Australian Journal of Crop Science
AJCS
AJCS 18(04):226-231 (2024) ISSN:1835-2707
https://doi.org/10.21475/ajcs.24.18.04.PNE-40

Received: 04/11/2023 | Revised: 25/12/2023 | Accepted: 02/02/2024

Genotype by environment (GxE) interaction and stability for seed yield of newly developed mung bean genotypes

Tong Van Giang[1], Chu Duc Ha[2], Doan Thi Huong Giang[3], Tran Dang Khanh[3], Nguyen Van Loc[4], Nguyen Thanh Tuan[4*]

[1]Department of Crop Science, Faculty of Agriculture, Forestry and Fishery, Hong Duc University, Thanh Hoa City, 40000, Vietnam
[2]Faculty of Agricultural Technology, University of Engineering and Technology, Vietnam National University Hanoi, Xuan Thuy, Cau Giay, Hanoi, 122300, Vietnam
[3]Department Genetic Engineering, Agricultural Genetics Institute, Pham Van Dong Street, Hanoi City 122000, Vietnam
[4]Faculty of Agronomy, Vietnam National University of Agriculture, Trau Quy, Gia Lam, Hanoi, 131000, Vietnam

***Corresponding author: thanglongmos@yahoo.com**

Abstract

Genotype by environment interaction (GEI) is crucial for selecting high performing and adapted genotypes for targeted breeding. The main goal of this study was to study genotype-by-environment interaction and stability of eight elite mung bean (*Vigna radiate* L.) genotypes (DTG01-DTG08) with a national check DX208 which laid out in RCBD with 3 replications across three locations (Ha Noi, Phu Tho, Thanh Hoa) in three crop seasons (summer 2018, summer 2019, spring 2019) at Vietnam. The analysis of variance showed that genotype, location, environment, and interaction between GxL were significant for grain yield. The seed yields of all varieties were significantly higher than those of the control variety (please check). Among these, DTG05 and DTG06 exhibited the highest yields, approximately 1.77 tons/ha and 1.89 tons/ha, respectively. AMMI model showed that DTG05 exhibited the best performance in the summer season, especially at Thanh Hoa, and Ha Noi. Thus, DT05 could have commercial potential for mung bean production in Northern and North Central Vietnam

Keywords: G×E interaction, GGE, AMMI, BLUP, mung bean.

Introduction

Mung bean (*Vigna radiate* L.) is one of the widely adapted, stress-tolerant, and nutritious grain legumes. It is an economical source of protein (24 - 26%), carbohydrate (51%), minerals (4%), and vitamins (3%) especially in Vietnam, other Asian countries and Africa (Karthikeyan et al., 2014; Hou et al., 2019). In combination with cereals and other grain legumes, it is a valuable component of cropping systems in many areas, with its ability to fix nitrogen and reduce soil erosion. The crop is grown on more than six million hectares in tropics and subtropics of Africa, Asia, Australia, and America (Nair et al., 2013). Grain yield is one of the complex quantitative traits, which has high environmental interaction. Hence, it is essential to carry out selection based on yield stability evaluation than average performance in multiple environmental conditions(Baraki et al., 2020; Samyuktha et al., 2020).
Mung beans are primarily cultivated in semiarid to sub-humid lowland tropics and subtropics with an annual rainfall ranging from 600 to 900 mm, and at elevations not exceeding 2,000 meters. This warm-season crop thrives within a mean temperature range of approximately 20°C to 40°C, but is susceptible to low temperatures and can be killed by frost (Baraki et al., 2020). The goal of most plant breeders is to enhance the quality and/or quantity of the crops, ensuring better adaptability and stability across diverse growing environments.
Grain yield is a complex trait and is genetically governed by many quantitative genes with small additive effects. Hence, the expression of this is generally affected by genotype, environment, and genotype×environment interaction (GEI). Understanding the GEI pattern among test entries in multi-environment trials (METs) is very crucial for plant breeders, as it complicates the selection of promising genotypes by declining the association between genotypic and phenotypic values (Pour-Aboughadareh et al., 2022). GEI is a major obstacle for the crop to attain full genetic gain (Nehe et al., 2019). Thus, plant breeding programs focus on increasing crop yield in a particular targeted macro environment or a wide range of growing conditions. GEI information in mung bean is critical required for identify the best cultivation methods, and select suitable variety for commercialization (Xavier et al., 2018)
The objectives of this research were to study the effect of G × E interaction toward the variation in grain yield across the Northern and North Central Vietnam amongst eight mung bean genotypes and to identify the best mung bean genotypes suitable for across environments and for a particular environment, based on grain yield.

