Evaluation of four Mungbean [*Vigna radiata* (L.) Wilczek] Genotypes for Yield and Yield Contributing Traits under Different Environmental Conditions

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ABSTRACT

Plant genotype and its interaction with environment are important factors determining the crop production. In order to evaluate four different genotypes of (*viz*., MUNG-1, MUNG-2, MUNG-3 and MUNG-4) under three different environment conditions (*viz*., E_1, E_2 and E_3) in terms of date of sowing in Jalandhar region, a field experiment was carried out at the research farm, Faculty of Agricultural Sciences, DAV University, Jalandhar, Punjab. The experiment was conducted in a randomized block design with four replications for the estimation of stability parameters by employing the Eberhart and Russell model. The environment wise analysis of variance revealed significant differences among the genotypes (at $p \leq 0.05$) for pod per plant, pod weight, pod length, number of seeds per pod, test weight and seed yield per plant. However, the differences among the genotypes were non-significant for days to 50% flowering and number of branches per plant, and plant height. Mean performance of genotypes under three environments indicated that the sowing of summer mungbean under Environment E_2 was found better followed by E_1 and E_3 for days to 50% flowering, plant height, number of branches per plant, pod per plant, number of nodules per plant, pod weight, pod length, number of seeds per pod, test weight, and seed yield per plant. Pooled analysis of variance indicated significant differences for genotypes (G), Environment (E) for all the traits except days to 50% flowering, plant height and test weight; whereas G×E interaction was significant for pod weight and test weight only. The linear component ($b_i \cong 1$) and non-linear ($S^2di \cong 0$) component of stability suggested that the genotype MUNG-1 was found stable and considered as adaptable for number of nodules per plant, pod weight, pod length, seeds per pod. MUNG-2 was found stable for days to 50% flowering, number of branches per plant, pods per plant, pod length, pod weight, plant height, number of pod per plant, and test weight. MUNG-3 was stable for day to 50% flowering, number of branches per plant, pod per plant, pod weight, pod length, test weight and seed yield per plant. Whereas, MUNG-4 is stable for branches per plant, pod per plant, number of nodules per plant, pod length, seeds per pod, test weight and seed yield per plant. Among the four genotypes, MUNG-3 and MUNG-4 were found to possess the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. However, the genotype MUNG-1 and MUNG-2 were found to possessed the linear component less than unity ($b_i < 1$) and non-linear component $S^2di \cong 0$ were considered as better adaptable to poor or unfavorable environment (above average stability) for seed yield per plant.

KEYWORDS

Genotype × Environment interactions, Stability analysis, Sowing time, Stable genotypes, Linear component, Non- linear component, Eberhart and Russell model

INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is a short duration pulse crop belonging to the family Leguminaseae and is considered a relatively drought resilient crop (Singh *et al*., 2019). Mungbean is variously known as greengram, goldengram, chickasano pea, oregon pea, chiroko or simply mung *etc.*, in different parts of India (Chauhan and Williams, 2018; Mehnandi *et al*., 2019). According to Vavilov, the centre of origin of mungbean lies in India and the Central Asia (Vavilov, 1926). In India, mugbean is ranked third after (bengal gram and red gram) in terms of area under cultivation, production and productivity. Major mungbean growing states of India are Karnataka, Orissa, Maharashtra, Andhra Pradesh, Telangana, Bihar, Rajasthan and Uttar Pradesh. It can be cultivated both as a kharif and a summer crop (under adequate water availability). Mungbean is well adapted to the dry conditions and can be grown in the warm season in tropical and subtropical conditions. A well-drained loamy to sandy loam soil is considered best for its cultivation (Pamei *et al*., 2020). It is an annual, wide spreading plant having medium to all plant (ranging from 25 to over 100 cm), erect to sub erect (sometime twining), with a height of about 0.15-1.24 m (Lambridges and Godwin, 2006; Magosti, 2006).

India is the largest producer, consumer, precursor and importer of mungbean (Akram *et al*., 2021). It is grown on around 4.74 million hectares with a total production of 2.62 Metric Tom and the productivity of 553 kg/hectare. During 2020 - 2021, the total production of mungbean in Punjab was 2.5 thousand tones with an average yield of 9.60 quintals per hectare (3.89 quintals/acre) (Wu *et al*., 2022).

