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Research Article

Stability of advanced generation of inter varietal crosses in black gram (*Vigna mungo* L.) through AMMI analysis

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Abstract
Fourteen blackgram genotypes (comprising 10 advanced generations and four parents) were evaluated for three different season *viz.,* Kharif, Rabi and summer both in open conditions as well as inter crop in coconut garden under six environments. Analysis of variance on the data pooled over seasons showed significant difference between genotypes for days to flowering, number of pod bearing branches, number of pods, length of pods, 100-seed weight and yield per plant. Environmental effect was significant for all the traits except plant height whereas genotype x environmental interaction were significant for all the traits. Analysis of genotype x environment interaction by AMMI model showed blackgram culture T6 (4.5.9; T9 x Rusami) as the best with respect to days to flowering, number of branches per plant, pod bearing branches per plant and number of pods per plant for all environments. The genotype T5 (4.5.8; T9 x Rusami) with high mean yield and stability can be selected for cultivation under all environments.

Key words
Black gram, environment, genotype, stability, AMMI model, biplot

Introduction

Blackgram (*Vigna mungo* L. Hepper), is an important pulse crop of Indian origin which has been a part of Indian cuisine in many forms. Being a rich source of protein, it acts as a supplement to cereals . The importance of this pulse is not restricted as a food or feed, rather it fixes atmospheric nitrogen, and can be used as inter crop. It is also adapted to be used as a catch crop as well as a contingency crop Kanade(2006). Absence of ideotypes suitable for different cropping systems and environments, poor harvest index and susceptibility to diseases add to the constraints in achieving higher yield Souframanien and Gopalakrishnan(2004). The creation of variability is difficult through hybridisation owing to its autogamos nature Deepalakshmi and Anandakumar(2004). The area under blackgram cultivation in India is 32.386 lakh ha with a production of 13.964 lakh tonnes and productivity of 431kg/ha GOI status paper on pulses(2016)

Lack of suitable varieties and genotypes with adaptation to local conditions are important among the factors affecting the significant decline in the pulse production in India. Even though several improved varieties in blackgram have been developed, most of them show inconsistent performance under varied environmental conditions due to genotye × environment interaction Shanthi *et al.(*2007). Genotype × environment interaction is important for plant breeding because it affects the genetic gain and recommendation and selection of cultivars with wide adaptability Deitos *et al.,* (2006). According to Nath *et al.* (2013), low levels of interactions are useful for some characters so as to ensure the stability performance over a wide range of environments. However, under certain situations high G x E interactions are beneficial and can be exploited.

Present study was taken up to elucidate genotype × environment interaction in black gram cultures developed by pure line selection from segregating generations of inter varietal crosses and varieties under different cropping seasons and to identify the stable cultures suitable for cultivation under varying environmental conditions.

Materials and Methods

The study was carried out in the Department of Plant Breeding and Genetics, College of Horticulture, Velanikkara. The study was conducted in three different season *viz.,* Kharif, Rabi and summer both in open conditions as well as inter crop in coconut garden.

Ten black gram cultures developed by pure line selection produced from four crosses in stabilised generation in the department along with four parents from which these advanced generations were developed viz., TAU – 1, T- 9, Sumanjana and Syama (Table 1) as check were used to study genotype × environment interaction. The study was conducted in six environments (Table 2). The plants were raised in plots of 25 m^2 at a spacing of

30×10 cm^2. Standard cultural and plant protection practices KAU(2011) were followed. The crop was harvested when 90 per cent of pods in the plants were dried.

Observations were recorded from 50 plants per replication from each treatment on days to first flowering, height of the plant, number of branches and pods, test weight, grain yield and protein content. Protein content was estimated by Lowry's method and is expressed a percentage.The data was analysed by AMMI model (Zobel *et al.*1798).

Result and Discussion

The analysis of variance for AMMI presented in Table 3 shows that the genotypic effects were significant for the traits, days to flowering, number of pod bearing branches, number of pods, length of pods, test weight and yield per plant. Environmental effect was significant for all the traits except plant height. Genotype x environmental interaction which is partitioned through interaction principal component analysis viz., IPCA1 and IPCA 2 were significant for all the traits.

