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Stability And G X E Interaction Studies In Mungbean (Vigna radiata (L.) Wilczek)

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Abstract

The present study was conducted to evaluate the stability of various mungbean (Vigna radiata L.) genotypes across multiple agronomic traits under varying environmental conditions. Stability analysis was performed for eleven key traits including days to 50% flowering, days to maturity, plant height, number of primary and secondary branches, number of clusters and pods per plant, number of pods per cluster, number of seeds per pod, 100-seed weight, and seed yield per plant. Genotypes such as TPM-260, AKM-4, BM 2002-1, BM 2003-2, BM 2021-1, and BM 2021-2 consistently showed average to above-average stability across several traits, indicating their adaptability to a wide range of environmental conditions. Conversely, genotypes like PKV Green Gold and BM 2002-1 exhibited below-average stability for key yield-contributing traits, suggesting their sensitivity to environmental variation. These findings are supported by previous studies including Naik (2008), Nath (2012), Singh and Sharma (2014), and Borude (2017), among others. The results provide valuable insights for selecting

stable genotypes for breeding programs aimed at enhancing mungbean productivity and stability across diverse agro-climatic zones.
Keywords: *stability, environment, genotypes, adaptability, Vigna radiata L*

INTRODUCTION

Pulses are the principal source of dietary protein among vegetarian. It is an integral part of human's daily diet because of its high protein content and good amino acid balance. Hence the pulses are often called lifeline of human being. *Vigna radiata* (L.) Wilczek commonly known as green gram or moong or golden gram is well known leguminous crop that belongs to the subgenus Ceratotropis (2n = 2x=22).

There are three subgroups of *Vigna radiata* one is cultivated (*Vigna radiata* genus Vigna sp. radiata) and two are wild (*Vigna radiata* subsp. *Sublobata* and *Vigna radiata* subsp. *glabara*) (Asari et al. 2019). Mungbean is believed to have originated in Indian subcontinent (De Candolle, 1886; Vavilov 1926). Since India has a wide range of genetic diversity of cultivated as well as weedy wild type of mungbean. It is considered as region of its first domestication. It is self-pollinated crop having papilionaceous flower, trifoliate leaves and pubescent plant surface and long cylindrical brown to black colour pod containing 5 to 15 green to dark green colour seeds.

According to Central Government third advance estimates green gram production in 2023-24 is at 29.16 lakh tones. In India major green gram producing states are Madhya Pradesh (13.23 lakh tones), Rajasthan (8.13 lakh tones), Bihar (1.11 lakh tones), Gujarat (1.05 lakh tones), Karnataka (0.92 lakh tones) and Orissa (0.88 lakh tones). First advance estimates of area production and productivity of mungbean in Maharashtra for the year 2024-25, 2.32 lakh ha, 1.42 lakh tones and 611.3kg/ha respectively. (Anonymous 2025).

It is a warm-season crop with short growing seasons that is mostly farmed in semi-arid to sub-humid tropical regions with 600–1000 mm of annual rainfall means temperatures between 22 and 35°C during crop production and elevations between 1800 and 2000 m above mean sea level. Warm weather and well-drained loam or sandy loam soil is ideal for a large yield. Mungbean contributes around 15% of the nation's total pulse production and is primarily grown in dry and semi-arid conditions during the summer or kharif season. Mungbean is regarded as a high-protein food (Engel et al., 1978). In terms of nutrition, mungbean is a staple grain high in protein, with 20–25% protein and amino acids. especially vitamins, minerals and lysine. So, aids in meeting the nutritional requirements of the nation's vegetarian population. It has 22–28 per cent protein, 1.0–1.5 per cent fat, 3.5–4.5 per cent fibre, 4.5–5.5 per cent ash and 60–65 per cent carbs on a dry weight basis. Due to its short duration of crop nitrogen fixing capability prevention of soil erosion and grown as part of intercropping or mixing cropping system. It content 24 per cent protein with all essential amino acids. It is particularly rich in leucine, phenylalanine, lysine, valine and isoleucine (Marawar et al., 2020).

The environment, encompassing physical, chemical, and biological components, plays a pivotal role in shaping phenotypic expression. The interaction between genotype and environment (G × E) is of considerable importance in plant breeding, as it influences the development and performance of improved cultivars. While minimal G × E interaction is advantageous for certain traits to ensure stable performance across diverse environments, in specific instances, high interaction levels may be beneficial and can be strategically exploited. Although genetic variability cannot be directly quantified, it is often inferred through phenotypic expression, which is a composite outcome of genotypic, environmental, and interactive effects. Variation in phenotypic traits across environments for a given genotype highlights the widespread nature of G × E interactions, which, as reported by Comstock and Moll (1963), can constrain the anticipated genetic gains from selection.

