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Research Article

Stability of blackgram (*Vigna mungo* L. Hepper) varieties for seed yield

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Abstract
Twelve blackgram varieties were evaluated for six seasons from *Rabi* 2009 to *Rabi* 2011 at Thrissur, Kerala, India to assess the genotype x environmental interactions. Analysis of variance on the data pooled over seasons showed significant difference between varieties, seasons and the interaction between varieties and seasons for days to flowering and yield. Flowering in blackgram was found to be influenced by photothermic index (PTI) rather than growing degree days (GDD). Rainfall received during the first three weeks after sowing had greater influence on seed yield. Analysis of genotype x environment interaction by AMMI model showed blackgram variety T9 as the best variety with respect to yielding ability suited for cultivation under favourable conditions. The varieties CO6 and TAU 1 with moderate yield capacity were found to be highly stable under differing environments and hence can be recommended for cultivation when prediction of environment is not possible.

Key words
Black gram, seasons, correlation, rainfall, PTI, stability, AMMI model

Introduction

Black gram (*Vigna mungo* L. Hepper), is an important pulse crop of Indian origin. It supplies major share of protein requirement of vegetarian population of India. It is grown in almost all agro-ecological zones of the country. Though several improved varieties have been developed, most of them show inconsistent performance under varied environmental and climatic conditions due to genotype x environment interactions (Shanthi *et. al.*, 2007). According to Sivaprakash *et.al.* (2004), lack of suitable varieties and genotypes with adaptation to local conditions is one of the important factors causing significant decline in the pulse production in India. In the context of climate change adaptation strategies, crops with adaptation to wider range of temperature and moisture stress play an important role. The optimum temperature for black gram ranges between 25^0C to 35^0C, but it can tolerate up to 42^0C. It is a hardy and drought resistant plant and can be grown in areas receiving moderate or low rain fall (Sikkim AGRISNET 2013). Considering this, cultivation of blackgram in non-traditional areas offers an opportunity to be used as a climate change adaptation strategy. However, performance of blackgram varieties vary under different environments and hence, selection of a suitable variety with high stability over environments is important.

Present study was taken up to elucidate the genotype x environment interaction of twelve blackgram varieties under different cropping seasons and to identify the stable varieties suitable for cultivation under varying environmental conditions.

Materials and methods

Twelve varieties of blackgram were evaluated under six seasons starting from *Rabi* 2009 to *Rabi* 2011 at Department of Plant Breeding and Genetics , College of Horticulture, Vellanikkara, Thrissur, Kerala. Genotypes used in the study were TAU -1, TAU-2, DU-1, T-9, Rusami, Sumanjana, Syama, CO-5, CO-6, Vamban-3, Vamban- 4 and Vamban -5 .The study was conducted under six environments namely, *Rabi* 2009, *Kharif* 2010, *Rabi* 2010, Summer 2011, *Kharif* 2011 and *Rabi* 2011.

The experiment was laid out in randomized block design with three replications. Each variety was sown in raised bed of 12 m^2 at spacing of 25 cm x 15 cm. Recommended agronomic practices as per Package of practices of Kerala Agricultural University (KAU, 2007), were followed throughout the growing season. Observations on number of days taken for first flowering was recorded when one plant in a plot showed flowering. Seed yield was taken on per plot basis and expressed in kg/ha. Analysis of variance was done to compare the performance of the varieties under different seasons using data pooled over the seasons. Photothermic index (PTI) for each season was calculated using the formula, PTI = Σ(DLi/24Tt), (Where, DLi - daily day length, Tt - thermal time) until flowering. Genotype x environment interaction of the genotypes over different seasons for yield was done by AMMI model using SAS statistical package (Thillainathan and Fernandez, 2001).

Results and discussion

Analysis of variance for yield and yield contributing characters pooled over seasons showed that there was significant variation between varieties and between seasons. The genotype x environment interaction was also found to be significant. The comparison of the data on days to flowering in black gram over the seasons showed that plants flowered early during 2011 as compared to 2009 and 2010 (Table 1). Photothermic index calculated for blackgram for different times of planting is given in Table 2. From the table, it can be interpreted that when the accumulated photothermic index (PTI) is 250 and above, the plants enter into reproductive phase. During 2011, the plants reached this value early and flowering got initiated. Varieties recorded longer period for flowering in Kharif 2010 followed by Rabi 2010 and Rabi 2009, where it took more days to reach the threshold PTI. Among varieties tested, Sumanjana flowered earlier over different seasons, whereas variety Syama was invariably late in flowering. (Table1).