Table 1. Mungbean genotypes used in this study.

Variety	Predigree
DTG01	D15-1-4 (ĐX044 x CB2)
DTG02	D15-1-6 (ĐX044 x CB2)
DTG03	MY3-2-3 (V123 x CB6)
DTG04	MY1-5-5-7 (V123 x CB6)
DTG05	D15-9-0-2 (ĐX044 x CB6)
DTG06	MY2-5-8 (ĐX044 x AM8)
DTG07	MY2-6-8-9 (V99-3 x AM4)
DTG08	D15-4-6-5 (ĐX044 x AM8)
DX208	Check (popular mung bean cultivar in Vietnam)

Table 2. Mean and ANOVA analysis for measured traits.

	Plant height (cm)		Primary branches		Pods per plant		Seeds per pod		1000 seed weight (g)		Seed yield (tons/ha)	
Genotype (G)												
DTG01	75.49	b	1.37	c	17.48	b	11.27	bcd	60.06	e	1.76	b
DTG02	73.83	cd	1.17	e	17.09	bc	11.14	cde	60.71	de	1.77	b
DTG03	74.18	bcd	1.13	e	14.99	d	11.63	a	61.64	b	1.71	c
DTG04	77.14	a	1.29	d	15.31	d	11.05	de	60.80	cde	1.72	c
DTG05	72.74	de	1.49	b	18.27	a	11.52	ab	64.19	a	1.89	a
DTG06	71.92	e	1.89	a	16.52	c	11.37	abcd	61.60	bc	1.77	b
DTG07	74.41	bc	1.11	e	15.46	d	11.61	ab	61.29	bcd	1.71	c
DTG08	74.76	bc	1.28	d	15.23	d	11.49	abc	59.19	f	1.64	d
DX208	70.26	f	1.36	c	15.46	d	10.83	e	54.27	g	1.51	e
Season (S)												
Spring 19	64.69	C	1.27	B	13.68	C	10.70	C	58.85	C	1.62	A
Summer 18	74.54	B	1.30	B	15.73	B	11.34	B	60.72	B	1.70	B
Summer 19	82.35	A	1.46	A	19.19	A	11.93	A	61.69	A	1.85	C
Location (L)												
Ha Noi	71.10	α	1.39	α	16.13	β	10.99	β	60.01	β	1.73	α
Phu Tho	73.88	β	1.25	β	15.59	γ	11.41	α	60.70	α	1.70	γ
Thanh Hoa	76.60	γ	1.39	α	16.88	α	11.57	α	60.55	α	1.74	α
G	**		**		**		**		**		**	
S	**		**		**		**		**		**	
L	**		**		**		**		*		**	
G×S	**		**		**		**		**		**	
G×L	**		**		*		**		**		**	
S×L	**		**		**		**		**		**	
G×S×L	ns		**		**		ns		**		**	

*Note: Values followed by the same letter in each treatment column are not significantly different at the 5% level by Fisher's LSD test. * and ** are significantly different at 0.05, 0.01 and 0.001 probabality, respectively. and "ns" is not significant.*

Results

Yield components and mung bean grain yield by environments and genotypes

The combined analysis of variance for mungbean genotypes (G) evaluated in three locations (L) across three seasons (S) is presented in Table 2. There was highly significant variation ($p < 0.01$) in plant height, primary branches, pods per plant, seeds per pod, 1000-seed weight, and seed yield among the genotypes (G), environments (S, L, S x L), and genotype-by-environment interactions (G x S, G x L, and G x S x L), except for SLG in 1000-grain weight (Table 2). These significant variations in the main effects and their interactions indicate that the ranking of genotypes changes from one environment to another, confirming the absence of a stable genotype across all environments and the presence of a significant genotype-by-environment interaction in this experiment.