A genotype that can modulate its genetic or phenotypic response to environmental fluctuations, thereby maintaining consistently high economic returns, is considered "well-buffered" (Singh and Singh, 1980). This characteristic is particularly relevant in regions such as India, where agricultural production is frequently subject to environmental instability and risk.

G × E interaction significantly contributes to the expression of quantitative traits, which are typically governed by polygenic systems and are highly susceptible to environmental variation. Despite the recognition of genotypic differences in adaptability, plant breeders have encountered challenges in fully utilizing these variations, primarily due to the complexity associated with defining and quantifying phenotypic stability. Several statistical methodologies have been proposed to address this issue. The model introduced by Finlay and Wilkinson (1963) employs the linear regression coefficient (bi) as an indicator of phenotypic stability across environments. This approach was later refined by Eberhart and Russell (1966), who incorporated an additional parameter deviation from regression (S^2di) to capture the unpredictable component of genotype performance in variable conditions.

A stable genotype is thus defined by its ability to adjust both phenotypic and genotypic traits in response to environmental changes, while maintaining consistent yield levels. Assessing such stability is integral to crop improvement programs, as G × E interactions play a critical role in determining genotype performance across heterogeneous agro-climatic conditions.

MATERIAL AND METHOD

The present investigation was conducted during four environments during Kharif, Late Kharif, Summer, Late Summer 2024-25. Experiment farm at Department at Genetics and Plant Breeding VNMKV, Parbhani situated at 19.500 N and 76.750 E at a height of 357m above the sea level and the soils are loamy type with clay. The material was evaluated in Randomized Block Design (Ronald Fisher, 1925). The experiment comprised of 3 replications, each containing 16 genotypes and 2 check entries. The data were subjected to statistical analysis for estimation of stability according to model proposed by Eberhart and Russell (1966). The experiment material is given in (Table 1).

Table 1. list of genotypes

Sr. No.	Name of genotype	Sr. No.	Name of genotype
1	TPM-145	10	PKV Green Gold
2	TPM-233	11	BPMR-145
3	TPM-235	12	AKM-4
4	TPM-245	13	BM-4
5	TPM-246	14	BM 2002-1
6	TPM-251	15	BM 2021-1
7	TPM-260	16	BM 2021-2
8	Phule Suvarna	17	BM 2003-2(C)
9	Kopargaon	18	Phule Chetak (C)

RESULT AND DISCUSSION

(A) Stability

1. Days to 50% flowering: The genotypes TPM-145, TPM-235, TPM-260, AKM-4 and BM 2021-2 recorded average stability for days to 50% flowering. The above average stability was observed for the genotypes PKV Green Gold, BM 2003-2 for the character days to 50% flowering. The below average stability was recorded for the genotype TPM-246 and BM 2002-1 for the character days to 50% flowering. The similar results are accordance with Naik (2008), Patel et al. (2009), Nath (2012) and Singh and Sharma (2014).

2. Days to maturity: The genotype TPM-233, TPM-245, TPM-260, Kopargaon, BPMR-145, BM 2002-1 and BM 2021-1 exhibited average stability for days to maturity. The similar results are accordance with Patil and Narkhede (1992), Naik (2008), Nath (2012) and Borude (2017) for days to maturity.

3. Plant height: The genotype BPMR-145, BM-4, BM 2021-1, BM 2021-2 and Phule Chetak exhibited average stability for plant height. The below average stability was recorded for the genotype PKV Green Gold, AKM-4, BM 2002-1. The similar results are accordance with Patel et al. (2009), Naik (2008), Nath (2012), Singh and Sharma (2014) and Borude (2017) in mungbean.

4. Number of primary branches: The genotypes BM-4 and BM 2021-1 were recorded average stability for number of primary branches per plant. The above average stability was observed for the genotypes TPM-251, Phule suvarna, BPMR-145, BM 2002-1, BM 2003-2 for the character number of primary branches per plant. The below average stability was recorded for the genotype AKM-4, BM 2021-2 for character number of primary branches per plant. Similar findings were obtained by Naik (2008) and Nath (2012) for number of primary branches per plant in mungbean.

5. Number of secondary branches: The genotypes TPM-145, TPM-235 and BM 2002-1 were recorded average stability for number of secondary branches. The above average stability was observed for the genotypes BM 2021-1 and BM 2003-2 for the character secondary branches per plant. The below average stability was recorded for the genotype TPM-251, BM 2021-1 for number of secondary branches. The similar results are accordance with Naik (2008), Nath (2012) and for this trait in mungbean.