Relative performances of crop varieties vary in different environments which is difficult to explain by variance component method. The AMMI model is a hybrid analysis that incorporates both the additive and multiplicative components of the two-way data structure. AMMI analysis is considered to be an effective tool to diagnose G x E patterns graphically. The principal component analysis (PCA), which provides a multiplicative model, is applied to analyze the interaction effect from the additive ANOVA model. The biplot display of PCA scores plotted against each other provides visual inspection and interpretation of G x E interaction components. The integration of biplot display and genotypic stability statistics enables grouping of genotypes on the basis of similarity in performance across diverse environments Mukherjee *et al*.(2013). From the values of mean and IPCA 1, the genotypes are classified under four distinct classes *viz.,* Class I: Genotypes with high mean and positive IPCA 1, Class II: genotypes with high mean and negative IPCA1, Class III: genotypes with low mean and negative IPCA1 and Class IV: Genotypes with low mean and positive IPCA1. The genotypes belonging to Class I and environments recording positive IPCA values interact positively and these genotypes can be recommended in these environments for that particular trait. Hence, in order to get a better picture about the stability of the fourteen genotypes tested in six environments the data was analysed using AMMI model and the results are presented in Table 4(a,b,c) and Table 5.

The IPCA value for T3 for days to flowering was placed near to zero and hence the culture T3 can be considered to be stable for the days to flowering. Based on biplot 2 (Fig. 1) the environment E1 *i.e.,* kharif season under open condition was having a long spoke indicating that environment exerted strong interactive forces on the genotypes. The environments E4 and E6 *i.e.,* shade condition under rabi and summer season exerted lesser interaction on the genotypes. The IPCA values of cultures T6 and T10 were present near to the origin indicating that these cultures were non sensitive to environmental interactive patterns and they showed early flowering also. Hence, these genotypes can be selected for days to flowering. Considering the interaction of genotypes and environments together, the genotypes belonging to Class I *viz.,* T2, T6, T9, T10, T11, T12 and T13 and environment E1 recorded positive values for IPCA 1. Hence, these genotypes can be recommended for environment E1 as the cultures flower early.

Based on IPCA values the environments E3 and E6 that is open condition under rabi season and shade condition under summer season exerted strong interactive forces to the genotypes with respect to plant height. The environment E5 that is open condition under summer season exerted least interactive forces to the height of the genotype and T3, T7, T8 and T14 were lesser sensitive to environmental interactive forces (Fig. 2).

Babu *et al*. (2009) studied the phenotypic stability in blackgram using AMMI model and identified two genotypes as stable as situated close to centre of IPCA axis in interaction biplot. Interaction of genotypes and environments when considered together, the genotypes T1, T2, T5, T8, T9 and T12 with high plant height and environment E1, E2 and E3 recorded positive IPCA 1 values and hence interacting with each other positively. These genotypes can be recommended in these environments to ensure good plant height.

The genotypes T1, T3 and T11 had similar interactive patterns for branch number as seen in biplot (Fig.3). Environment E1 and E2 that is open and shade condition under kharif season exerted strong interactive forces on the genotypes for branch number. The environments E4 and E6 that are shade condition under rabi and summer season exerted less interactive forces to the branch number of genotype and T6 and T9 were found to be non sensitive to environmental interactive forces. Both these genotypes were having moderately high branch number and hence can be selected.

Considering interaction of genotypes and environments together, the genotypes expect T1, T3, T4, T5 can be recommended E1, E3 and E4 to ensure maximum number of branches.

The interaction biplot (Fig. 4) showed that T1 and T3 and T2, T4, T6, T7, T8 and T10 exhibited similar main and interaction effects for number of pod bearing branches. The environments E1 and E2; open and shade condition under kharif season exerted strong interactive forces while the environments E4 and E5 shade condition under rabi season and open condition under summer season exerted lesser interactive effect. The T6 and T8 were comparatively non sensitive to environment with respect to number of pod bearing branches. Hence, T6 with high number of pod bearing branches can be selected. The genotypes T4, T7, T9, T10 and T11 with high number of pod bearing branches interacted positively to environments E1, E3 and E4 indicating, when these genotypes recommended for these environments can produce maximum number of pod bearing branches.