Mung bean yield is a complex traits and highy responsed to enviroment condition. In this study, significant interaction of G×S×L in grain yield and yield related traits of mung bean genotypes were reported. Overall, mean yield performance of newly developed mung bean varieties showed significant higher than check DX208 (Figure 2). Thus, it confirmed the novelty of breeding methodology and breeding potential of Vietnam mungbean breeders. Among them, DTG05 had highest seed yield and significantly higher than check variety DX208. Seed yield peformance of all varieties in summer season significantly higher than spring season.

Analysis of GEI using various models for mung bean grain yield

Analyzing multi-environment trials using AMMI model

In this study, AMMI showed great visualization of seed yield performance of mungbean varities under diference season and location (Figure 3). DTG05 had highest yield in Summer season in both three locations.

Analyzing multi-environment trials using GGE biplot Model

In this biplot, the visualization of the mean and stability of genotypes is achieved by drawing an average environment coordinate (AEC) on the genotype-focused biplot. First, an

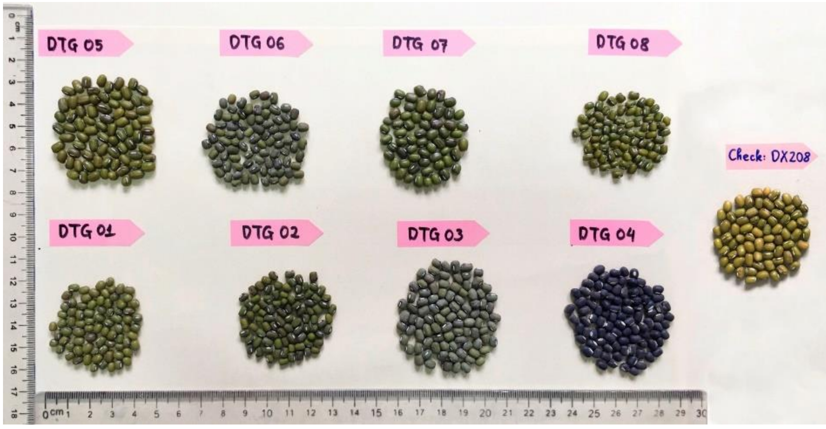

Fig 1. Seeds of 8 mung bean genotypes with a check DX208.

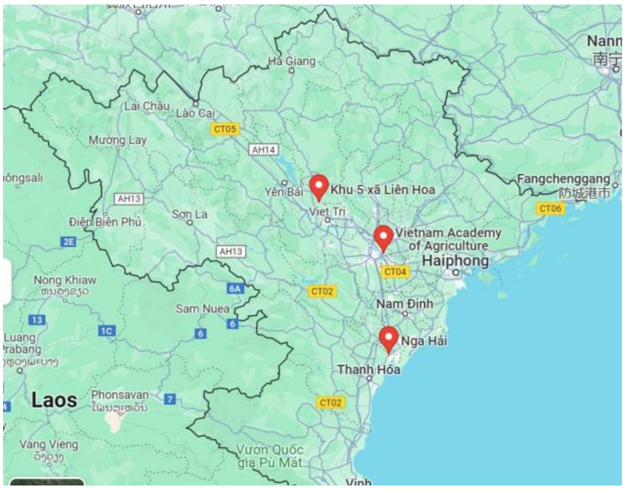

Fig 2. The locations for the experiments are Phu Tho (Northern Midlands and Mountains), Hanoi (Red River Delta), and Thanh Hoa (Northern Central).