6. Number of clusters per plant: The genotypes BM 2003-2 were recorded average stability for number of clusters per plant. The above average stability was observed for the genotypes TPM-246, Phule suvarna, BM-4, BM 2021-2 and Phule Chetak for the character number of clusters per plant. The below average stability was recorded for the genotype PKV Green Gold, BPMR-145 For character number of clusters per plant. These findings are in conformity with the results obtained by Pathak and Lal (1987), Nath (2012) and Borude (2017) for number of clusters per plant in mungbean.

7. Number of pods per cluster: The genotypes Kopargaon, BM-4 and BM 2021-2 exhibited average stability for number of Pods per cluster. The above average stability was observed for the genotype TPM-245 for the character number of pods per cluster. The findings align with Patil and Narkhede (1989), Singh and Sharma (2014) for pods per cluster in mungbean.

8. Number of Pods per plant: The genotype Kopargaon, BPMR-145, AKM-4, BM-4, BM 2003-2 and Phule Chetak exhibited average stability for number of pods per plant. The below average stability was recorded for the genotype PKV Green Gold for the character number of pod per plant. The similar results are accordance with Naik (2008), Nath (2012) and Borude (2017) for this trait in mungbean.

9. Number of seeds per pod: The genotypes Phule suvarna, kopargaon, PKV Green Gold, BPMR-145, AKM-4, BM-4 and BM 2003-2 were recorded average stability for number of seeds per pod. The above average stability was observed for the genotypes BM 2021-1 and BM 2021-2 for the character number of seeds per pod. The below average stability was recorded for the genotype BM 2002-1 for the character number of seed per pod. The similar results are accordance with Patil and Narkhede (1989), Singh and Sharma (2014) for seeds per pod in mungbean.

10. 100 seed weight (g): The genotype TPM-251, BPMR-145 and BM 2003-2 were recorded average stability for 100 seed weight. TPM-246, Kopargaon and PKV Green Gold for the character 100 seed weight indicating their suitability for poor or unfavourable environment. The below average stability was recorded for the genotype TPM-260, BM 2002-1, BM 2021-1, BM 2021-2 for the character 100 seed weight. Similar findings were found by Patel et al. (2009), Nath (2012) and Singh and Sharma (2014) for 100-seed weight in mungbean.

11. Seed yield per plant (g): The genotypes Phule suvarna, kopargaon, BPMR-145, AKM-4, BM 2003-2 and Phule Chetak exhibited average stability for seed yield per plant. The below average stability was recorded for the genotype PKV Green Gold and BM-4 for the character seed yield per plant. The similar results are accordance with Krishnaswamy and Ratnaswamy (1982) Naik (2008), Nath (2012) Borude (2017) for seed yield per plant in mungbean.

(B) Estimation of Environmental Index

The evaluation of environmental effects on trait performance revealed that Environment E_1 (18th June) was the most conducive for the expression of all studied agronomic traits. These included days to 50% flowering, days to maturity, plant height, number of primary and secondary branches per plant, number of clusters per plant, pods per cluster, number of pods per plant, seeds per pod, 100-seed weight, and seed yield per plant, indicating that E_1 provided optimal climatic and edaphic conditions for both vegetative and reproductive development.

Environment E_2 (16th July) also supported the favorable expression of several key traits, namely days to 50% flowering, days to maturity, plant height, number of clusters per plant, pods per cluster, number of pods per plant, seeds per pod, 100-seed weight, and seed yield per plant. However, this environment exhibited a limiting effect on primary and secondary branching, suggesting that the environmental conditions prevailing during early vegetative growth were suboptimal for branch development.

In contrast, Environment E_3 (18th January) was found to be favorable exclusively for branching traits, specifically primary and secondary branches per plant, while the remaining traits were adversely affected, possibly due to cooler temperatures and shorter photoperiods during this period.

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Environment E_4 (20th February) exerted a negative influence across nearly all traits, indicating that late-season growing conditions were least favorable for mungbean growth and productivity.
Collectively, these results identify Environment E_1 (18th June) as the most suitable sowing window for maximizing performance and stability of agronomic traits in mungbean across genotypes.

Table 2: Estimates of environment index (Ij) under different environment

Sr. No.	Observation	Environmental Index (Ij)			
		E_1	E_2	E_3	E_4
1	Days to 50% flowering	0.95	2.67	-0.64	-2.98
2	Days to maturity	1.86	2.62	-0.51	-3.96
3	Plant height (cm)	18.98	14.87	-17.43	-16.41
4	Number of primary branches	0.03	-0.30	0.40	-0.13
5	Number of secondary branches	0.16	-0.10	0.01	-0.08
6	Number of Clusters per plant	0.43	0.14	-0.28	-0.29
7	Number of Pods per cluster	0.21	0.15	-0.21	-0.15
8	Number of pods per plant	2.84	0.27	-0.92	-2.20
9	Number of seeds per pod	2.07	1.08	-1.15	-2.01
10	100 seed weight (g)	0.15	0.18	-0.08	-0.26
11	Seed yield per plant (g)	1.17	0.11	-0.33	-0.94