Mungbean plays an important role in human nutrition (mainly as a good source of protein and bio-active compound), it also fulfill the protein requirements of the unprivileged masses, thus mungbean could also be referred as the 'Poor man's meat' (Hall *et al.*, 2017). It is a rich source of proteins, vitamins, minerals and carbohydrates. In addition, mungbean is an excellent source of vitamin B_9, also known as folate (Kumar and Pandey, 2020). Besides its nutritional importance, Mungbean help in maintaining the soil fertility due to its ability to assist biological nitrogen fixation (Jat *et al*., 2014; Mehandi *et al*., 2019). The subsequent crop yield increases after its production, due to residual N form it and the decomposition of its residues (Beckie *et al*., 1997; Bremer *et al.,* 2011). The majority of N derived from rhizo-deposition remained in the soil itself, therefore it could be important for soil organic matter build-up also, which is important for sustainability in agriculture (Pataczek *et al*., 2018). Mungbean in rhizodeposition to the soil N pool for subsequent crops and can ultimately help in improving the soil fertility too (Zhang *et al*., 2015; Ro *et al.*, 2016). Optimum planting time and the appropriate environmental conditions are the important factors, which enhance vegetative and reproductive growth period (Sadeghipour, 2008). The time of planting also affects other production factors, like harvest and ultimately crop yields and quality of the produce (Soomro, 2003). The main objective is to obtain the best out of the genotype. Any delay in the sowing of mungbean varieties not only reduces the yield but also creates problem for harvesting of the same, if there are pre-monsoon showers. Therefore, there must be specific date of sowing and appropriate environment condition for different genotypes to obtain maximum yield (Pamei *et al*., 2020). Moreover, a specific genotype does not exhibit the same phenotypic characteristics in all environmental conditions. Stability play important role in selecting and developing improved genotypes for different environments. The study of genotype × environment interaction helps in the identification of highly responsive and high yielding genotypes suitable for production in targeted environment condition. Stability for morphological and phonological traits has been found to be playing an important role in imparting stability for grain yield. Therefore, the present study was performed to estimate genotype × environment interaction with the help of stability parameters and the evaluation of genotypes for yield attributing traits in Jalandhar (Punjab) region.

MATERIAL AND METHODS

The present study was conducted at the Experimental farm, Faculty of Agricultural Sciences, DAV University, Jalandhar during the summer season of the year 2022. Seeds of four different mungbean (*V. radiata*) genotypes were collected from different regions of Punjab. Four mungbean genotypes (MUNG-1, MUNG-2, MUNG-3 and MUNG-4) collected from different regions of Punjab, were sown under three different environments (*viz*., E_1, E_2 and E_3) in terms of date of sowing (*i.e.*, 5th March, 15th March and 25th March, respectively). The experiment was laid out in a Randomized Block Design (RBD) with four replications. The plot size for each replication of a treatment was 2×2.3 m (*i.e.*, length × breadth) and the seed rate was kept at 25-30 kg/ha with a spacing of 30×10 cm (*i.e.*, row to row distance × plant to plant distance) for each plot, during sowing. All the observations on yield and yield attributing traits *i.e*., days to 50% flowering, plant height (cm), number of branches per plant, number of pod per plant, number of nodules per plant, pod length (cm), pod weight (g), number of seeds per pod, seed yield per plant (g) and test weight (g) were analyzed statistically. The data collected was subjected to analysis of variance (ANOVA) using BBM software (BMM soff. Corporation, Sen Francico, California) as per the stability model proposed by Eberhart and Russell (1966). The data on each character for the varieties were subjected to standard analysis of variance for each environment, separately (Panse and Sukhatme, 1978).

RESULT AND DISCUSSION

Pooled analysis of variance

Pooled analysis of variance for the ten characters over three environments (Table 1), indicated that the mean squares due to replications in environments were non-significant for all the characters. Similar finding were also observed by several other workers (Nath *et al*., 2013; Pathak and Lal, 1987; Naidu and Satyanarayana, 1991; Patel *et al.*, 2009; Raturi *et al*., 2012). The variance due to environment were significant for days to 50% flowering, number of branches per plant, number of pods per plant, number of nodules per plant, pod weight (g), pod length (cm), number of seeds per plant, seed yield per plant (g). Several other workers also found that the significant differences among the genotypes and environment for all yield related traits (Imrie and Butler, 1982; Pathak *et al*., 1990; Gupta *et al*., 1991; Swamy and Reddy, 2004; Nath, 2013). However, a non-significant difference due to environment among the genotypes was recorded in case of plant height (cm) and test weight (g). The mean squares due to genotypes were significant for all the characters except days to 50% flowering. In another study it was recorded that the analysis of variance depicts significant differences present among genotypes (treatments) over different environments (Mahalingam *et al*., 2018). The mean squares due to genotypes × environments were significant for pod weight and test weight and rest all traits were non-significant. The significance of mean square due to G × E for some traits indicated that the genotypes interacted similarly significantaly with environments (Gomashe *et al*., 2008). Pooled analysis of variance over three different environments showed that the genotypes differed significantaly when tested against G × E interaction. In the present study results are in a close to proximity to the findings of earlier researchers, which observed the significant differences among the genotypes, environments and G × E interaction in mungbean (Abbas *et al*., 2008; Chaudhary and Haque, 1977; Gomashe *et al*., 2003; Gomashe *et al*., 2008; Miah and Corangal, 1986; Nath *et al*., 2013; Pathak *et al*, 1990; Reddy *et al*., 1990; Reddy *et al*., 2004).

