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RESEARCH ARTICLE

GERMPLASM× ENVIRONMENT INTERACTION AND STABILITY FOR SEED YIELD COMPONENTS AND MATURITY DURATION IN MUNGBEAN

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ABSTRACT

In the present investigation, twenty five mungbean (*Vigna radiata* L. Wilczek) germplasms were evaluated in 8 environments in West Bengal during the *pre-kharif* season (summer) for five years (2012–2016). The main purpose of the investigation was to estimate the stability of yield and maturity duration of twenty five germplasms for improving selection in mungbean. The study was conducted using a randomized block design with three replications. G × E interaction and yield stability were estimated using Eberhart and Russell model. The pooled mean study revealed a wide range of variation for seed yield and its components across environments.The environment 8 (E_8) which had average rainfall and temperatures as well as slightly more acidic soil pH than other location was found to be a more favorable environment for better expression of pods plant^{-1}, seed pod^{-1}, seed yield plant^{-1} and early maturity.The results of the combined analysis of variance showed highly significant variance for both germplasms, environments and interaction effect, which ultimately emphasized the utilization of stability analysis in crop improvement programme. On the basis of stability parameters, the high yielding early maturing germplasms B1, UPM-99-3 and Shonamung 1 exhibit the stable performance across the environments. The germplasms such as APDM-116, 24 Pargana Local and Shonamung 2 recorded favourable mean performance for all the parameters studied, but their performance was unstable due to significant deviation from regression.A correlation study following Spearman's coefficient of rank correlation recorded the presence of a highly significant link between pods plant^{-1} with seed yield and plant height with maturity duration suggests that seed production is mostly depends on pods whereas early maturity on plant height.

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INTRODUCTION

The world population of 7.349 billion now is expected to overshoot 9.6 billion over 2040–2050 (Global population growth 2015). This overpopulation causes severe damages by changing the climatic condition as well as food security. Hence there is an urgent need to protect the environment by utilizing the resources of land and water more competently for crop yield. Additionally, consumers demand healthy food and high value ingredients. In spite of increasing consciousness to monoculture cropping systems that depends on inorganic N fertilizers, scanty of attention has been given to the crucial role that increased use of legumes will play for agriculture´s sustainability. Mungbean (*Vigna radiata* L. Wilczek), one of the major protein rich (24%) pulse, is the third most economically important pulse crop in Asia. Highest biological value, easily digestible protein and carbohydrate (80.2 % digestibility), low phytic acid (72% of total phosphorus content) content and wide genetic variability of mineral concentrations (e.g. 0.03-0.06 g Fe kg^{-1}, 0.02-0.04 g Zn kg^{-1}) allows it to be used by people as a healthier alternative to meat. In the Indo-Gangetic Plains of South Asia, rice-wheat is the major cropping system. In India alone, this system covers over 10 million hectares. The system of growing cereal after cereal results in multiple adverse effects on soil health, and water reservoirs. Further, it gradually increases the occurrence of diseases, insect-pests and environmental hazards. Thus, there is an urgent need to alter this cropping pattern with some short duration crops to address the said problems successfully. The mungbean cultivars released for the spring /summer season in the past were generally of long duration (80-85 days) and thus, did not fit well for cultivation in rice-wheat cropping system. Mungbean is cultivated either as summer (pre *kharif*) or *Kharif* crop because of its high degree of heat tolerance that is up to 40°C plus. Therefore, the short duration (50 -55 days) varieties could be successfully cultivated with wheat-rice rotation without affecting this popular cropping pattern. After wheat harvest and before the

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transplantation of rice, 60-65 days are available in which no longer duration crop could fit in.But,evaluation and selection from a few repeatedly used parental lines and segregating progenies resulted in relatively low genetic variability and ultimately low productivity as well as longer maturity duration. Moreover, environmental stresses impose major restrictions in mungbean cultivation by minimizing the yield and also by maximizing the maturity duration as well.Therefore, a broad base germplasms should be encouraged in breeding programs to extend its genetic base.