Table 3 (a) Stability parameters in respect of seed yield and yield contributing traits across all environments

Sr. No	Genotypes	Days to 50% flowering			Days to maturity			Plant height (cm)			Number of primary branches per plant		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1.	TPM-145	38.92	0.88	-0.17	60.33	1.32	-0.57	44.72	0.82	-1.61	4.08	1.92	-0.03
2.	TPM-233	39.33	1.36	-0.18	60.42	0.98	1.08	46.28	1.01	-0.34	4.05	0.08	-0.01
3.	TPM-235	38.83	0.84	-0.30	62.00	0.91	2.17	51.80	0.91	4.02	3.92	1.94	-0.02
4.	TPM-245	39.58	1.16	1.08	60.25	0.94	-0.47	42.48	0.92	-0.81	3.50	1.18	0.13
5.	TPM-246	39.50	1.37	2.67	60.33	0.79	1.28	42.83	0.91	1.05	3.10	0.82	0.02
6.	TPM-251	38.92	1.15	2.42	62.83	0.96	2.07	45.92	0.96	0.41	4.23	0.41	0.05
7.	TPM-260	38.92	0.91	-0.42	59.00	0.81	-0.24	45.42	1.11	16.20	3.70	2.20	0.01
8.	Phule Suvarna	40.00	1.02	0.46	61.75	1.02	-0.44	45.85	0.92	6.84	4.12	0.06	0.01
9.	Kopargaon	40.42	1.06	-0.57	60.42	1.07	0.39	45.75	0.96	2.34	3.75	0.87	-0.02
10.	PKV Green Gold	40.33	0.60	0.68	62.42	0.98	1.08	47.57	1.31	-0.89	3.77	1.50	0.07
11.	BPMR-145	37.75	1.20	-0.34	60.92	1.06	2.27	51.92	1.11	3.09	4.42	0.12	0.08
12.	AKM-4	39.25	0.95	-0.07	62.08	0.90	3.88	49.07	1.23	2.95	4.13	1.82	0.02
13.	BM-4	41.00	1.22	-0.39	61.25	1.31	-0.08	49.50	0.80	1.16	4.22	1.19	-0.02
14.	BM 2002-1	40.25	1.26	2.60	60.67	1.19	1.21	49.63	1.23	0.73	4.28	0.53	-0.02
15.	BM 2021-1	38.67	0.77	-0.28	59.42	1.19	0.79	48.43	0.88	-1.43	4.83	0.88	-0.01
16.	BM 2021-2	38.42	1.06	-0.30	61.50	0.73	3.46	47.93	1.00	-0.82	4.15	1.53	-0.01
17.	BM 2003-2(C)	39.92	0.61	0.06	62.00	0.98	-0.73	50.13	1.07	11.07	4.40	0.29	-0.02
18.	Phule Chetak(C)	38.58	0.59	-0.10	61.33	0.89	0.92	47.58	0.85	4.00	5.02	0.69	0.03
Population mean		39.37	-	-	61.05	-	-	47.38	-	-	4.09	-	-

Table 3 (b) Stability parameters in respect of seed yield and yield contributing traits across all environments

Sr.	Genotypes	Number of secondary	Number of clusters per	Number of pods per cluster	Number of pods per plant