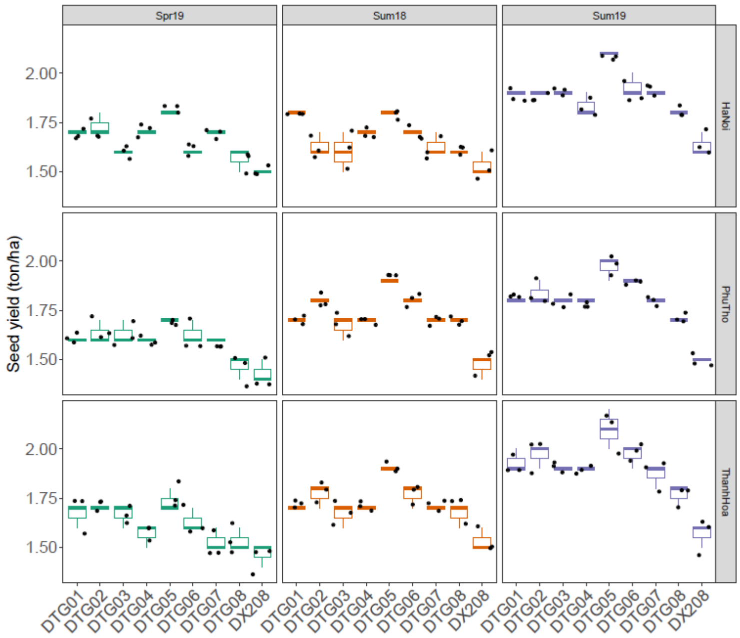

Fig 3. The mean value of seed yield of mung bean genotypes at three locations across three crop seasons

average environment, represented by the small circle, is defined by the mean PC1 and PC2 scores of the environments. The line that passes through the biplot origin and the AEC may be called the average. Ranking genotypes view of GGE biplots for grain yield of mungbean showed that DTG5 was found to be the most stable and productive variety (Figure 4).

Analyzing multi-environment trials using BLUP

The BLUP analysis predicted means for munbean genotypes on seed yield across season and envirionment. The result showed that DTG05, DTG02, DTG06, DTG01 achieved higher than DTG03, DRG07, DTG08 and check variety DX208 (Figure 5).

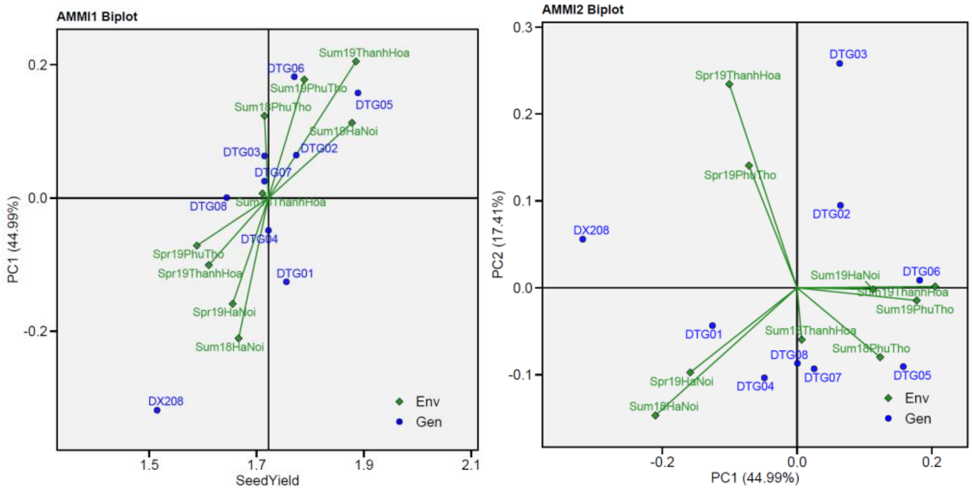

Fig 4. AMMI biplot of mung bean genotypes across three locations.