Table 1: Summary of Pooled analysis of variance (Pooled for three different environments) for various characters of mungbean (Mean Sum of Squares)

Source	d.f	DF	PH(cm)	NB	PP	NP	PW(g)	PL(cm)	NS	TW(g)	SY(g)
Replication (in env.)	9	0.68	7.16	0.11	0.60	0.74	0.27	0.26	0.29	0.23	0.163
Environments	2	**64.42***	14.95	**2.57***	**28.96***	**2.24***	**16.90***	**1.54***	**2.67***	2.85	**9.892***
Genotypes	3	4.17	**10.262***	**2.818***	**78.37***	**4.07***	**7.25***	**4.27***	**7.42***	**24.26***	**1.324***
Genotype × environment	6	0.19	8.83	0.24	2.07	0.52	**0.93***	0.22	0.12	**3.05***	0.135
Error	27	0.88	5.33	0.21	1.00	0.49	0.34	0.11	0.11	1.14	0.182

*Significant at $p \leq 0.05$

Here, d.f is degree of freedom, DF- days to 50% flowering, PH- plant height(cm), NB- number of branches, PP- pods per plant, NP- number of nodules per plant, PW- pod weight (g), PL- pod length (cm), SP- number of seeds per pod, TW- Test weight (g) and SY- seed yield per plant (g).

Table: 2 Estimate of Range and general mean of different characters of mungbean under three different environments

		E1		E2		E3		Pooled over environments		
S. No.	**Characters**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**GM**	**CD**
1.	**Days to 50% flowering**	46.0- 47.5	46.80	38.00-39.50	38.90	43.50- 44.50	43.90	38.90- 46.80	43.25	1.83
2.	**Plant height (cm)**	39.5- 48.7	44.12	45.50- 49.20	46.60	38.30- 47.00	42.80	42.80- 46.60	44.53	4.51
3.	**No. of branches per plant**	8.00-8.55	8.31	8.45-10.05	9.17	6.80-8.20	7.71	7.71-9.17	8.35	0.89
4.	**No. of pods**	9.2- 16.2	12.32	14.45- 18.60	16.37	8.50- 14.60	11.30	11.30-16.37	13.33	1.87
5.	**Number of nodules**	7.50-8.20	7.97	8.30-9.90	8.86	6.45-8.00	7.40	7.40-8.86	8.04	1.38
6.	**Pod weight (g)**	2.68- 3.58	3.01	4.91-7.87	6.21	1.83- 3.24	2.39	2.29- 6.21	3.88	1.95
7.	**Pod length (cm)**	6.01- 7.49	6.75	7.03-8.50	7.71	5.88- 7.09	6.56	6.56- 7.71	7.00	0.68
8.	**No. of seeds per pod**	8.35-10.35	9.35	9.80- 11.45	10.43	7.90- 9.75	8.83	8.83- 10.43	9.54	1.06
9.	**Test weight (g)**	38.72-42.39	40.11	39.27- 43.9	40.64	38.50- 39.75	39.20	39.20-40.64	39.98	2.08
10.	**Seed yield per plant (g)**	3.34-5.37	4.36	6.45-7.72	7.21	3.91-5.47	4.63	4.36-7.21	5.40	0.89

The comparison of mean of different traits across the environments presented in table 2 indicated that mean values of different traits decreased with delay in sowing. According to the results, the second sowing (15th March) is the best followed by the first sowing (5th March) and third sowing (25th March) for all the traits. Early sowing of mungbean leads to a poor germination, while too late sowing lowers the seed yields, because unfavorable environment for growth and development mainly during reproductive phase. Late sowing reduces the yield of summer mungbean due to the unfavorable environment (Chovatia *et al*., 1993). Thus, optimum sowing time plays an important role for enhancing grain yield of timely sown crop. Optimum sowing time confirms greater balance and relationship between the weather and plant, resulting in a higher yield (Hussain *et al*., 2022). In the present study, environment-E_2 (15th March) is the optimum date for sowing of summer mungbean. In another study, it was found that the delay in sowing causes a substantial decrease in all the growth and development parameters of mungbean. Soomro, (2003) also reported the highest seed yield from the 15th March sowing which might be due to the suitable prevailing temperature accompanied by a higher moisture content due to the sufficient rainfall, which enhances the vegetative as well as reproductive growth.