Comparison of average grain yield of black gram varieties (Table 3) over seasons revealed that high grain yield was obtained during *Kharif* 2010 which was on par with *Rabi* 2011. Varieties recorded significant higher yield during these seasons compared to other seasons. Table 4 describes the correlation of rainfall received by blackgram varieties in each week after sowing to yield and days to flowering. Grain yield had high correlation with rainfall received during early vegetative phase up to three weeks after sowing and during flowering. Variety T9 exhibited highest grain yield over seasons (1622.22k/ha). The performance of vareties TAU-1, TAU-2, Rusami,Sumanjana,CO-5, CO-6, Vamban-4 and Vamban -5 were on par with respect to grain yield .

The study revealed that yield and days to flowering were highest during *Kharif* 2010. Similarly, the grain yield and days to flowering were lowest during summer 2011. However, no significant influence of days to flowering over yield of varieties was noticed in the study. Yield of black gram during *Kharif* season was found to be higher than growing in *Rabi* and summer seasons.

Genotype x environment interaction is of universal occurrence for any quantitative character. A specific genotype does not exhibit the same phenotypic value under all environments. The different genotypes respond differently to a specified environment (Vidyarani, 2005). Analysis of variance by AMMI model revealed that there was significant G x E interaction which was partitioned in to PCA components one to four as given in Table 5. The percentage contribution of PCA components showed that PCA 1 account for 62.96 percentage of the interaction sum of squares and PCA 2 account for 26.97 per cent. Of the total interaction effect 89.93 per cent was attributed by PCA 1 and 2.

A stable genotype possesses an unchanged performance regardless of any variation of the environmental conditions. This stable genotype shows no deviation from the expected character level (Karimizadeh *et. al.,* 2013) . Based on the yield, the variety T9 had highest mean value for yield. However, its PCA1 value was 0.93 indicating that the variety will perform better under favourable environments. The performance of the varieties TAU-1, TAU-2, Rusami, Sumanjana ,CO-5, CO-6, Vamban-4 and Vamban -5 with respect to grain yield was on par. Of these varieties TAU1, CO-6 and Vamban 4 with low PCA values are comparatively stable.

Considering PCA 1 and 2 together, the genotypes TAU 1, CO-6 and Vamban 3 were having low PCA values indicating the stable nature of the varieties. Of these varieties TAU – 1 and CO-6 were having high mean yield also. Hence, these varieties can be recommended for planting under all the seasons. Based on the present study, variety T 9 can be recommended for cropping under favourable environments where the recommended management practices can be ensured for the crop. The varieties CO-6 and TAU-1 with comparatively high yield capacity were found to be highly stable under differing environments. These varieties can be recommended for cultivation when prediction of environmental interaction is not possible.

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Table 1. The days to first flowering black gram varieties grown under different seasons

G.No	Variety	Rabi 2009	Kharif 2010	Rabi 2010	Summer 2011	Kharif 2011	Rabi 2011	Average
1	TAU-1	36.00	37.67	36.33	29.00	36.00	30.67	34.28^{bcd}
2	TAU-2	33.00	40.67	33.33	29.00	32.00	30.67	33.11^{c}
3	DU-1	37.00	39.00	37.67	30.00	32.00	30.33	34.33^{bcd}
4	T-9	36.00	38.33	36.00	30.00	28.00	30.00	33.06^{cd}
5	Rusami	37.67	38.33	38.33	30.00	29.00	29.67	33.83^{de}
6	Sumanjana	31.00	31.00	38.67	29.00	33.00	29.00	31.95^{f}
7	Syama	37.33	37.33	37.67	34.00	35.00	30.00	35.22^{a}
8	CO-5	38.00	37.33	37.67	34.00	30.00	30.67	34.61^{abc}
9	CO-6	37.00	35.67	37.33	36.00	30.00	30.00	34.33^{bcd}
10	Vamban-3	37.00	41.67	37.67	30.00	31.00	31.67	34.84^{ab}
11	Vamban-4	37.00	39.00	37.67	30.00	31.00	31.33	34.33^{bcd}
12	Vamban-5	37.00	40.67	37.33	31.00	31.00	31.33	34.72^{abc}
CV		5.89	8.28	5.22	7.32	7.14	3.19	
SE		0.36	0.53	0.32	0.38	0.38	0.16	
	Average	36.17^{3}	38.06^{1}	37.14^{2}	31.00^{4}	31.50^{4}	30.44^{4}	