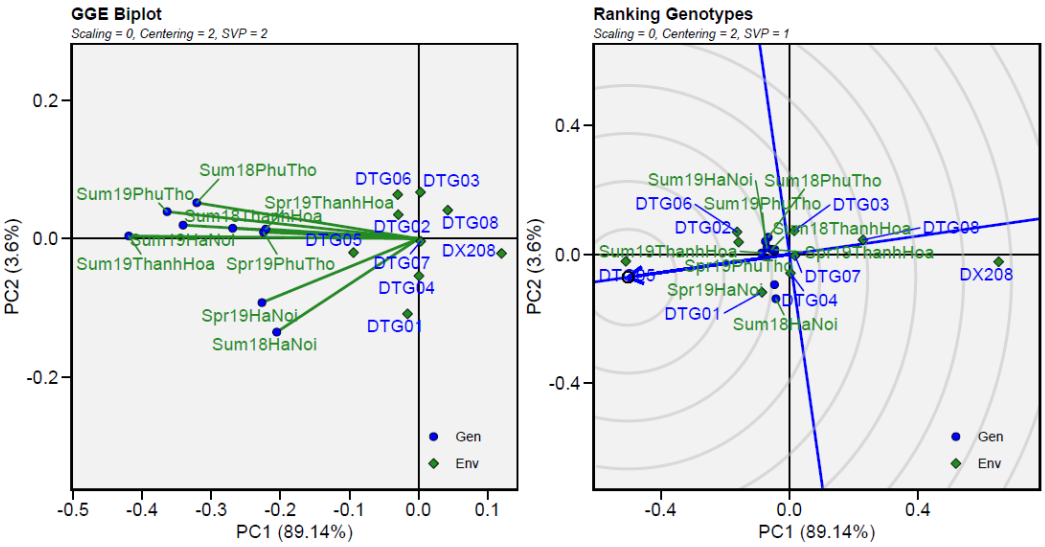

Fig 5. GGE biplot for Mean performance vs. stability on a genotype x environment yield data in three location.

Multi-trait stability index (MTSI)

In this study, multi-trait stability index was used to select the best performance genotype across the multi environment. The result showed that DTG05 have lowest MSTI value, thus considered as the elite vareity for promote the mungbean production in the North of Vietnam (Figure 6).

Discussion

Yield is a complex quantitative characteristic controlled by multiple genes, environment, and genotype×environment (GE) interactions (Islam et al., 2021). A genotype/variety is considered more adaptive and stable if it consistently yields high means with low fluctuations when grown in diverse environments (Kulsum et al. 2012). Thus, GEI is a challenging aspect for plant breeders and plays a crucial role in developing new varieties (Akhtar et al., 2010). Evaluating crop performance across different environments is the important work for selecting high-yielding and stable genotypes (Yang et al., 2001). In this study, our data indicated that differences in grain yield and components between mungbean cultivars in each region are caused by both the aforementioned climate variables and the edaphic factors. The findings of stable genotypes might be helpful for both breeders and farmers to choose appropriate genotypes for sustainable mung bean production.

More specifically, the genotype ranking changed from environment to environment, confirming the lack of a stable genotype across all environments and the presence of a substantial genotype by environment interaction (Baye et al. 2010). This phenomenon was confirmed as reported in the previous studies in mung bean plant (Pathak et al., 1990; Asfaw et al., 2012; Akhtar et al. 2010; Baraki et al., 2020). For example, a highly significant variation ($p < 0.01$) of mung bean grain yield among the G, E and G × E interaction has been recorded (Baraki et al., 2020). The considerable GEI in grain yield of six mung bean genotypes, including SML-668, Black bean, Bored, Local Gofa, SML-32 and Local 2-Sheraro tested in diverse locations (Asfaw et al., 2012). Taken together, our comparison indicated that cross over GEI is particularly common when genotypes are investigated in multi-location yield experiments.

Next, the expressed traits of a plant's genotype may manifest differently dependent on the environment in which it is situated. This GEI has significant implications in the realm of plant breeding, as it determines the potential adaptability and stability of plant varieties across disparate environments (Asfaw et al., 2012; Baraki et al., 2020). In this study, DTG05 has been regarded as the ideal genotype with significantly higher grain yield and relatively good stability. Evaluation of the characteristics of each cultivars by environments and genotypes could be an useful approach to assess their stability.

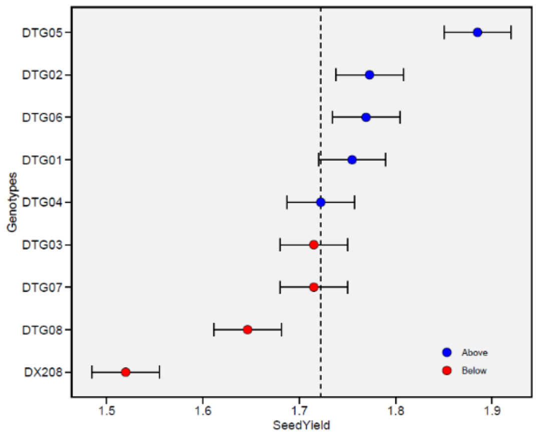

Fig 6. Ranking of mung bean genotypes based on the analysis of multi-environment for seed yield trials using BLUP.