The environment E1 and E3 that is open condition during kharif and rabi exhibited strong interactive forces on the genotype with respect to number of pods while, environment E5 and E6 that is open and shade condition during summer exhibited least interactive forces on the genotypes. The T1 and T6 were found to be non sensitive to environmental interactive forces (Fig. 5). Of this two genotypes, T6 with high number of pods per plant can be selected. Babu *et al*.(2009) studied the phenotypic stability in blackgram using AMMI model and identified four genotypes as stable as situated close to centre of IPCA axis in biplot 2. Stability studies using AMMI model by Pratap *et al*. (2009), in green gram indicated that seven genotypes out of 12 were stable for number of pods per plant. Interaction of genotypes and environments when considered together, the high pod bearing genotypes T1, T3, T5, T6, T7, T8 and T9 and environment E1and E2 recorded positive IPCA 1 values and hence interacting with each other positively. These genotypes can be recommended in these environments to obtain maximum pods.

For length of pods, the interaction biplot (Fig. 6) showed that the environments E2 and E5 *i.e.*, shade condition under kharif season and open condition under summer season exerted strong interactive forces respectively while the environment E6 that is shade condition under summer season exerted less interactive forces on the genotypes. The T1 and T3 were comparatively non sensitive to environmental interactive forces. Of this two genotypes, T3 having longer pods can be selected. Maximum length of pods can be obtained if the genotypes belonging to Class I *viz.*, T6, T7, T12 and T13 are recommended in the environments E2 and E6.

T10 which had IPCA 1 value near to zero can be considered as stable for number of seeds per pod. The environments E1 and E6 that is open condition under kharif season and shade condition under summer season exerted strong interaction and the environment E2 shade condition under kharif season exerted less interaction over the genotypes for the trait (Fig. 7). Babu *et al*. (2009) studied the phenotypic stability in blackgram using AMMI model and identified three genotypes as stable across environments for seeds per pod. The positive interaction of the genotypes belonging to Class I (T1, T2, T3, T5 and T7) in the environments E1 and E6 suggests that they can be recommended in E1 and E6 for the trait.

The 100/1000 seed weight under environment E2 and E3 shade condition under kharif season and open condition under rabi season exerted strong interaction while the environments E4 and E5 that is shade condition under rabi season and open condition under summer season exerted lesser interactive forces on the genotypes. The T2 and T9 were non sensitive to environmental interactive forces (Fig. 8). Both the genotypes were having moderately high mean value indicating that these genotypes can be selected. Babu *et al*. (2009) studied the phenotypic stability in blackgram using AMMI model and identified three genotypes as stable across environments. Stability studies using AMMI model by Pratap *et al*. (2009), in green gram indicated that four genotypes out of 12 were stable for 100 seed weight. Genotypes T1, T2, T3, T4, T6, T9, T10 and T11 can be recommended for E3, E4 and E5 for getting maximum test weight.

T10 and T6 were having high main effects for yield per plant but away from IPCA 1 indicate that even though they are high yielders, the performance cannot be predicted. The environments E6 and E3 that are shade condition under summer season and open condition under rabi season exerted strong interactive patterns and the environments E4 and E2 that is shade condition under kharif and rabi season exerted lesser interactive patterns on the genotype for yield per plant. T5 and T11 were nonsensitive to environment (Fig. 9). Of these two genotypes the T5 with high mean value (14.54) can be selected. Babu *et al*. (2009) studied the phenotypic stability in blackgram using AMMI model and identified three genotypes as stable for yield per plant. Considering the interaction of genotypes and environments together, the high yielding genotypes T2, T3, T6, T7 and T8 and environment E2 and E3 recorded positive IPCA 1 values and hence interacting with each other positively. Hence, these selected genotypes can be recommended in this environment for high yield.The protein content of T10 with IPCA score near to zero was comparatively stable over environments. T13 and T14 were having similar interactive patterns. The environments E1, E2, E4 and E5 exerted strong interactive patterns while the environment E6 alone exerted lesser interactive patterns indicating the effect of environment in determining the trait protein content. The protein content of T1, T4 and T5 were comparatively stable over environments (Fig. 10). Of these, T5 with high mean value can be selected. Babu *et al*. (2009) studied the phenotypic stability in blackgram for protein content using AMMI model and identified three genotypes as stable. Stability studies using AMMI model by Pratap *et al*. (2009), in green gram indicated that four genotypes out of 12 were stable for protein content. Interaction of genotypes and environments when considered together, the genotypes with high protein content T1, T2, T5, T6, T7, T8 and T9 and environments E4, E5 and E6 recorded positive IPCA 1 values and hence interacting with each other positively. Hence, they can be recommended in these environments for high protein yield.