The data depicted in the present study suggested that the least numbers of days to 50% flowering were observed under Environment-E_2 (sown on 15 March) which was significantaly lower than all other environments. Some other workers also found that sowing on 15 March was better than all other sowing dates for this trait (Jaiswal, 1995; Tajudir *et al*., 2014). Another study indicated that there was significant reduction in phonological parameter *i.e.* days to 50% flowering with delayed sowing of mungbean (Rehman *et al.,* 2009). Early sown mungbean took significantaly higher number of days to phonological maturity observed by (Hussain *et al*., 2022). This trait is generally affected by day length. Number of days required for first flowering was reduced with delay in sowing the might be due to increased temperature and sufficient moisture content (Miah *et al*., 2009). The higher plant height (46.60cm) were observed under Environment-E_2 (sown on 15 March), which was statistically at par with Environment-E_1 (sown on 5 March) and E_3 (sown on 25 March). Findings are in accordance with the earlier researchers, they also found that the growth parameters, like plant height were increased with the delay in sowing due to increase in temperature and sunshine hour in mungbean (Palsaniya *et al*., 2016; kabir and Sarkar, 2008). This might be due to favorable soil moisture and temperature for growth during optimum date of sowing (Kumar and Kumawat, 2014; Rehman *et al*., 2009; Mule *et al*., 2020; Miah *et al*., 2009). Increase in plant height might be due to more growing period in normal sowing (Singh *et al*., 2011). The results are contradictory with earlier workers, who stated that linear decline in the plant height with delay in sowing of mungbean (Singh *et al*., 2012). The highest number of branches per plants were observed under Environment-E_2 (sown on 15 march), which was significantaly higher than all other environments. The highest number of branches per plant produces might be due to more space for nutrient absorption in presence of proper soil moisture content during the growth period (Sarkar *et al.*, 2004). The highest number of pods per plants were observed under E_2 (sown on 15 march), which was significantaly higher in comparison to other environments. Some other researchers was suggested that sowing crop on 15 March lead to the significantly higher number of pods per plant in mungbean (Chovatia *et al.*, 1993; Tzudir *et al*., 2014; Soomro, 2003; Siddique *et al*., 2006). Some other workers also reported in the same way that sowing on 15 March produced highest number of pods per plant in comparison to other sowing (Singh and Vashit, 2005). The maximum number of nodules per plant was obtained under Environment-E_2 (sown on 15 March), which was statistically at par with Environment-E_1 (sown on 5 March). Thus, Environment-2 (E_2 is 15 March) was found to be better and at par with (E_1 is 5 March) for number of nodules per plant. Various workers have been reported that increase in number of root nodules in second sowing (15 March), might be due to photosynthesis and partition to assimilate to nodules confirmed by (Ram and Dixit, 2000; Singh and Singh, 2009). It has also been previously recorded that nodule formation is influence by date of sowing in mungbean crop (Singh *et al*., 2010). The maximum pod weight per plant were observed under Environment-E_2 (sown on 15 March), which was significantaly highest than all other environments. In the present study results are in a close proximity to the findings of earlier researchers observed that pod weight increase in second sowing (15 March) might be due to optimum temperature, sunshine was available (Kumar *et al*., 2015). Some other workers also suggested that the earlier sown crop got the longer time period for the crop growth and development and produced more assimilated thus it resulted in production of longer pods with more grains and however, delay in sowing faced higher temperature and high rain during the flowering stages which led to smaller pods with less grains (Ahmed *et al*., 2021). The maximum pod length was observed under Environment E_2 (sown on 15 March) in compared to all other environment. In the present study results are in close proximity with the findings of earlier researchers observed that second sowing was found to be better that other, this might be due to optimum sowing date (Patil *et al*., 2003; Sarkar *et al*., 2004; Reddy, 2009). Some other workers also suggested that delay in sowing faced higher temperature and high rain during the flowering stages which led to smaller pods. However, the earlier sown crop got the longer time period for the crop growth and development and produced of more assimilated thus, it resulted in production of longer pods (Ahmed *et al*., 2021). Some other workers found that the pod length increase with delayed (15 March) in sowing might be due to higher temperature, higher moisture content and sunshine (Singh and Singh, 2009). The maximum number of seeds per pod was observed under Environment-E_2 (sown on 15 March). In the present study results are in a close proximity to the findings of earlier researchers observed that increase in number of seeds per pod was might be due to higher dry matter production which resulted in greater translocation of food material to the reproductive parts of mungbean crop (Subbulakshmi, 2021; Vakeshwaran *et al*., 2016). The maximum test weight was observed under Environment-E_2 (sown on 15 March), which was statistically at par with Environment-E_1 and Environment-E_3. The present results are in a close proximity to the findings of earlier workers reported that second sowing (15 March) is best in comparison to other sowing (Kumar *at al*., 2014). Some other workers also observed that crop sown on March 15 recorded the higher test weight in comparison to other sowing dates in mungbean (Singh and Vaishit, 2005; Bhowmick *et al*., 2008). The data depicted in present study that the maximum seed yield per plant was obtained under Environment-E_2 (sown on 15 March), which was significantaly maximum than all other Environments. Several other researchers was also suggested that the lower seed yield of mungbean in early planting might be due to lower temperature at early stages of crop growth (Kumar *et al*., 2008). The increase in seed yield when seed was sown on 15th March, this might be due to suitable temperature prevailing accomplished by the higher soil moisture content due to sufficient rainfall, which enhanced the vegetative as well as the reproductive growth of the crop (Sinha *et al*., 1989; Poehlman, 1991). The present results are in a close proximity to the findings of earlier researchers observed that the seed yield was reduced with delaying in sowing caused the poor performance and also found that that early sowing before 2 March summer mungbean caused a substantial decrease in growth and yield of mungbean (Miah *et al*., 2009; Sadeghipur, 2008).