No		branches per plant			Plant								
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1.	TPM-145	4.00	0.85	0.01	3.10	1.47	0.02	2.37	1.32	-0.02	4.48	0.74	-0.08
2.	TPM-233	3.90	0.59	-0.01	2.98	1.45	0.00	2.62	1.50	-0.01	6.03	0.94	-0.06
3.	TPM-235	4.35	-0.86	0.33	3.48	0.81	0.02	2.73	-0.21	-0.02	6.30	0.88	-0.05
4.	TPM-245	3.70	-1.85	1.01	3.52	0.42	0.00	3.03	-0.08	0.01	5.32	0.64	0.28
5.	TPM-246	3.48	-1.95	0.76	3.77	0.15	-0.01	2.40	0.75	-0.01	5.58	0.64	-0.02
6.	TPM-251	4.00	1.95	0.01	3.20	0.59	0.05	2.55	0.34	0.04	5.22	0.55	0.03
7.	TPM-260	3.92	-0.38	0.38	3.10	0.34	-0.01	2.62	-0.38	0.05	5.40	0.60	0.28
8.	Phule Suvarna	3.77	1.72	0.26	3.68	-0.04	0.11	2.82	4.08	0.02	5.27	0.72	0.52
9.	Kopargaon	3.58	1.18	0.04	3.40	2.16	-0.01	2.77	1.14	-0.01	8.38	1.04	-0.05
10.	PKV Green Gold	3.27	2.68	0.22	4.62	3.74	0.01	3.90	5.89	0.02	11.87	2.03	0.26
11.	BPMR-145	3.93	3.80	0.30	3.92	3.17	0.05	2.63	0.53	0.02	9.32	1.28	0.23
12.	AKM-4	3.70	1.13	0.11	3.52	1.93	-0.02	2.60	0.54	0.00	8.37	1.34	0.00
13.	BM-4	3.77	1.81	0.35	3.72	0.27	0.03	2.88	0.98	0.05	8.05	1.16	0.59
14.	BM 2002-1	4.22	1.31	0.01	3.32	0.76	-0.01	2.70	0.63	0.00	6.53	1.02	-0.05
15.	BM 2021-1	4.58	2.20	-0.01	3.37	0.02	0.03	2.70	0.59	0.03	6.12	0.95	0.23
16.	BM 2021-2	4.37	0.38	0.21	3.57	-0.53	0.01	2.98	-1.00	0.00	6.63	1.09	0.56
17.	BM 2003-2(C)	4.07	0.53	0.67	3.55	1.54	-0.02	2.83	1.64	-0.01	8.65	1.22	0.42
18.	Phule Chetak(C)	4.68	2.92	0.10	3.97	-0.25	0.00	2.55	-0.26	0.05	8.02	1.17	0.04
Population mean		3.96	-	-	3.54	-	-	2.76	-	-	6.97	-	-

Table 3 (c) Stability parameters in respect of seed yield and yield contributing traits across all environments

Sr. No	Genotypes	Number of seeds per pod			100 seed weight (g)			Seed yield per plant (g)		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1.	TPM-145	4.15	0.75	0.04	3.55	-0.10	-0.01	2.13	0.79	-0.02
2.	TPM-233	5.15	1.39	0.11	3.59	0.81	0.04	2.13	0.76	-0.02
3.	TPM-235	4.97	1.34	0.52	3.45	0.72	-0.02	2.02	0.80	-0.02
4.	TPM-245	5.13	1.01	0.04	3.38	1.10	0.00	2.17	0.72	-0.01
5.	TPM-246	5.77	1.22	0.03	4.45	0.21	0.05	1.97	0.74	-0.01
6.	TPM-251	6.62	0.77	-0.04	4.52	0.84	-0.01	1.89	0.55	-0.01
7.	TPM-260	6.63	1.06	0.07	4.57	2.09	0.00	2.25	0.71	0.00
8.	Phule Suvarna	8.95	1.30	-0.05	4.26	0.95	0.02	3.08	0.86	0.01
9.	Kopargaon	9.83	1.33	0.04	4.58	0.42	-0.01	3.37	1.17	0.00
10.	PKV Green Gold	10.72	1.25	0.01	4.47	0.48	0.09	5.45	1.51	-0.01
11.	BPMR-145	8.37	1.04	-0.04	5.00	0.99	-0.01	3.95	1.23	0.12
12.	AKM-4	9.62	0.78	-0.06	4.33	1.13	0.05	3.66	1.29	-0.02
13.	BM-4	7.78	1.06	0.07	4.16	0.34	0.00	3.70	1.34	-0.01
14.	BM 2002-1	8.05	1.53	1.89	4.96	2.27	0.00	2.92	1.04	-0.01
15.	BM 2021-1	8.03	0.35	-0.06	5.35	1.58	0.04	2.95	0.96	0.00
16.	BM 2021-2	8.13	0.35	0.18	5.45	2.47	0.00	2.93	0.98	0.00
17.	BM 2003-2(C)	9.47	0.92	1.74	5.40	1.19	-0.01	3.61	1.30	-0.01

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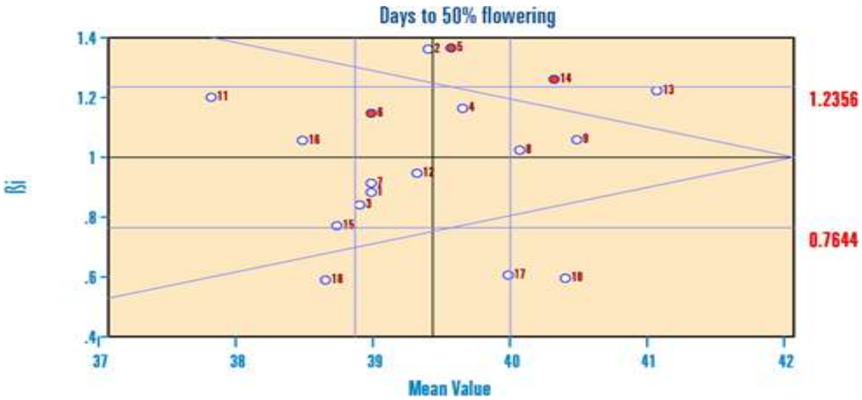
18.	Phule Chetak(C)	8.53	0.57	0.15	4.38	0.54	-0.01	3.35	1.27	0.01
Population mean		7.55	-	-	4.44	-	-	2.97	-	-

1.