Based on AMMI analysis of the fourteen blackgram genotypes over six environments, the culture T6 (4.5.9; T9 x Rusami) which was stable for days to flowering, number of branches per plant, pod bearing branches per plant and pods with early flowering and high number of branches per plant, pod bearing branches per plant and pods can identified as the best genotype suitable for all environments for these traits. Even though the stability parameters of this genotype for yield is not promising the genotype exhibited higher values of mean yield. Hence, the genotype can be considered as best genotype. Based on the grain yield alone the T5 with high mean yield and stability can be selected for cultivation under all environments.

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Table 1. Details of the environment

Sl. No	Season / condition	Environment	Symbol
1	Kharif (Open)	Environment 1	E1
2	Kharif (Shade)	Environment 2	E2
3	Rabi (Open)	Environment 3	E3
4	Rabi (Shade)	Environment 4	E4
5	Summer (Open)	Environment 5	E5
6	Summer (Shade)	Environment 6	E6

Table 2.Detail of cultures and check varieties used in the study

S.N	advanced generation	Details of advanced generation	Parental cross
1.	T_1	4.1.1	T9 x TAU 1
2.	T_2	4.5.2	T9 x Rusami
3.	T_3	4.5.3	T9 x Rusami
4.	T_4	4.5.7	T9 x Rusami
5.	T_5	4.5.8	T9 x Rusami
6.	T_6	4.5.9	T9 x Rusami
7.	T_7	4.5.9	T9 x Rusami
8.	T_8	4.5.18	T9 x Rusami
9.	T_9	4.6.1	T9 x Sumajana
10.	T_{10}	6.4.1	Sumanjana x T9
11.	TAU-1	-	-
12.	T-9	-	-
13.	Sumanjana	-	-
14.	Syama	-	-

Table 3. Analysis of variance for AMMI for different traits

Source of variations	Df	Days to flowering	Plant height	Number of branches	Number of pod bearing branches	Number of pods	Length of pods	Number of seeds per pod	Test weight	Protein content	Yield per plant
Genotypes	13	2.72*	23.65	0.44	0.41*	56.01*	0.20*	0.32	0.59*	4.13	11.64*
Environments	5	14.97*	18.72	54.83*	49.29*	1675.14*	1.94*	1.78*	0.26*	18.38*	48.23*
G x E Interaction	65	1.07	28.30	0.38	0.30	11.01	0.06	0.17	0.06	2.34	1.41
IPCA1	17	1.91*	52.32*	1.10*	0.64*	30.73*	0.14*	0.32*	0.11*	3.33*	3.91*
IPCA2	15	1.37*	30.31*	0.22*	0.36*	8.62*	0.06*	0.22*	0.07*	2.60*	0.92*
Residual	20	0.38	8.17	0.02	0.04	0.65	0.01	0.02	0.02	1.02	0.25