The productivity of mungbean varies due to the suitability of different varieties to different growing environments. Substantial success in crop production and identification of the most superior germplasm for wide or specific cultivated zones, based on stability for yield and yield components, may be possible by conducting multi-environmental field trials on different germplasms (Singh *et al*., 2009, Lal *et al*., 2010). Comstock and Moll, (1963) also reported that G × E interaction is the interactions of genetic and non-genetic factors on phenotypic expression. Therefore, the most important tool to develop improved varieties through plant breeding programs is Germplasm× Environment interaction. Eberhart and Russell (1966) proposed that the ability to display a lowest interaction with the environment is called stability. Henceforth, the stability of germplasm performance is directly connected to the outcome of G × E interaction (Campbell and Jones, 2005). This method is based on regression analysis of stability parameters for germplasms by analyzing experiments conducted over years and/or locations. Therefore, the present study was conducted to estimate the stability of different yield components and maturity duration to identify some early maturing high productive stable germplasms of mungbean (*Vigna radiata* L. Wilczek).

MATERIALS AND METHODS

The trials were conducted with twenty five mungbean germplasms at three different locations (Baruipur, Arambagh and Udaynarayanpur) of West Bengal over the seasons, which constituted eight environments and were referred as E_1, E_2, E_3, E_4, E_5, E_6, E_7 and E_8 (Table 1). At each experimental location, all the germplasms were grown in a randomized block design with three replications. Two to three ploughing followed by cross ploughings and laddering was done to prepare the land for mungbean cultivation. After final land preparation, farmyard manure (FYM) was given @12. 5 tonnes ha^{-1}. Two seeds were sown 3cm deep in each pit along the line with a spacing of 20cm and the spacing between two lines was 30cm (Dept. Of Agriculture, 2010 and Agri farming 2015).Normal inter-culture operations were practiced throughout the growing period. Observations from five randomly selected disease free healthy plants from each replication were recorded on days to maturity, plant height (cm), number of branch $plant^{-1}$, number of pods $plant^{-1}$, number of seed pod^{-1}, 100 seed weight (g) and seed yield $plant^{-1}$ (g).

Recorded data were subjected to the analysis of variance (ANOVA) following Eberhart and Russel's Model to combine the growing years by respective locations. Stability analysis was performed when the germplasm× environment interactions for different yield components were determined as statistically significant ($p \leq 0.01$). The regression coefficient (b_i) (Finlay and Wilkinson, 1963) and mean square of deviation from regression (S^2d_i) (Eberhart and Russell, 1966) values were used as the stability parameters. A correlation study was conducted between the stability parameters and agromorphological characters following Spearman's coefficient of rank correlation (r) (Steel and Torrie, 1980). All the calculations were performed using the SPSS *var.* 21.0 and SPAR 2 softwares.

RESULTS AND DISCUSSION

G × E interaction: The results of analysis of variance for all the observed parameters are given in Table 2. The effects of all the environments and germplasms on the observed parameters were statistically significant ($P \leq 0.01$ *and* $P \leq 0.05$). The results also revealed that the germplasm × environment interactions were found to be significant for the investigated parameters also (Table 2). Moragues *et al*., (2006) reported that the changes in maturity duration and yield components were determined by the germplasm as well as by the environment. However the linear and non-linear components indicated that the germplasms responded linearly to environmental changes and significant linear component indicated that the prediction of performance of the germplasms over the environments would be difficult. The Environment to germplasm × environment interactions recorded high magnitude for all the characters assessed. The values due to pooled deviation (non-linear) were also significant for all the traits studied, indicating considerable genetic diversity in the materials studied. Such inferences were supported by the results of Perkins and Jinks (1968), Nath and Dasgupta (2013). Pooled mean data for different characters for eight environments are presented in Table 3. Mean data showed a great deal of variations in plant height, number of branch $plant^{-1}$, number of pods $plant^{-1}$, seed yield $plant^{-1}$. The environment 8 (E_8) which had average rainfall and temperatures as well as slightly more acidic soil pH than other location (Table 1), was found to be a more favourable environment for better expression of pods $plant^{-1}$, seed pod^{-1}, seed yield $plant^{-1}$ and early maturity. The optimum temperature range in between 27-30 ^{o}C with adequate rainfall from flowering to late pod fill and slightly acidic soil is very much essential for ensuring high yield in mungbean (Mungbean production guideline 2010). Therefore, on the basis of mean performance it is very difficult to recommend germplasms for future breeding programme.Pham and Kang (1988) reported that G × E interaction minimizes the effectiveness of germplasms by changing their yield performances.Therefore, it is very essential to study the stability of mungbean germplasms in multiple environments. Sakin *et al*. (2011) also reported that, stability analysis is very much essential when GE interaction recorded significant values. Singh *et al*. (2009), Nath, (2012), Akhtar *et al*. (2010) and several others also studied the stability parameters of different characters of mungbean germplasms in different environments to identify the germplasm and environmental interactions.