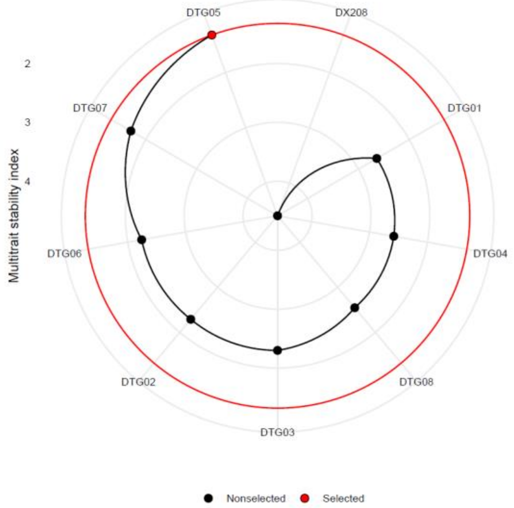

Fig 7. Ranking of mung bean genotypes in ascending order based on Multi-trait stability index (MTSI). The selected genotypes based on this index are shown in red. The central red circle represents the cutpoint according to the selection pressure.

Materials and methods

Plant material

The plant materials consist of eight recently developed mung bean genotypes designated as DTG01, DTG02, DTG03, DTG04, DTG05, DTG06, DTG07, and DTG08, alongside a national check variety, DX208 (Table 1 and Figure 1). These genotypes inherited and selected from the research results of the project "Selection of high-yield and uniform-maturity mung bean varieties for the provinces in Northern Vietnam".

Experiment design

The field experiments were carried out in the summer season 2018, 2019, and spring season 2019 in Hanoi city, Thanh Hoa and Phu Tho provinces (Figure 2). The experiment was arranged in a randomized complete block design with 3 replications. The experimental plot area is 10 m^2 (4m x 2.5m) with planting density 25 plants/m^2, and planting spacing 40 x 10 cm. Fertilizer application per hectare included 1 ton of organic fertilizer + 400 kg of lime powder + 40 kg of N + 60 kg of P_2O_5 + 60 kg of K_2O kg according to Vietnam National technical regulations on Testing the Value of Cultivation and Used of mung bean varieties (QCVN 01-62:2011/BNNPTNT).

Data collection

Phenotypic traits collection according to Vietnam National technical regulations on Testing the Value of Cultivation and Used of mung bean varieties (QCVN 01-62:2011/BNNPTNT).

Statistical analysis

Data collection from this study was handle by Microsoft Excel and analyzed by ANOVA in Statistix ver. 10. Multi-trait stability index (MTSI) proposed by Olivoto et al. (2019) to select the best performance genotype across the multi environment. AMMI, GGE, and BLUP models were computed by "*metan*" package in R 4.1.1 (R Development Core Team, 2022).

Conclusion

This study found that significant interaction of G×S×L in grain yield and yield related traits of mung bean genotypes were reported and were consistented with previous mung bean study. Overall, mean yield performance of newly developed mung bean varieties showed significant higher than check DX208 might due to the breeding menthodology improvement of Vietnamese breeders. AMMI, GGE biplot and MSTI indicated DTG05 variety showed seed yield best performance in all three location across three seasons, thus have comercial potential.

References

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

Asfaw A, Gurum F, Alemayehu F, Rezene Y (2012) Analysis of multi-environment grain yield trials in Mung bean *Vigna radiate* (L.) Wilczek based on GGE bipot in Southern Ethiopia. J Agricul Sci Technol. 14: 389-398.

Baraki F, Gebregergis Z, Belay Y, Berhe M, Zibelo H (2020) Genotype x environment interaction and yield stability analysis of mung bean (*Vigna radiata* (L.) Wilczek) genotypes in Northern Ethiopia. Cogent Food Agricul. 6: 1729581.