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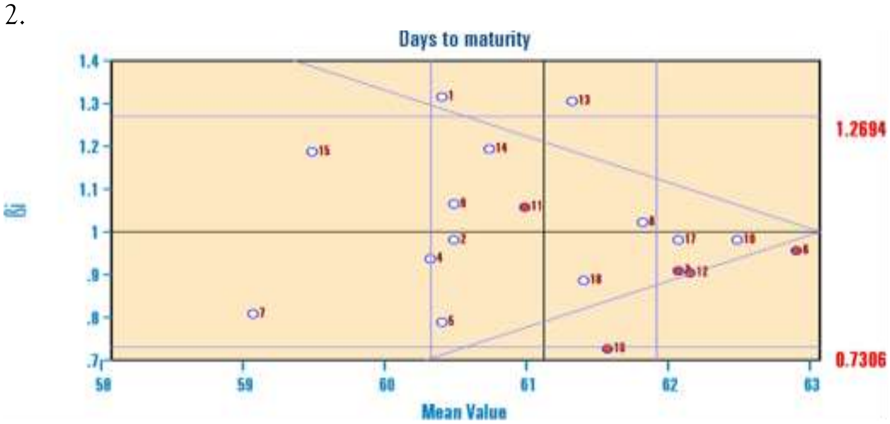

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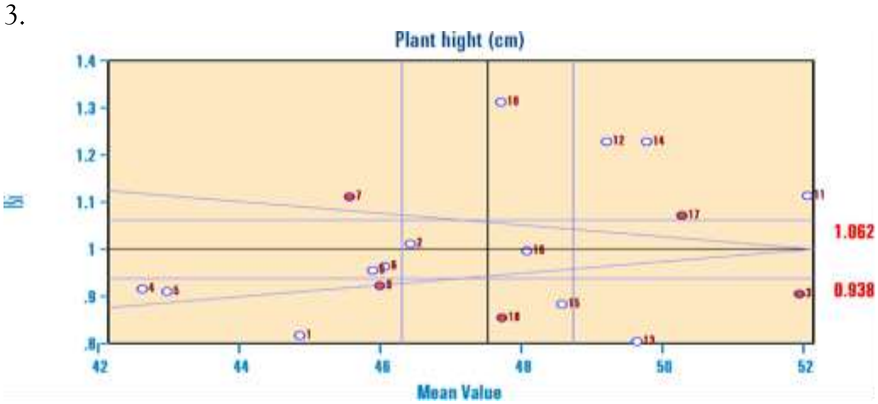

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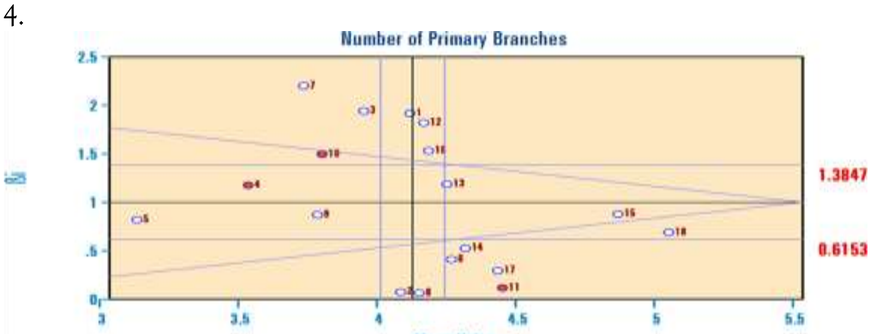