Stability analysis

The regression model of stability proposed by Ebarhart and Russell (1966), considered that b_i as a parameter of response and S^2d_i indicates instability due to the deviation from zero. However, the significance of the coefficient of regression (b_i) means responsiveness either to favourable environment (b_i is more than unity) or poor ones (b_i is less than unity).

Table 1. Description of experimental location

Locations	Baruipur				Arambagh		Udaynarayanpur	
Latitude	22˚N				22.88˚N		22.72˚N	
Longitude	88.26˚E				88.78˚E		87.98˚E	
Altitude (above the sea level)	9.75m				12 m		7 m	
Seasons	2012	2013	2014	2015	2014	2015	2015	2016
Date of sowing	8th March	15th March	10th March	5th March	4th March	15th March	28th March	20th March
Environment	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8
Avg temp. (˚C)								
March	20.3	21.4	25.3	26.1	25.2	26.5	25.8	27.6
April	24.1	23.2	27.5	28.4	27.9	28.6	27.4	30.3
May	21.5	24.3	31.6	30.2	31.5	30.3	31.6	30.7
June	25.6	27.2	28.2	29.4	30.2	29.4	29.3	30.8
Avg rainfall (mm)								
March	25.3	31.6	26.2	26.5	18.3	18.6	20.5	22.4
April	34.6	46.8	38.7	46.2	40.2	38.5	31.6	35.2
May	58.1	72.3	60.3	100.5	72.9	81.3	49.2	47.5
June	138.6	210.9	140.8	212.3	136.2	186.2	126.4	135.6
Soil pH	6.8	6.7	6.8	6.9	6.9	7.1	6.6	6.5

Table 2. Results of variance analysis for yield components and grain yield of 25 germplasms of mungbean grown at eight different environments

Source	df	MSS						
		EBERHART AND RUSSEL'S MODEL						
		Plant Height (cm)	No. of branch plant^{-1}	Days to maturity	Number of pods plant^{-1}	Number of seed pod^{-1}	100 seed weight (g)	Seed Yield plant^{-1} (g)
Germplasm	24	859.6**	26.6*	83.8**	1046.1**	31.4**	21.0*	51.9**
Environment	7	549.0**	21.5*	42.5**	678.2**	15.6*	10.2*	51.2**
G × E	168	85.9**	15.8*	25.3*	50.0**	26.9*	18.9*	16.9*
Env. + (Germplasms×Env.)	175	582.4**	26.8*	14.9*	326.5**	11.5*	19.4*	69.5**
Environment (linear)	1	1086.3**	559.2**	362.5**	1022.6**	328.4**	258.1**	1088.1**
Germplasms× Env.(linear)	24	109.6**	68.9**	21.6*	259.3**	16.9*	18.2*	159.3**
Pooled Deviation	150	78.6**	60.9**	15.9*	369.8**	26.8*	18.9*	26.5*
Pooled Error	192	25.9	11.5	0.3	30.5	15.2	1.59	18.2