*****significant at 5% level

Table 4.a. Mean and IPCA scores of different genotypes and environments

Genotypes	Days to flowering			Plant height			Number of branches		
	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2
1	36.58	-0.49	-1.01	45.22	3.80	1.58	4.77	-0.42	-0.47
2	34.89	0.62	-0.45	40.75	0.25	0.92	4.67	0.12	-0.61
3	35.85	-0.05	-0.68	41.92	-0.64	0.40	4.85	-0.42	-0.25
4	35.66	-0.94	0.60	44.01	-1.39	1.19	4.89	-0.27	0.79
5	36.24	-0.67	-0.38	42.42	0.07	1.16	4.90	-0.78	0.04
6	34.80	0.20	-0.17	44.35	-0.56	1.68	4.98	0.08	0.07
7	35.57	-0.52	0.30	43.89	-0.71	-0.86	4.98	0.27	0.27
8	36.22	-0.64	0.19	45.48	0.42	-0.73	5.03	0.08	-0.34
9	35.45	0.24	-0.47	42.03	0.79	-1.30	5.14	-0.18	-0.02
10	34.94	0.16	0.00	42.45	-0.65	-1.49	5.17	0.39	0.38
11	35.00	0.37	1.29	43.76	-2.01	1.27	4.76	0.62	-0.07
12	36.06	1.60	0.07	43.79	2.22	-1.59	5.67	1.42	0.37
13	36.52	0.39	0.18	41.18	-1.41	-1.56	5.32	0.45	-0.53
14	36.79	-0.29	0.52	38.02	-0.19	-0.67	5.31	0.08	-0.07
E1	36.11	2.12	0.23	40.75	2.01	1.30	7.82	0.10	1.04
E2	36.29	-0.87	1.16	42.49	0.46	3.29	7.17	1.34	-0.83
E3	33.79	-0.27	1.06	44.20	3.38	-2.67	4.18	-0.78	0.04
E4	35.79	-0.24	-0.84	43.27	-2.63	-0.91	3.45	-0.49	0.090
E5	36.79	-0.50	-0.78	42.85	-0.58	-0.10	3.56	-0.49	-0.18
E6	35.78	-0.24	-0.83	43.27	-2.63	-0.91	3.48	-0.61	-0.15

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Table 4.b. Mean and IPCA scores of different genotypes and environments

Genotypes	Number Pod bearing branches			Number of pod			Length of pods		
	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2
1	4.45	-0.49	-0.16	34.83	0.00	-0.18	4.43	-0.18	-0.04
2	4.48	-0.10	-0.52	37.40	-0.82	0.37	4.53	-0.15	0.48
3	4.54	-0.51	-0.13	40.13	1.22	-1.84	4.52	-0.20	-0.02
4	4.70	-0.04	0.91	35.61	-1.98	0.56	4.42	-0.11	0.46
5	4.47	-0.82	-0.10	40.91	3.32	-0.13	4.27	-0.26	-0.28
6	4.92	0.06	-0.34	38.86	1.27	0.25	4.85	0.16	-0.26
7	4.83	0.01	0.29	41.66	4.07	-0.62	4.38	0.07	-0.33
8	4.53	0.14	-0.12	43.04	5.45	1.97	4.46	-0.07	0.15
9	4.87	-0.35	0.11	38.72	1.13	-0.08	4.40	-0.34	-0.09
10	4.73	-0.05	0.26	37.10	-0.49	-0.04	4.25	-0.29	-0.16
11	4.34	-0.24	0.23	33.15	-4.44	0.47	4.10	-0.07	0.37
12	5.25	1.01	0.53	34.50	-3.09	0.97	4.22	0.79	0.04
13	4.82	0.61	-0.69	36.14	-1.45	-0.34	4.28	0.72	0.01
14	5.08	0.74	-0.29	34.19	-3.40	-1.37	4.23	-0.06	-0.32
E1	7.26	0.97	1.12	51.57	3.29	1.92	5.04	-0.41	-0.43
E2	6.76	1.09	-0.98	51.70	1.07	-0.99	4.62	0.81	-0.30
E3	4.63	-0.72	0.14	32.73	-3.21	1.98	4.14	-0.75	-0.21
E4	3.53	-0.47	0.08	29.71	-0.51	-0.96	4.15	-0.03	0.56
E5	3.15	-0.25	-0.27	29.71	-0.51	-0.96	4.15	-0.03	0.56
E6	2.96	-0.63	-0.9	30.12	-0.13	-0.98	4.19	0.40	-0.17

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Table 4.c. Mean and IPCA scores of different genotypes and environments