Fig 1 to 4: The Relation of characters with stability

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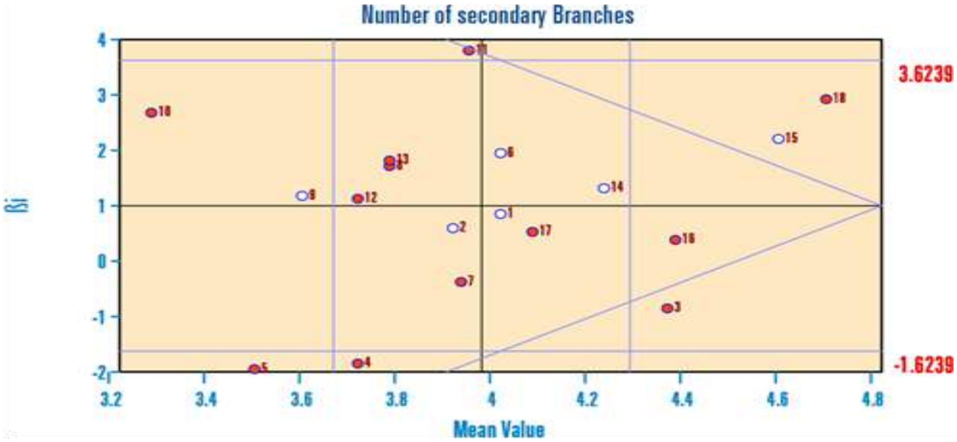
5.



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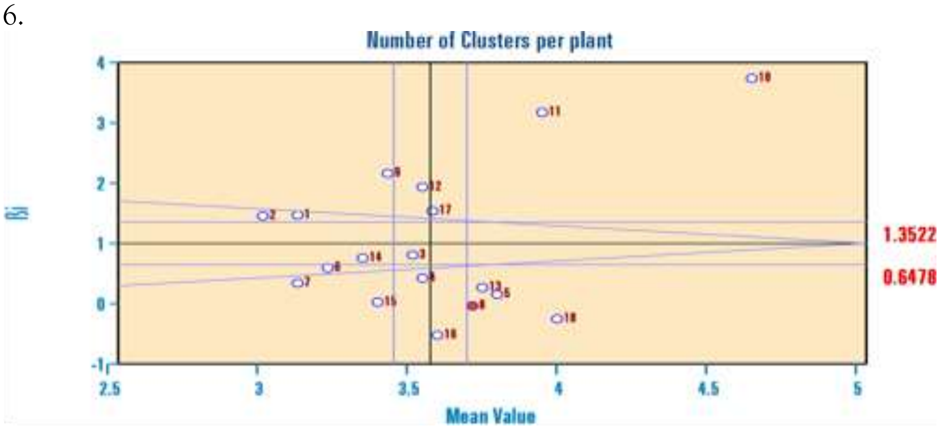

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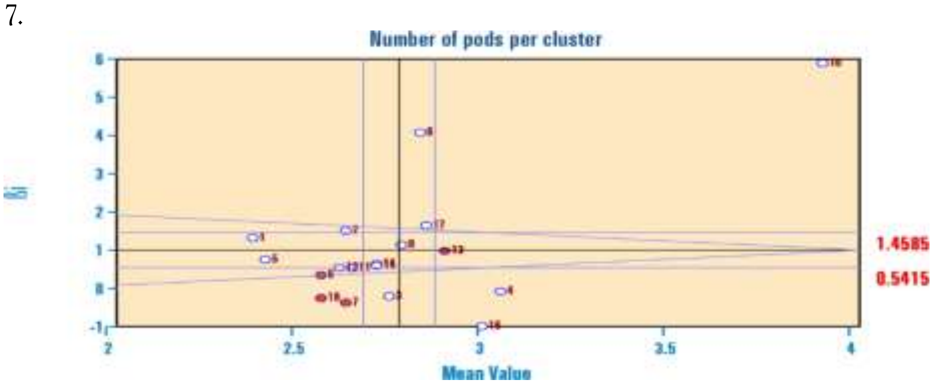

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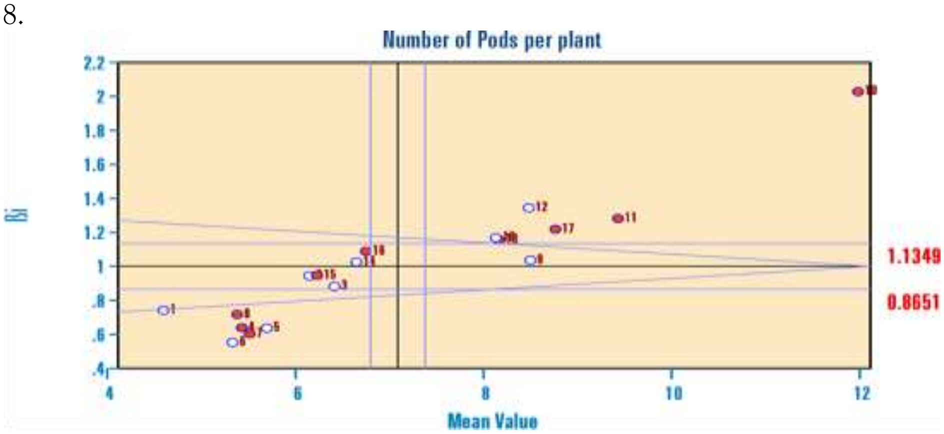
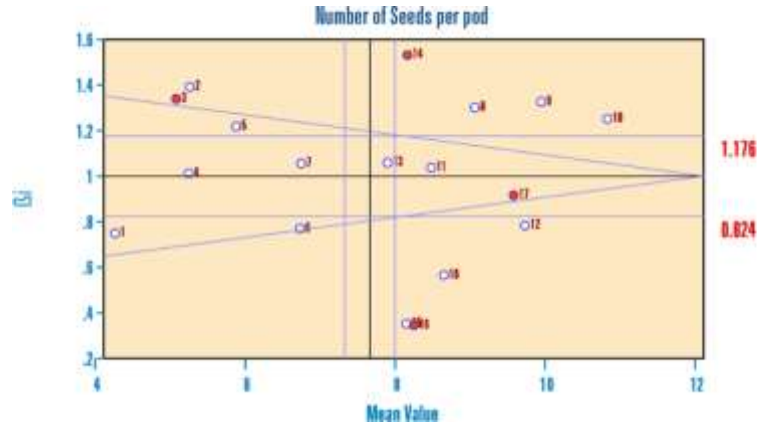