** indicates significance at 1% level and * indicates significance at 5% level

Table 3. Pooled mean values of different seed yield components and maturity duration for 25 mungbean germplasms at eight environments

Germplasms	Plant Height (cm)	Number of BranchPlant^{-1}	Days to maturity	Number of Pods Plant^{-1} (g)	Number of SeedsPod^{-1}	100 seed weight (g)	Seed yield Plant^{-1} (g)
1. APDM-84	44.98^{g}	7.79^{c-g}	65.59^{f}	31.34^{h-k}	10.25^{c-g}	3.68^{b-g}	14.80^{g-h}
2. MH-98-1	56.81^{d-f}	6.79^{g}	66.93^{ef}	32.70^{g-j}	11.33^{ab}	4.16^{bc}	15.53^{e-g}
3. B1	52.26^{fg}	10.02^{a}	60.04^{ij}	63.86^{a}	11.23^{a-c}	3.19^{f-i}	23.25^{a}
4. PS-16	72.72^{ab}	9.23^{a-c}	66.19^{ef}	34.79^{f-i}	10.97^{b-d}	3.92^{b-e}	16.37^{ef}
5. PTM-11	70.84^{a-c}	7.18^{fg}	72.26^{b}	18.31^{m}	10.78^{b-e}	3.92^{b-e}	12.00^{h}
6. SML-302	53.09^{e-g}	7.27^{fg}	70.16^{b-d}	34.70^{f-i}	10.12^{d-g}	4.03^{b-d}	16.59^{d-f}
7. ML-5	66.33^{a-d}	7.33^{fg}	69.50^{cd}	23.25^{j-m}	10.67^{b-e}	4.01^{b-d}	11.66^{h}
8. APDM-116	56.89^{d-f}	9.76^{ab}	69.43^{cd}	40.89^{d-h}	10.21^{d-g}	4.27^{b}	18.44^{c-e}
9. UPM-99-3	74.33^{a}	8.80^{a-e}	60.29^{ij}	62.33^{ab}	11.41^{ab}	3.91^{b-e}	21.96^{ab}
10. 24 Pargana local	66.89^{a-d}	7.40^{e-g}	70.16^{b-d}	48.71^{c-e}	11.38^{ab}	3.70^{b-g}	18.41^{c-e}
11. Pusa Baisakhi	52.60^{fg}	8.92^{a-d}	61.73^{hi}	51.31^{cd}	12.13^{a}	3.44^{d-h}	19.66^{b-d}
12. Pusa-9632	55.64^{d-f}	9.79^{ab}	60.55^{ij}	55.13^{a-c}	10.60^{b-e}	3.29^{e-h}	20.75^{a-c}
13. K-851	60.96^{c-f}	9.66^{ab}	60.45^{ij}	51.01^{cd}	9.59^{fg}	4.18^{bc}	20.26^{a-c}
14.Shonamung1	64.09^{a-c}	7.18^{fg}	60.33^{hi}	53.70^{bc}	11.10^{b-d}	3.30^{e-h}	20.10^{a-c}
15. PM-2	61.43^{c-f}	7.93^{c-g}	70.49^{bc}	21.20^{lm}	9.92^{e-g}	3.60^{c-g}	12.36^{gh}
16. BL1	60.63^{c-f}	7.69^{d-g}	63.07^{gh}	53.13^{bc}	8.20^{i}	3.78^{b-f}	18.77^{b-e}
17. BL3	66.71^{a-d}	7.18^{fg}	65.33^{f}	46.82^{c-e}	10.13^{d-g}	3.57^{e-h}	15.80^{ef}
18. Shonamung 2	58.28^{d-f}	6.77^{g}	64.73^{fg}	42.44^{d-g}	9.55^{fg}	3.12^{g-i}	16.02^{ef}
19. Panna	64.53^{a-d}	7.16^{fg}	68.04^{de}	45.70^{c-e}	10.53^{b-f}	3.31^{e-h}	16.23^{ef}
20. Baruipur local2	66.44^{a-d}	9.11^{a-d}	60.03^{ij}	50.71^{cd}	9.44^{gh}	6.89^{a}	19.69^{b-d}
21. Howrah local	61.88^{b-f}	6.68^{g}	66.86^{ef}	45.03^{c-f}	10.83^{b-e}	2.95^{hi}	16.15^{ef}
22. Purulia local	60.33^{c-f}	6.58^{g}	70.33^{b-d}	38.95^{e-i}	9.31^{gh}	2.65^{hi}	16.46^{d-f}
23. Bankura local	60.43^{c-f}	7.99^{c-g}	69.91^{cd}	21.79^{k-m}	8.56^{hi}	3.34^{e-h}	11.68^{h}
24. WBM-29	57.00^{d-f}	7.27^{fg}	75.21^{a}	34.82^{f-i}	7.83^{i}	3.36^{e-h}	14.75^{f-h}
25. Samrat	63.05^{b-f}	8.44^{b-f}	66.33^{ef}	30.24^{i-l}	8.04^{j}	3.60^{c-g}	13.26^{f-h}
General mean	61.17±6.16	8.00±0.83	66.16±0.88	41.31±5.36	10.17±0.55	3.73±0.16	16.84±1.91
Range	44.98-74.33	6.58-10.02	60.04-75.21	18.31-63.86	7.83-12.13	2.65-6.89	11.66-23.25
Environment with							
Highest mean	E6	E1	E7	E8	E8	E1	E8
Lowest mean	E8	E7	E8	E3	E6	E7	E6

