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Research paper

Simultaneous selection for yield and stability in pigeonpea of north east plain zone of India

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ABSTRACT

Yield improvement is the prime objective of any varietal development programs. Therefore, stability of the yield becomes an important criterion in pigeon pea because it is cultivated in rainfed conditions. For the varietal development program, multi-environment trials are conducted to advance the entries at different stages of the trial and in turn to release as varieties. Multi-environmental trials have generally significant genotype and genotype × environment interactions effect, and different univariate and multi-variate stability methods have been used to study the genotype × environment interactions. The present study comprises fourteen pigeon pea entries of the initial varietal trial that were evaluated at five locations viz. Varanasi, Dholi, Ranchi, Kanpur, and Araul representing the North East Plain Zone of All India Coordinated Research Project on pigeon pea program during Kharif 2020-21. The AMMI model is used for genotype × environment interactions investigation. The combined index Model -I and II were used based on the weighted average for stability and yield components at 50:50 in model-I and 20:80 in model-II respectively. Based on both the combined indices the entries IPA18-33 and IPA203 were recorded as highly stable high-yielding entries for future use.

***Key words*: AMMI, Pigeonpea, Selection indices, Stability.**

INTRODUCTION

Pulses are the major source of dietary protein and other nutritional requirements for a large mass of vegetarian population in India. Pulses are generally grown under the diverse agro-climatic conditions of the country. Among the different pulses grown in India, pigeonpea (*Cajanus cajan* (L.) Millisp.) stands second in terms of area (4.015 m ha) and production (3.312 mt), after chickpea (Directorate of Pulses Development, 2022; Directorate of Economics and Statistics, 2022). Pigeonpea thrive in hot dry climates; their drought tolerance and ability to use residual moisture with low inputs make them the important choice of dry land farming.

Yield has been given the top priority for varietal development program in almost all the crops and stability of the yield becomes an important criterion therein (Singh *et al.*, 2018; Sawargaonkar *et al.*, 2011; Deepak *et al.*, 2020). A vast area of pigeon pea cultivation is under rainfed conditions in the country where environmental factors control a significant proportion of the genotypic expression (Ramesh *et al.*, 2017). The importance of genotype and environmental interaction (GEI) in breeding programs and multi-location genotype evaluations under all India-coordinated trials and state adoptive trials are well-known in many crops, including chickpea (Hemant *et al.*, 2020). The yield fluctuations over the years and locations can be attributed to variations in biotic as well as abiotic factors prevalent in different ecological regions of the country. Yield stability between genotypes is variable due to the wide occurrence of GEI i.e., the ranking of genotypes depends on particular environmental conditions where they are grown (Beckor and Leon, 1988).

GEI poses a continuous challenge to the plant breeder and agronomists in making cultivar recommendations for farmers because of the associated implications especially when selection is based solely on yield (Kang, 1993). This may be due to a lack of emphasis on both yield and stability in most breeding programs (Mekbib, 2002), as well as a lack of policies in which varieties are released without consideration of yields and stability simultaneously. Kang (1993) cautions that cultivar recommendations made based on yield only as it is conventionally done, can pose a serious risk to growers who may not realize that they are growing varieties that do not perform well under certain conditions. Therefore, it is essential to establish selection indices that simultaneously combine yield and stability in the pigeonpea variety development program. Rao and Prabakaran (2005) developed an additive main effects and multiplicative interaction (AMMI) based selection index for selecting genotypes tested across multiple environments that integrates both yield and stability. This study therefore aimed to identify the varieties that have a stable performance across regions using the AMMI-based selection index in pigeonpea in the Northeast Plain Zone of India.

MATERIALS AND METHODS

The present experimental materials composed of 14 promising pigeonpea entries of the initial varietal trial were evaluated at five locations viz. Varanasi, Dholi, Ranchi, Kanpur, and Araul representing the North East Plain Zone of All India Coordinated Research Project on the pigeonpea program during 2020-21. At all five locations, the experiment was laid out in a Randomized Complete Block Design (RCBD) with each genotype replicated three times in a plot size of 20 m^2. At each location, the experiment was laid down using standard agronomic practice to raise healthy crops and each experimental plots were kept free of weeds by different means. Mineral fertilizers and/ or supplementary water through irrigation were applied during the crop growth periods as and when it was required to raise the good crop stand. The threshed grain per plot was then weighed on a plot basis to obtain plot grain yield which was later extrapolated to yield per hectare.