Stability analysis.

Mungbean genotypes differed significantly among themselves in respect of yield contributing characters and yield. Results of pooled analysis of variance for stability parameters for seed yield and its component (b_i and S^2di) present in table 3 revealed that mean squares due to genotype were significant for all the traits indicated significant differences among them. The significance of mean squares may be due to the variability present among the environments (Gomashe *et al,* 2008). Some other workers also found significant variation due to environment for all the yield related characters (Imrie and Butler, 1982; Pathak *et al*., 1990; Akhtar *et al*., 2010; Nath, 2013). In present study, the environment linear component was also significant in all the cases indicated the existence of substantial differences among four genotype under different environments.

Table: 3 Analysis of variance for different characters in four genotypes of mungbean.

Character	d.f	DF	PH	NB	PP	NP	PL	PW	SP	TSH	SY
Genotypes	3	**1.4166***	**25.637***	**0.70133***	**19.59***	**1.01746***	**1.0649***	**1.1812***	**1.8562***	**6.06786***	**1.324***
Env+ (env. × gen.)	8	**16.1407***	**5.394***	**0.68667***	**7.6281***	**0.65913***	**0.4244***	**4.407***	**0.6884***	**1.2823***	**2.574***
Env.(linear)	1	**128.8438***	**29.8951***	**128.8438***	**57.91***	**4.48874***	**3.077***	**33.807***	**5.3324***	**5.709***	**19.785***
G × E (linear)	3	0.0016790	**0.40019***	0.0016790	0.8322	0.16408	**0.099***	0.3816	0.046	**1.470***	**0.135**
Pooled deviation	4	0.058862	0.315610	0.058862	0.1530	0.07057	0.005	0.076	0.008	**0.132***	0.017
Pooled error	27	0.29475	0.1775	0.29475	0.3323	0.16398	0.038	0.112	0.099	0.069	0.192

*Significant at $p \leq 0.05$

Here, d.f is degree of freedom, DF- days to 50% flowering, G×E is Genotype into Environment interaction, DF- days to 50% flowering, PH- plant height (cm), NB- number of branches, PP- pods per plant, NP- number of nodules per plant, PW- pod weight (g), PL- pod length (cm), SP- number of seeds per pod, TW- Test weight (g) and SY- seed yield per plant (g).