Table 4. Stability parameters and mean values for seed yield components and maturity duration of Mungbean germplasms grown at three locations in two growing seasons by Eberhart and Russel's Model

Germplasms	Plant Height			Number of Branch Plant^{-1}			Days to maturity			Number of Pods Plant^{-1}		
	b_i	S^2_{di}	μ_i	b_i	S^2_{di}	μ_i	b_i	S^2_{di}	μ_i	b_i	S^2_{di}	μ_i
1. APDM-84	0.05	120.36**	44.9	0.19	18.62**	7.7	1.00	-0.20	65.5	0.74	0.07	31.3
2. MH-98-1	4.69	8.56	56.8	2.63	12.33*	6.9	0.59	-0.56	66.9	0.69	3.26*	32.7
3. B1	1.00	28.30	52.2	1.00	9.22	10.2	0.66	1.18	60.2	1.00	0.61	63.8
4. PS-16	1.22	44.95	72.7	0.88	8.11	9.3	1.02	0.59	66.1	0.42	0.08	34.7
5. PTM-11	0.83	115.26**	70.8	0.62	20.45**	7.8	1.22	3.69*	72.2	1.00	6.32**	18.3
6. SML-302	0.59	36.02	53.0	0.71	8.44	7.7	0.49	1.02	70.1	0.99	1.22	34.7
7. ML-5	1.00	23.69	66.3	1.05	8.40	7.3	1.06	0.66	69.5	1.00	0.66	23.2
8. APDM-116	0.44	30.11	56.8	0.62	10.22*	9.6	0.39	4.59**	69.4	0.52	8.23**	40.8
9. UPM-99-3	1.44	59.66	74.3	1.00	6.92	8.8	0.98	1.02	60.0	1.00	0.96	62.3
10. 24 pargana local	0.93	65.02	66.8	1.69	12.42*	7.4	0.66	5.14**	70.1	0.63	9.96**	48.7
11. Pusa Baisakhi	1.31	72.11	52.6	0.50	11.11*	8.9	1.75	10.20**	61.7	0.96	1.66	51.3
12. Pusa-9632	0.55	55.46	55.6	0.49	22.74**	9.9	2.66	0.69	60.5	1.00	1.59	55.1
13. K-851	1.33	44.80	60.9	0.69	22.55**	9.6	-1.26	-0.52	60.4	0.82	6.29**	51.0
14. Shonamung 1	0.55	56.02	64.0	1.00	7.29	7.1	1.00	2.33	60.3	0.93	2.02	53.7
15. PM-2	0.98	46.02	61.4	0.92	5.44	7.3	0.99	2.56	70.9	1.00	0.46	21.2
16. Baruipur Local 1	1.00	32.01	60.6	1.66	9.63	7.9	0.44	7.59**	63.0	0.42	0.06	53.1
17. Baruipur Local 3	0.96	29.63	66.7	0.92	7.28	7.8	1.59	9.66**	65.3	0.66	0.55	46.8
18. Shonamung 2	0.44	102.33**	58.2	0.41	5.23	6.7	0.66	8.96**	64.7	0.49	8.69**	42.4
19. Panna	0.42	36.02	64.5	0.09	6.11	7.6	3.65	1.59	68.0	1.02	1.06	45.7
20. Baruipur Local 2	0.50	69.04	66.4	1.26	6.54	9.1	0.96	2.33	60.03	3.26	9.63**	50.7
21. Howrah local	0.60	52.01	61.8	1.00	4.88	6.8	1.00	0.96	66.8	1.22	2.56*	45.0
22. Purulia local	0.26	49.32	60.3	0.69	6.21	6.8	0.56	-1.59	70.3	0.59	3.66*	38.9
23. Bankura local	1.02	90.55*	60.4	0.12	20.44**	7.9	1.00	0.55	69.9	2.00	0.96	21.7
24. WBM-29	0.45	46.11	57.0	0.46	9.62	7.7	0.44	1.59	75.2	0.96	3.55*	34.8
25. Samrat	0.96	48.32	63.5	0.98	8.41	8.4	1.09	0.69	66.3	1.00	2.69	30.2