Geno types	Number of seeds per pod			Test weight			Yield per plant			Protein content		
	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2	Mean	IPCA 1	IPCA 2
1	5.11	0.57	0.87	4.01	0.05	0.41	12.74	-0.47	-0.64	20.05	0.39	0.07
2	4.96	0.52	-0.50	4.39	0.05	0	13.69	0.62	-0.23	19.69	0.59	0.43
3	5.27	0.53	-0.31	4.47	0.43	-0.03	14.67	1.39	0.55	20.98	-1.06	-0.04
4	4.90	-0.10	0.37	4.48	0.13	0.12	14.30	-0.88	0.51	19.90	-0.51	-0.24
5	5.10	0.68	0.09	4.68	-0.22	0.02	14.54	-0.20	-0.19	21.60	0.04	-0.44
6	5.11	-0.10	0.04	4.73	0.59	-0.52	16.36	1.21	0.30	20.44	1.07	-0.07
7	4.85	0.14	-0.13	4.57	-0.11	-0.16	14.41	0.47	-0.71	20.93	0.36	-0.96
8	4.97	-0.17	0.20	3.76	-0.22	-0.08	14.40	0.78	-0.37	21.14	0.30	1.09
9	5.05	-0.50	0.05	4.43	0.07	0	14.10	-0.09	1.17	20.07	1.35	-0.23
10	4.80	-0.04	-0.34	4.36	0.41	0.07	15.92	-1.25	-0.01	20.33	-0.97	0.61
11	4.56	-0.66	0.30	4.20	0.06	0.63	12.19	-0.07	-015	19.95	-0.07	1.49
12	4.50	-0.17	-0.09	3.95	-0.40	-0.44	12.37	-0.20	-0.65	18.65	-1.20	-0.41
13	4.80	-0.30	-0.53	3.98	-0.57	0	11.99	-0.49	0.15	19.14	-0.13	-0.61
14	4.56	-0.40	0	3.85	-0.29	0	12.12	-0.82	0.27	19.23	-0.15	-0.71
E1	5.57	0.47	1.13	4.21	-0.61	-0.40	15.85	-0.49	-1.05	18.36	-1.39	-1.39
E2	4.95	0.03	-0.38	4.21	-0.56	0.76	15.96	0.35	-0.47	20.31	-0.57	-0.57
E3	4.90	-0.81	-0.17	4.50	0.75	0.10	14.64	2.45	0.27	21.43	-0.76	-0.76
E4	4.68	-0.40	0	4.31	0.27	0.06	12.32	-0.67	0.06	21.07	0.95	0.95
E5	4.68	-0.40	0	4.31	0.27	0.06	12.20	-0.84	-0.31	20.45	1.49	1.49
E6	4.60	1.08	-0.60	4.10	-0.12	-0.57	12.09	-0.81	1.49	19.28	0.29	0.29

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Table 5. Classification of genotypes into distinct classes based on mean and IPCA 1

Genotypes	Days to flowering	Plant height	Number of branches	Number Pod bearing branches	Number of pod	Length of pods	Number of seeds per pod	Test weight	Yield per plant	Protein content
	Class									
1	II	I	II	II	I	II	I	I	II	I
2	I	I	I	II	II	II	I	I	I	I
3	II	II	II	II	I	II	I	I	I	II
4	II	II	II	I	II	II	II	I	II	II
5	II	I	II	II	I	II	I	II	II	I
6	I	II	I	II	I	I	II	I	I	I
7	II	II	I	I	I	I	I	II	I	I
8	II	I	I	II	I	II	II	II	I	I
9	I	I	II	I	I	II	II	I	II	I
10	I	II	I	I	II	II	II	I	II	II
11	I	II	I	I	II	II	II	I	II	II
12	I	I	I	I	II	I	II	II	II	II
13	I	II	I	II	II	I	II	II	II	II
14	II	II	I	II	II	II	II	II	II	II

