect and multiplicative interaction, analysis of grain wheat varieties in Lithnania Agro Research. 4(1):91-98.

Venkateswarlu O (1999). Genotype × environment interaction for grain yield in greengram [*Vigna radiata* (L.) Wilczek]. Legume Res. 22(2):135-136.