b_i= The regression coefficient; S^2_{di} = mean square of deviation from regression; μ_i = mean value; ** indicates significance at 1% level and * indicates significance at 5% level

Table 4. Contd.Stability parameters and mean values for seed yield components andmatyrity duration of Mungbean germplasms grown at three locations in two growing seasons by Eberhart and Russel's Model

Germplasms	Number of Seeds Pod^{-1}			100 seed weight			Seed yield Plant^{-1}		
	b_i	S^2_{di}	μ_i	b_i	S^2_{di}	μ_i	b_i	S^2_{di}	μ_i
1. APDM-84	0.44	0.007	10.2	0.59	0.002	3.6	1.23	232.8	14.8
2. MH-98-1	2.65	-0.004	11.3	0.49	-0.001	4.1	0.96	356.2	15.5
3. B1	1.00	0.067	11.2	0.96	0.028	3.9	1.00	121.9	23.2
4. PS-16	0.86	0.007	10.9	2.36	0.005	3.9	1.23	959.8**	16.3
5. PTM-11	0.26	0.094*	10.7	0.94	0.005	3.9	1.01	237.2	12.0
6. SML-302	0.54	0.007	10.1	1.96	0.102*	4.0	0.92	233.5	16.5
7. ML-5	1.03	0.048	10.6	0.96	0.010	4.0	0.94	124.6	11.6
8. APDM-116	0.30	0.370**	10.2	0.55	-0.001	4.2	0.63	954.8**	18.4
9. UPM-99-3	1.03	0.043	11.4	1.00	0.009	3.9	0.90	234.5	21.9
10. 24 pargana local	0.88	0.126**	11.3	0.99	0.012	3.7	0.42	955.0**	18.4
11. Pusa Baisakhi	1.00	0.009	12.1	0.93	0.006	3.4	1.04	161.4	19.6
12. Pusa-9632	1.00	0.061	10.6	0.98	0.008	3.2	1.00	155.1	20.7
13. K-851	0.52	0.009	9.5	0.72	0.009	4.1	1.96	967.7**	20.2
14. Shonamung 1	1.03	0.082	11.1	1.02	0.005	3.3	1.02	239.3	20.1
15. PM-2	0.83	0.012	9.92	1.06	0.003	3.6	1.03	261.5	12.3
16. Baruipur Local 1	0.44	0.067	8.2	1.98	0.115*	3.7	3.26	454.2	18.7
17. Baruipur Local 3	0.59	0.037	10.1	2.56	0.007	3.5	1.90	563.1	15.8
18. Shonamung 2	0.13	0.445**	9.55	2.33	0.009	3.1	0.45	962.1**	16.0
19. Panna	0.96	0.369**	10.5	1.02	0.009	3.3	1.13	315.1	16.2
20. Baruipur Local 2	2.27	0.069	9.44	1.06	0.113*	6.8	1.44	966.6**	19.6
21. Howrah local	0.77	0.044	10.8	0.55	0.007	2.9	1.76	344.9	16.1
22. Purulia local	0.82	0.269**	9.3	0.36	0.003	2.6	0.82	111.3	16.4
23. Bankura local	0.93	0.096*	8.5	0.96	0.006	3.3	2.50	630.8	11.6
24. WBM-29	0.42	0.558**	7.8	0.42	0.105*	3.3	1.00	963.0**	14.7
25. Samrat	0.55	0.074	8.0	0.99	0.081	3.6	1.03	869.2	13.26