The G × E interactions were significant for plant height, pod length and test weight. The results are in a close proximity to the findings of earlier researchers observed the significant G × E interaction for pods per plant and seed yield (Reddy, 1980; Swamy and Reddy, 2004; Abbas *et al*., 2008; Singh *et al*., 2009; Akhtaar *et al*., 2010; Nath, 2013; Rao and Suryawanshi, 1988; Patel and Narkhede, 1989; Sood *et al*., 2000; Kumar *et al*., 2005). The mean squares due to genotype × environment (linear) was also significant for days to 50% flowering, plant height, number of seeds per pod and 100-seed weight indicated the presence of predictable genotype × environment interaction (Singh *et al*., 2018). The similar observations were recorded by earlier worker that partitioning of G × E interaction showed that G × E (linear) effect was significant for most of the characters when tested against pooled error, indicating the predictability of the performance of genotypes over environments (Borude *et al*., 2021). Both linear and non-linear components of G × E interactions were significant indicating that genotypes responded linearly to environmental changes for all the characters. Environment (linear) effect was significant for seed yield per plant, when tested against pooled deviation and pooled error (Nath *et al.*, 2013).

According to Eberhart and Russell, (1966) this model of stability of genotypes can be studied on the basis of mean ($\bar{x}$) performance, regression coefficient of the genotypes (b_i) and deviation from regression (S^2di). These stability parameters (mean, b_i and S^2di) have been used by several other workers to identify the suitable and superior genotypes (Singh *et al*., 2012). A genotype with unit regression ($b_i \cong 1$ average stability) and least deviation from regression ($S^2di \cong 0$) suggested as a stable one (Nath *et al*., 2013).

Table: 4 Summary of response of the genotypes under different environments on the basis of stability parameters (Nath *et al.*, 2013)

Linear component	Non-linear component	Response to environment
If, $b_i \cong 1$	$S^2di \cong 0$	b_i approaching to unity were regarded as having general adaptability or average stability.
If, $b_i > 1$		b_i significantaly greater than unity is considered as better adaptable to rich or favorable environment.
If, $b_i < 1$		b_i significantaly less than unity and considered as better adaptable to poor or unfavorable environment.

The character wise stability analysis

In table 5 and 6 the stability parameters, according to the model of Eberhart and Russell are given. In case of days to 50% flowering, MUNG-2 (b_i=0.968 and S^2di=0.095) and MUNG-3 (b_i=1.007 and S^2di=0.001) were found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component $S^2di \cong 0$ were regarded as having general adaptability or average stability. However, the genotype MUNG-4 (b_i=0.007 and S^2di=0.001) was found to possessed the linear component less than unity (b_i<1) considered as better adaptable to poor or unfavorable environment. The present study results are in a close proximity to the findings of earlier researcher found that some genotypes of the mungbean show the consistent stability and adaptability under different environment (Gomashe, 2003).

In case of plant height, the genotypes MUNG-2 (b_i=0.995 and S^2di=0.180) was found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) having average stability. The genotype MUNG-1 (b_i=0.556 and S^2di=0.155) and MUNG-3 (b_i=0.413 and S^2di=0.007) were found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$ were finding of earlier researchers observed that genotypes show adaptability to poor environmental condition (Sharma and Johnson, 2017). However, the genotype MUNG-4 (b_i=2.033 and S^2di=0.334) was found to possessed the linear component b_i greater than unity is considered as better adaptable to rich or favorable environment for this trait. In another study earlier researcher also found that some genotypes of mungbean having b_i component greater than unity (Pathak and Lal, 1987).

In case of number of branches per plant, the genotypes MUNG-3 (b_i=1.172 and S^2di=0.160) and MUNG-4 (b_i=1.017 and S^2di=0.120) was found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. The genotype MUNG-1 (b_i=0.903 and S^2di=0.04) and MUNG-2 (b_i=0.906 ad S^2di=0.000) were found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$ were considered as better adaptable to poor or unfavorable environment. The results are in close in close proximity to the finding of earlier researchers (Sharma and Johnson, 2017; Singh *et al*., 2014; Patel *et al*., 2009). In case of number of pods per plant, the genotypes MUNG-2 (b_i=0.885 and S^2di=0.670), MUNG-3 (b_i=1.070 and S^2di=0.005) and MUNG-4 (b_i=1.29 and S^2di=0.173) were found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. However, the genotype MUNG-1 (b_i=0.740 and S^2di=0.366) was found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$ were considered as better adaptable to poor or unfavorable environment. The present results are in a close proximity to the findings of earlier researchers (Sharma and Johnson, 2017; Singh *et al.*, 2009). In case of number of nodules per plant, the genotypes MUNG-1 (b_i=1.388 and S^2di=0.181) and MUNG-4 (b_i=1.268 and S^2di=0.000) were found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. However, the genotype MUNG-2 (b_i=0.663 and S^2di=0.067) and MUNG-3 (b_i=0.680 and S^2di=0.033) was found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$ were considered as better adaptable to poor or unfavorable environment. The present results are in a close proximity to the findings of earlier researchers observed that some genotypes of mungbean show stability under different environment and while some other show adaptability to poor or unfavorable environment (Magagane and Gordene, 2011).