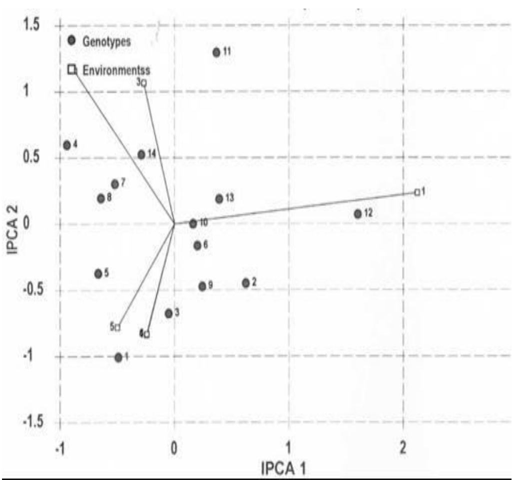


Fig. 1. Interaction biplot of Days to flowering

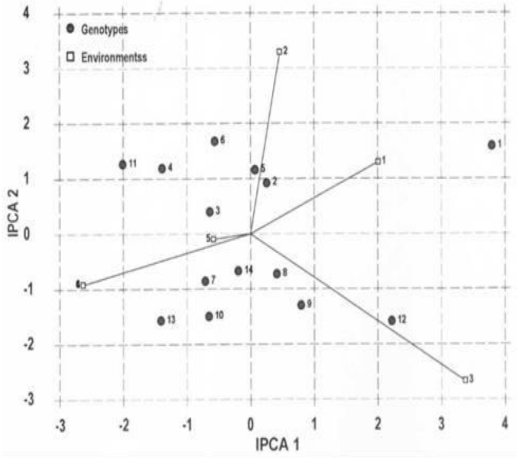


Fig. 2. Interaction biplot of Plant height

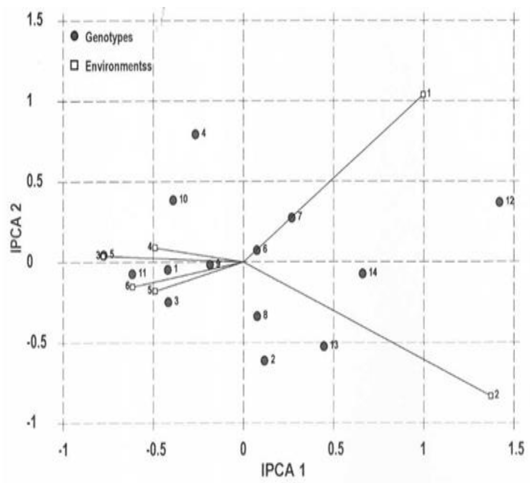


Fig. 3. Interaction biplot of number bearing branches per plant

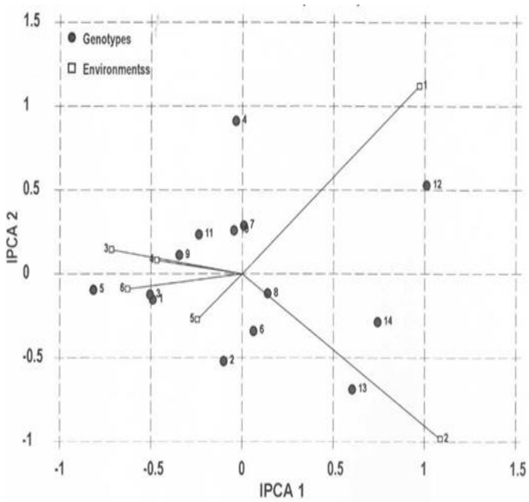
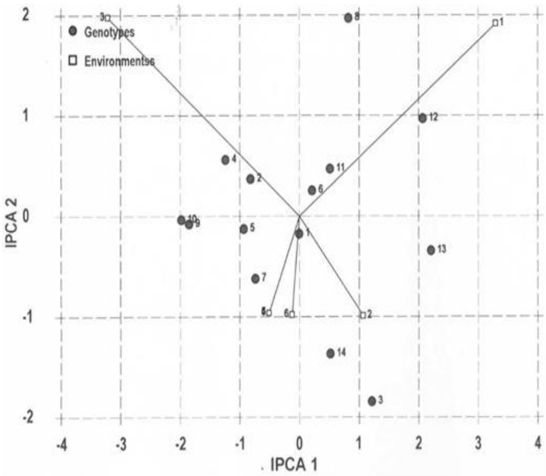