b_i= The regression coefficient; S^2_{di} = mean square of deviation from regression; μ_i = mean value; ** indicates significance at 1% level and * indicates significance at 5% level

Table 5. Correlation between stability of seed yield and its components

S^2d_i	Correlation (r)	S^2d_i	Correlation (r)
Seed yield plant^{-1}and plant height	0.003	Days to maturity and plant height	0.225*
Seed yield plant^{-1}and Number of branch plant^{-1}	-0.164	Days to maturity and Number of branch plant^{-1}	-0.133
Seed yield plant^{-1}and Number of pods plant^{-1}	0.453**	Days to maturity and Number of pods plant^{-1}	0.193
Seed yield plant^{-1}and Number of seed pod^{-1}	0.242	Days to maturity and Number of seed pod^{-1}	0.206
Seed yield plant^{-1}and 100 seed weight	0.338*	Days to maturity and 100 seed weight	0.019
Seed yield plant^{-1}and Days to maturity	0.074	Days to maturity and Seed yield plant^{-1}	0.074

** indicates significance at 1% level and * indicates significance at 5% level

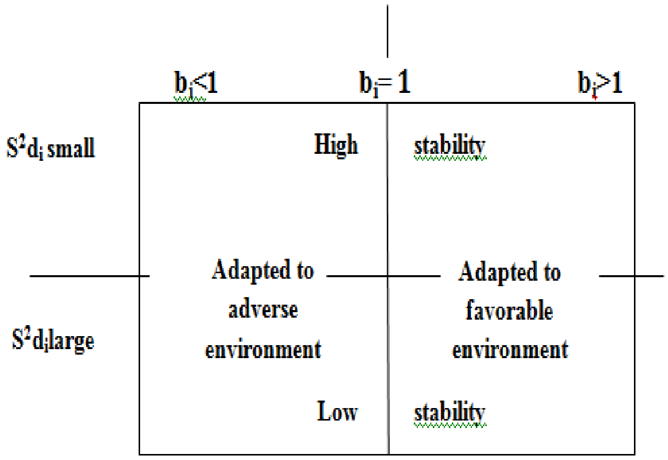

Figure 1. Schematic representation of genotypic adaptation (Adapted from Becker & Leon, 1988)