Table: 5 Estimates of stability parameters for days to 50% flowering, plant height (cm), number of branches per plant.

Genotypes	**Days to 50% flowering**			**Plant height (cm)**			**Number of branches**			**Number of pods per plant**			**Number of nodules per plant**		
	Mean	**b_i**	**S^2 di**	**Mean**	**b_i**	**S^2di**	**Mean**	**b_i**	**S^2di**	**Mean**	**b_i**	**S^2di**	**Mean**	**b_i**	**S^2di**
MUNG-1	43.50	1.018	1.383	48.19	0.556*	0.155	8.38	0.903	0.04	16.48	0.74	0.366	8.65	1.388	0.1815
MUNG-2	43.58	0.968	0.095	43.54	0.995	0.180	8.35	0.906*	0.00	11.70	0.88	0.670	8.67	0.663	0.067
MUNG-3	43.08	1.007	0.001	45.12	0.413*	0.007	8.93	1.172	0.16	14.33	1.07*	0.005	8.18	0.680	0.033
MUNG-4	43.83	0.007	0.001	41.23	2.033*	0.334	7.75	1.017	0.12	10.33	1.29	0.173	7.25	1.268*	0.000
Range	43.08- 43.83			41.23- 48.19			7.75- 8.93			10.88-16.48			7.25-8.67		
GM	43.4975			44.52			8.3525			1.334			8.038		
CD	1.06			2.505			0.517			1.080			0.799		

*Significant at p≤ 0.05

Here, GM is Grand Mean, CD is Critical difference, (*viz*., MUNG-1, MUNG-2, MUNG-3 and MUNG-4 respectively) represents four mungbean genotypes bi represents linear component of G×E interaction and S di represents non- linear component of G×E interaction.

Table: 6 Estimates of stability parameters for number of seeds per pod, test weight (g) and seed yield per plant (g)

Genotypes	**Pod weight (g)**			**Pod length (cm)**			**Number of seeds per pod**			**Test weight (g)**			**Seed yield per plant (g)**		
	Mean	**b_i**	**S di**	**Mean**	**b_i**	**S di**	**Mean**	**b_i**	**S^2 di**	**Mean**	**b_i**	**S^2 di**	**Mean**	**b_i**	**S^2di**
MUNG-1	4.90	1.252	0.090	7.71	1.229*	0.069	10.51	1.105	0.018	42.04	**2.5155***	0.0870	6.91	0.884	0.039
MUNG-2	3.42	0.191	0.083	6.71	0.466*	0.019	9.20	0.760	0.014	39.28	**0.3973***	0.0047	6.11	0.863	0.104
MUNG-3	4.03	1.068	0.062	7.30	1.135*	0.044	9.76	0.974	0.000	40.11	**0.6284***	0.2238	5.89	1.246	0.034
MUNG-4	3.14	0.770	0.067	6.38	1.171*	0.051	8.68	1.210	0.0166	38.83	**0.4562***	0.2628	4.74	1.047	0.009
Range	3.145- 4.903			6.38-7.71			8.68-10.51			38.83- 42.04			4.74-6.91		
GM	3.87			7.02			9.54			40.06			5.92		
CD	1.955			0.32			0.61			1.20			0.51		

*Significant at p≤ 0.05

Here, GM is Grand Mean, CD is Critical Difference, (*viz*., MUNG-1, MUNG-2, MUNG-3 and MUNG-4 respectively) represents four mungbean genotypes bi represents linear component of G×E interaction and S di represents non- linear component of G×E interaction.