Significant at 0.05% CD = 0.23; LCD value for interaction – 1.860

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Table 2. Photothermic index calculated for different date of sowing in blackgram

Date of sowing	Days to flowering	Day length	Photothermic index
Rabi 2009	36.0	11.6	314.7
Kharif 2010	37.7	12.5	321.4
Rabi 2010	36.3	11.5	283.8
Summer 2011	29.0	11.7	254.7
Kharif 2011	31.0	12.5	260.0
Rabi 2011	30.7	12.3	256.4

Table 3. Grain yield (kg/ ha) of blackgram varieties over seasons

Variety	Rabi 2009	Kharif 2010	Rabi 2010	Summer 2011	Kharif 2011	Rabi 2011	Average yield
TAU-1	815.55	3273.33	815.55	644.44	1333.33	2024.44	1484.44[abc]
TAU-2	724.44	3806.66	726.67	573.33	931.11	1264.44	1337.78[abcd]
DU-1	811.11	1793.33	815.55	1068.89	1917.78	1113.33	1253.33[bcd]
T-9	906.67	3200.00	888.89	706.67	1177.78	2886.66	1622.22[a]
Rusami	682.22	2460.00	666.67	682.22	1808.89	2575.55	1480.00[abc]
Sumanjana	473.33	2015.55	473.33	673.33	1733.33	2842.22	1368.89[abcd]
Syama	371.11	1628.89	371.11	568.89	1233.33	2408.89	1097.78[cd]
CO-5	471.11	2622.22	473.33	762.22	2622.22	2328.89	1546.67[ab]
CO-6	488.89	1377.78	488.89	693.33	1682.22	2486.66	1200.00[cde]
Vamban-3	528.89	1022.22	504.44	806.67	1695.55	1555.55	1020.00[e]
Vamban-4	544.44	2755.55	548.89	751.11	1484.44	2046.66	1355.55[abcd]
Vamban-5	482.22	1806.66	473.33	624.44	1982.22	2595.55	1326.67[abcd]
CV	30.75	45.51	32.75	29.95	37.35	26.64	
SE	31.21	175.35	32.98	35.61	101.67	96.71	
Average	608.89[3]	2313.33[1]	604.44[3]	713.33[3]	1633.33[2]	2177.78[1]	

Significant at 0.05% CD = 1.48

Table. 4. Correlation of rain fall with yield and days to flowering in blackgram

Week after sowing	Days to flowering	Correlation with Yield
1	0.43	0.84*
2	0.15	0.66*
3	0.11	0.87*
4	-0.41	-0.21
5	-0.03	-0.03
6	-0.24	0.59*
7	0.01	0.54*
8	0.13	0.61*
9	-0.14	0.23
10	-0.26	-0.05

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Table 5. Analysis of variance for the AMMI model

Source	dt	SS	MS	F	Contribution of PCA components (%)	Probability
Genotype	11	43.20	3.93			
Environment	5	779.10	155.82			
Genotype x environment	55	255.78	4.65			
PCA 1	15	161.06	10.73	4.53	62.96	0.00
PCA 2	13	69.00	5.30	5.57	26.97	0.00
PCA 3	11	24.74	2.25	36.10	9.67	0.00
PCA 4	9	0.97	0.10	15.89	0.03	0.00
G x E residual	7	0.65				
Total	71	1078.09				

Table 6. Yield and PCA scores of genotypes and environments by AMMI model

Genotype	Average yield(kg/ha)	IPCA 1	IPCA2
TAU-1	1484.44^{abc}	-0.13	-0.18
TAU-2	1337.78^{abcd}	-0.23	0.63
DU-1	1253.33^{bcd}	0.35	0.19
T-9	1622.22^{a}	-0.93	-0.11
Rusami	1480.00^{abc}	0.83	-0.46
Sumanjana	1368.89^{abcd}	0.63	-89
Syama	1097.78^{cd}	0.58	-0.56
CO-5	1546.67^{ab}	0.28	0.88
CO-6	1200.00^{cde}	0.11	-0.29
Vamban-3	1020.00^{e}	0.12	0.11
Vamban-4	1355.55^{abcd}	-0.59	0.20
Vamban-5	1326.67^{abcd}	0.89	-0.43
Environment			
Rabi 09	608.89^{c}	-0.75	0.58
Kharif 10	2313.33^{a}	-0.30	-0.37
Rabi 10	604.44^{c}	-0.84	0.59
Summer 11	713.33^{c}	0.54	0.89
Kharif 11	1633.33^{b}	0.15	0.77
Rabi 11	2177.78^{a}	0.11	-0.25