Baye TM, Abebe T, Wilke RA (2010) Genotype–environment interactions and their translational implications. Personal Med. 8(1): 59.

Chapman SC, Crossa J, Edmeades GO (1997) Genotype by environment effects and selection fordrought tolerance in tropical maize: I. Two mode pattern analysis of yield. Euphytica. 95:1-9.doi:10.1023/A:1002918008679.

Hou D, Yousaf L, Xue Y, Hu J, Wu J, Hu X, Feng N, Shen Q (2019) Mung bean (*Vigna radiata* L.): Bioactive polyphenols, polysaccharides, peptides, and health benefits. Nutrients. 11: 1238.

Islam MR, Sarker BC, Alam MA, Javed T, Alam MJ, Zaman MS, Azam MG, Shabbir R, Raza A, Dessoky ES, Islam MS (2021) Yield stability and genotype environment interaction of water deficit stress tolerant mung bean (Vigna radiata L. Wilczak) genotypes of Bangladesh. Agronomy. 11(11): 2136.

Karthikeyan A, Shobhana VG, Sudha M, Raveendran M, Senthil N, Pandiyan M, Nagarajan P, (2014) Mungbean yellow mosaic virus (MYMV): a threat to green gram (*Vigna radiata*) production in Asia. Intern J Pest Manag. 60: 314-324.

Kulsum U, Sarker U, Karim A, Mian K (2012) Additive main effects and multiplicative interaction (AMMI) analysis for yield of hybrid rice in Bangladesh. Trop Agr Develop. (56): 53-61.

Nair RM, Yang RY, Easdown WJ, Thavarajah D, Thavarajah P, Hughes, JdA, Keatinge J (2013) Biofortification of mungbean (*Vigna radiata*) as a whole food to enhance human health. J Sci Food Agricul. 93: 1805-1813.

Nehe A, Akin B, Sanal T, Evlice AK, Ünsal R, Dinçer N, Demir L, Geren H, Sevim I, Orhan Ş, Yaktubay S, Ezici A, Guzman C, Morgounov A (2019) Genotype x environment interaction and genetic gain for grain yield and grain quality traits in Turkish spring wheat released between 1964 and 2010. PLOS ONE. 14: e0219432.

Olivoto T, Lúcio ADC, da Silva JAG, Sari BG, Diel MI (2019) Mean Performance and Stability in Multi-Environment Trials II: Selection Based on Multiple Traits. Agron J. 111: 2961-2969.

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

Pour-Aboughadareh, A., Khalili, M., Poczai, P., Olivoto, T., 2022. Stability Indices to Deciphering the Genotype-by-Environment Interaction (GEI) Effect: An Applicable Review for Use in Plant Breeding Programs. Plants. 11:, 414.

R Development Core Team (2022) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from https://cran.r-project.org/bin/windows/base on March 10, 2022.

Samyuktha SM, Malarvizhi D, Karthikeyan A, Dhasarathan M, Hemavathy AT, Vanniarajan C, Sheela V, Hepziba SJ, Pandiyan M, Senthil N (2020) Delineation of Genotype × Environment Interaction for Identification of Stable Genotypes to Grain Yield in Mungbean. Front Agron. 2: 577911.

Thangavel P, Anandan A, Eswaran R (2011) AMMI analysis to comprehend genotype-by-environment (G× E) interactions in rainfed grown mungbean (Vigna radiata L.). Aust J Crop Sci. 5: 1767-1775.

Xavier A, Jarquin D, Howard R, Ramasubramanian V, Specht JE, Graef GL, Beavis WD, Diers BW, Song Q, Cregan PB, Nelson R, Mian R, Shannon JG, McHale L., Wang D, Schapaugh, W, Lorenz AJ, Xu S, Muir WM, Rainey KM (2018). Genome-Wide Analysis of Grain Yield Stability and Environmental Interactions in a Multiparental Soybean Population. G3. 8: 519-529.

Yan W, Cornelius PL, Crossa J, Hunt LA (2001) Two types of GGE biplots for analyzing multi-environment trial data. Crop Sci. 41: 656-663.