Fig 5 to 8: The Relation of characters with stability

9.



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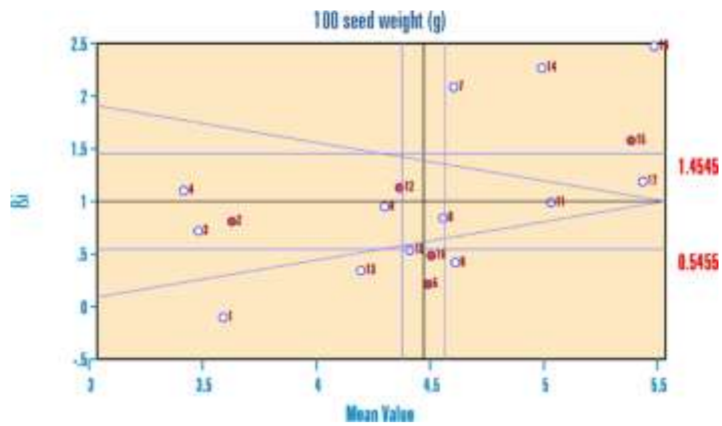

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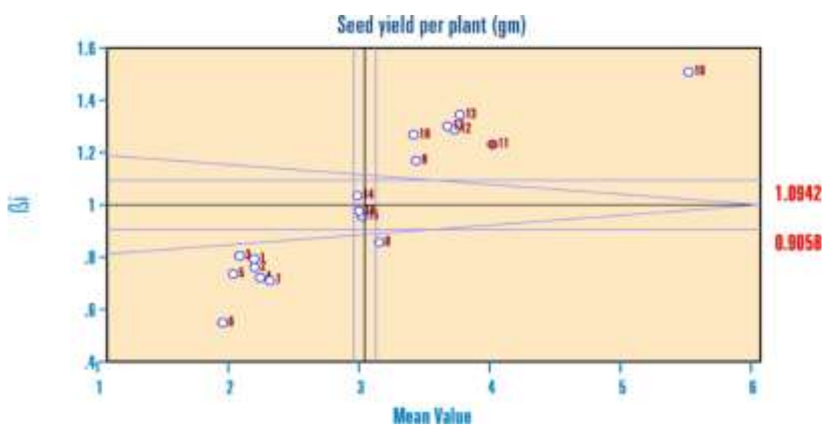

Fig 9 to 11: The Relation of characters with stability

1	TPM-145	10	PKV Green Gold
2	TPM-233	11	BPMR-145
3	TPM-235	12	AKM-4
4	TPM-245	13	BM-4
5	TPM-246	14	BM 2002-1
6	TPM-251	15	BM 2021-1
7	TPM-260	16	BM 2021-2

8	Phule Suvarna	17	BM2003-2(C)
9	Kopargaon	18	Phule Chetak(C)

CONCLUSION

The stability analysis of mungbean genotypes across different environments revealed significant variability in performance for key agronomic traits. Genotypes such as BM 2003-2, BM 2021-1, BM 2021-2, and TPM-260 exhibited consistent average to above-average stability across multiple traits, indicating their potential adaptability and suitability for diverse growing conditions. In contrast, genotypes like PKV Green Gold and BM 2002-1 showed below-average stability for several important traits, suggesting limited adaptability. Among the environments, E_1 (18th June) was found to be the most favorable, while E_4 (20th February) was the least supportive of optimal growth. These findings provide valuable insights for the selection of stable genotypes in future mungbean breeding programs aimed at improving yield stability under varying agro-climatic conditions.

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