The stability parameters and mean performance of the investigated mungbean germplasms are presented in Table 4.Schematic representation of genotypic adaptation (Becker and Leon, 1988) is presented in Figure 1. The relative performance of the germplasms for individual yield and its component traits were discussed below. Some high yielding early maturing germplasms namely B1, UPM-99-3, Shonamung1 and some poor yielding late maturing germplasms namely Samrat, ML-5 and PM-2 recorded regression value nearer to unity, i.e., b_i=1 and non-significant deviation from regression (S^2d_i) and were found to be the most stable germplasms with respect to performance across environments. Samrat, ML-5 and PM-2 recorded lower differential responses to the changes in the environment regardless of their low yielding ability. Similar findings are also reported by Hristov *et al*. (2011), Karimizadeh *et al*. (2012), Temesgen *et al*. (2015). The germplasms Pusa-9632 and Pusa Baishakhi were found to have the wider adaptability for seed yield as they exhibited a higher number of pod plant^{-1}, number of seed pod^{-1},100 seed weight and seed yield plant^{-1} along with b_i nearer to 1 as well as non-significant $S^2d_{i,}$ but both of them can be considered as specially adapted germplasms to a favourable environment for maturity duration as they registered shorted maturity duration along with b_i value >1 and non-significant S^2d_i.

The germplasms PS-16 and Baruipur local 2 also registered shorter maturity duration along with b_i nearer to 1 and non-significant S^2d_i indicating wider adaptability to all environments for maturity duration, but their yield performance could be unpredictable as they recorded significant S^2d_i value along with b_i value greater than unity. The germplasms such as APDM-116, 24 Pargana Local and Shonamung 2 recorded favourable mean performance for all the parameters studied, low regression value (b_i < 1) and significant deviation from regression (S^2d_i) indicating unstable performance across the environments and they are appropriate for poor environments. The germplasms MH-98-1, PTM-11 and SML-302 also registered b_i value nearer to the unity along with non-significant S^2d_ibut they are poorly adapted to all environments as they showed lower mean performance for seed yield. The stability parameter study of germplasms for maturity duration along with seed yield and its components in mungbean has also been reported by Manivannan *et al*., (1998), Natarajan (2001), Patel *et al*., (2009), Kamannavar *et al*., (2011), Singh *et al*., (2013), Aziz *et al*., (2015) and others.

The simultaneous consideration of these stability parameters for the individuals revealed that germplasms such as B1, UPM-99-3, Shonamung1, Pusa-9632 and Pusa Baisakhi are early maturing high yielders and showed stable performance across the environments. Among the joint regression stability measures, S^2d_i was largely used to rank the relative stability of cultivars (Becker and Leon, 1988), which indicates that b_i could be used to describe the general response to the integrity of environmental conditions, whereas, S^2d_i actually measures the yield stability (Fikere *et al*., 2008). Correlation study among mean square of deviation from regression (S^2d_i) of each character with seed yield and days to maturity are recorded in Table 5. Pods plant^{-1},100 seed weight recorded positive significant correlations with seed yield plant^{-1}, whereas plant height recorded positive significant correlation with days to maturity. Therefore, if pods plant^{-1} and 100 seed weight were stable then seed yield will also be stable. Likewise, if plant height was more stable then days to maturity will be stable. So these two reproductive and one vegetative character can be a meaningful measure for stability description.

Conclusion

Multilocation trials are very much essential to establish the uniformity, uniqueness, and stability of germplasms. The results of this study indicate a strong influence of environmental conditions on plant height, number of branch plant^{-1}, days to maturity, number of pod plant^{-1}, number of seed pod^{-1},100 seed weight and seed yield plant^{-1}. The analysis of variance study showed significant germplasm × environment interactions, which exhibit the effect of alterations in environment on seed yield performance as well as on maturity duration of mungbean germplasms.Among the twenty five germplasms, five early maturing high yielding germplasms such as B1, UPM-99-3,Shonamung1, Pusa-9632 and Pusa Baisakhi were considered as the most stable in performance across environments and, thus, could be used for general cultivation under the favourable environmental conditions of the tested locations.The presence of a highly significant link between pods plant^{-1} and seed yield as well as plant height and maturity duration suggests that seed production is mostly depends on pods whereas early maturity on plant height.Hence, this information should be economically useful for plant breeders to identify the stable mungbean germplasms on the basis of most related traits as well as environmental condition.

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