Fig. 4. Interaction biplot of number of pod of branches per plant



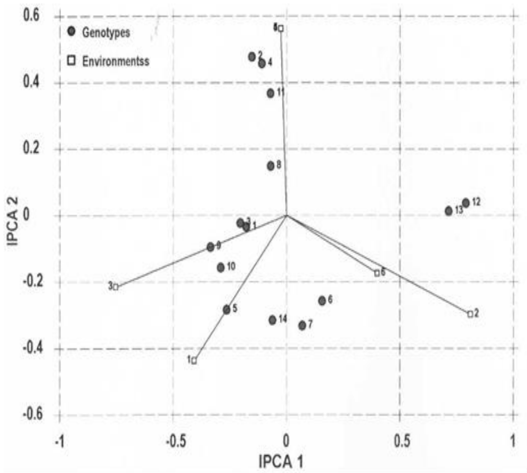


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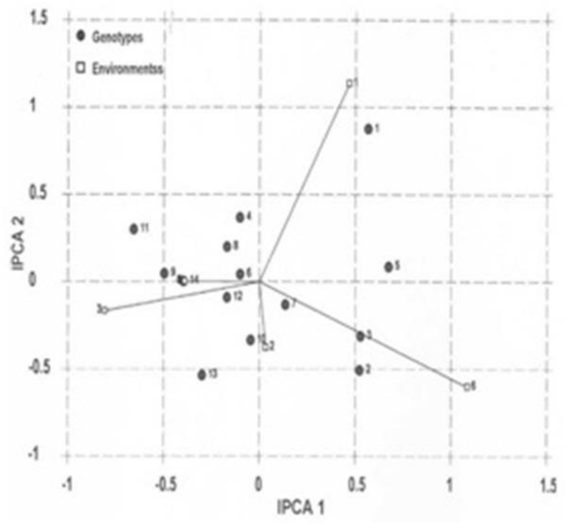
Fig. 5. Interaction biplot of number of pods/plant **Fig. 6. Interaction biplot of length of pods**



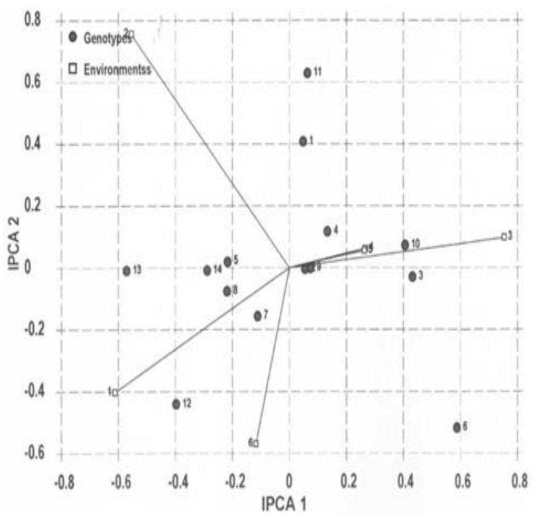
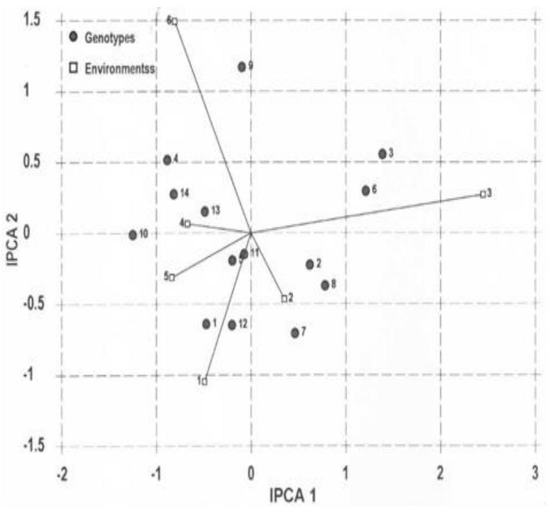


Fig. 7. Interaction biplot of number of seeds/pod **Fig. 8. Interaction biplot of test weight**



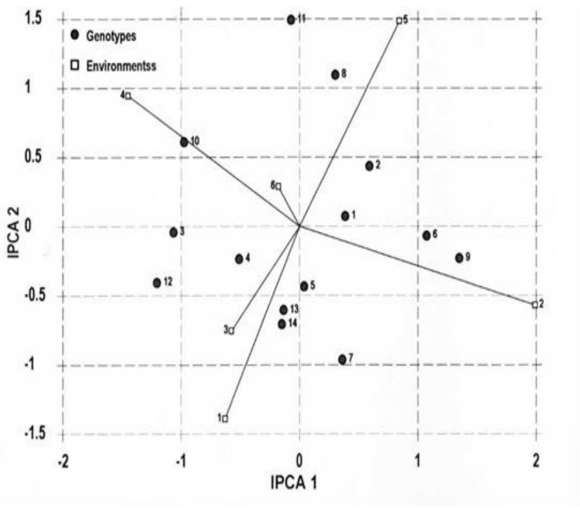


Fig. 9. Interaction biplot of yield per plant **Fig.10. Interaction biplot of protein content**