In case of pod weight, the genotypes MUNG-1 (b_i=1.252 and S^2di=0.090) and MUNG-3 (b_i=1.068 and S^2di=0.062) were found to be possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. Some other workers was also found that genotypes having the average stability to the environments (Sarkar and Sabyachi, 2017). However, the genotype MUNG-2 (b_i=0.191 and S^2di=0.083) and MUNG-4 (b_i=0.770 and S^2di=0.067) were found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$ were considered as better adaptable to poor or unfavorable environment (above average stability). Similar findings were also observed by earlier workers (Nath *et al*., 2013). In case of pod length, the genotypes MUNG-1 (b_i=1.229 and S^2di=0.096), MUNG-3 (b_i=1.135 and S^2di=0.044) and MUNG-4 (b_i=1.135 and S^2di=1.171) were found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. However, the genotype MUNG-2 (b_i=0.466 and S^2di=0.019) was found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$. Earlier researcher also found that genotypes were considered as better adaptable to poor or unfavorable environment for pod length (Dobhal and Gautam, 1994). Some other researchers evaluated sixteen genotypes of mungbean over four environments observed the stability of genotypes for pod length (Patil and Narkhede, 1989). In case of number of seeds per pod, the genotypes MUNG-1 (b_i=1.105 and S^2di=0.018) and MUNG-4 (b_i=1.210 and S^2di=0.016) were found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having general adaptability or average stability. The present study results are in a close proximity to the findings of earlier worker observed the average adaptability or stability in mungbean (Gomashe *et al*., 2008). However, the genotype MUNG-2 (b_i=0.760 and S^2di=0.014) and MUNG-3 (b_i=0.974 and S^2di=0.000) were found to possessed the linear component less than unity b_i<1 and non-linear component $S^2di \cong 0$ were considered as better adaptable to poor or unfavorable environment. Similar findings were observed by several other workers that linear component of G × E interaction was significant for seeds per pod in mungbean (Nath *et al*., 2013; Patil and Narkhede, 1989; Singh *et al*., 2009**)**. In case of test weight, the genotypes MUNG-2 (b_i=0.397 and S^2di=0.047), MUNG-3 (b_i=0.628 and S^2di=0.223) and MUNG-4 (bi=0.456 and S^2di=0.262) were found to possessed the linear component less than unity (b_i<1) and non-linear component $S^2di \cong 0$ were considered as better adaptable unfavorable environments (Gomashe *et al*., 2008). While, MUNG-1 (b_i=2.5155) was found to possessed the linear component greater than unity b_i>1is considered as better adaptable to rich or favorable environment. In case of seed yield per plant, the genotypes MUNG-3 (b_i=1.246 and S^2di= 0.034) and MUNG-4 (b_i=1.047 and S^2di=0.009) were found to possessed the linear component b_i approaching to unity ($b_i \cong 1$) and non-linear component ($S^2di \cong 0$) regarded as having adaptability or average stability. However, the genotype MUNG-1 (b_i=0.884 and S^2di=0.039) and MUNG-2 (b_i=0.863 and S^2di=0.104) was found to possessed the linear component less than unity ($b_i<1$) and non-linear component $S^2di \cong 0$ was considered as better adaptable to poor or unfavorable environment. On the basis of earlier finding, also observed that the genotypes found high yielder, stable performer in response to different environments (Kamannaver *et al*., 2011; Mahalingam *et al*., 2018; Patel *et al*., 2009). The present study results are in a close proximity to the findings of earlier researchers observed the stability of mungbean genotypes under different environments (Patel *et al*., 2009; Singh *et al*., 2013).

CONCLUSION AND FUTURE SCOPE

Genotypes were pooled over the environments (E_1, E_2 and E_3) for ten characters indicated that sowing of summer mungbean under Environment-E_2 (sown on 15th March) was found better followed by Environment-E_1 (sown on 5th March) and Environment-E_3 (sown on 25th March) for plant height (cm), number of branches per plant, pods per plant, nodules per plant, pod weight (g), pod length (cm), number of seeds per pod, thousand seed weight except seed yield per plant. Mean performance of genotypes under different environment condition (E_1, E_2 and E_3) indicated that the genotype MUNG-1 is better for days to 50% flowering, plant height (cm), number of braches per plant, number of pods per plant, number of nodules per plant, pod length (cm), pod weight (g), number of seeds per pod, test weight (g), seed yield per plant (g) except number of branches per plant under environment-E_3 and for number of nodules per plant under Environment-E_1. The linear ($b_i \cong 1$) and non-linear ($S^2di \cong 0$) component of stability suggested that the genotype MUNG-1 stable for number of nodules per plant, pod weight (g), pod length, seeds per pod. MUNG-2 is stable for days to 50% flowering, number of branches per plant, pods per plant, pod length (cm), pod weight (g), plant height (cm) pod per plant and test weight (g). MUNG-3 is stable for day to 50% flowering, number of branches per plant, pod per plant, pod weight (g), pod length (cm), test weight (g) and seed yield per plant (g). MUNG-4 is stable for branches per plant, pod per plant, number of nodules per plant, pod length (cm), seeds per pod, test weight, seed yield per plant. The results of present study may be useful for breeders as well as farmers to select suitable genotypes under optimum environment for sustainable mungbean production.

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