The AMMI model for T genotypes and S environments is given as

$$Y_{ij} = \mu + g_i + e_j + \sum_{n=1}^{n'} \lambda_n \alpha_{in} \gamma_{jn} + \theta_{ij}$$

$\theta_{ij} \sim N(0, \sigma^2)$, i =1, 2,……, T; j =1, 2,……, S

The model can be re-parameterized as

$$Y_{ij} = \mu + g_i + e_j + Z_{ij}$$

$$Z_{ij} = \sum_{n=1}^{n'} \lambda_n \alpha_{in} \gamma_{jn} + \theta_{ij}$$

Z_{ij} is the interaction in the $(i,j)^{th}$ cell, and matrix notation, Z= Z_{ij} is a matrix of order T ×S.

Where,

Y_{ij} =the mean yield of i^{th} genotype in the j^{th} environment;

g_i = i^{th} genotypic effect;

e_j = j^{th} location effect;

λ_n = the non-zero eigenvalues of Z'Z or ZZ' (in descending order)

α_{in} = the principal components of the rows of the sum of squares and cross-product matrix ZZ'

γ_{jn} = the principal components of the columns of the sum of squares and cross-product matrix Z'Z

n' =the number of PCA axes retained in the model.

The stability measure, $ASTAB_i$ for i^{th} genotypes is given as

$$ASTAB_i = \sum_{n=1}^{n'} \lambda_n \alpha_{in}^2$$

A variety is considered more stable when the value of $ASTAB_i$ is lower (Rao, and Prabhakaran, 2005),

The selection indices (I_i) consist of (a) a yield component, measured as the ratio of the average performance of the i^{th} genotype to the overall mean performance of the genotypes under test, and (b) a stability component, measured as the ratio of stability information (l/$ASTAB_i$) of the i^{th} genotype

The simultaneous selection index is computed as

$$I_i = v1 \frac{\bar{Y}_i}{\bar{Y}_{..}} + v2 \frac{(1/ASTAB_i)}{\sum_{i=1}^{T}(1/ASTAB_i)}$$

Where, v1 and v2 are the weight given to the yield index and stability information index, so that v1+v2=1. Two simultaneous selection models were tested based on different weightages given to each index. In Model I, the yield and stability component weightage were 50% and 50%, respectively, while in Model II, the weightage of the yield component was 80% and the stability component was 20%.

RESULTS AND DISCUSSION

Variance due to genotypic × environment was significant for yield per ha over the locations in the present study. The presences of genotypic

× environmental interactions exhibit a challenge to crop breeders for developing wide adoptive varieties for a zone is in consideration. However, significant G × E implies the responsive behavior of the genotype in that particular environment wherein it is grown; this can be an advantage for selecting location-specific varieties (Ceccarini, 1989; Hill, 1975). However, the all-India Coordinated Research trials generally target the wide adoptive zone-specific or multi-zone adoptive varieties. Under such circumstances, the performance of any one genotype relative to the remaining genotype(s) grown in the same environment would be inconsistent, causing alterations to the ranking of the genotypes from environment to environment.

The mean performance of the genotypes over the locations can lead to changes in the absolute difference between genotypic per se mean for the trait under consideration; however, the rank order of the genotype may remain unchanged upon the use of simultaneous or combined selection indices (Tukamuhabwa *et al*., 2012). The entry IPA 19-26 recorded the high yield index (1.09294) corresponding to yield rank one, whereas for stability it has rank eight (Table 1). Similarly, the most stable ranked entry IPA 18-33, recorded the yield rank eight. The deviation for yield and stability is largely due to genotypic × environment interactions, selecting entries based on individual statistics will lead to confusion for advancing stable high-yielding entries across the locations (Table 1). Eisemann, 1990, opined that the approach of exploiting the breeder's objectives by analyzing and interpreting genotypes and environments enables researchers to determine the causes of genotype × environment interactions and provides opportunities to modify these interactions through genetic or environmental manipulations to improve the performance of entries. However, selecting such responsive genotypes (high yield low stable) is often resource intensive and the slightest variation in the environmental factors may lead to significant deviation in per se mean performance.

Table 1. Yield index, stability index, and corresponding rank of entry

S. No.	Entries	Yield index	Yield Rank	Stability Index	Stability Rank
1	Bahar	1.00974	6	0.95619	5
2	MA6	1.03919	5	0.73616	10
3	IPA203	0.97701	9	1.51833	2
4	Pusa196	0.94359	12	0.61402	11
5	IPA19-55	0.94111	13	0.78154	9
6	DA2020-2	1.09255	2	0.93655	6
7	IPA18-33	0.98286	8	3.20533	1
8	IPA19-6	0.96244	10	0.35584	13
9	IPA19-26	1.09294	1	0.88217	8
10	KA18-1	0.95083	11	1.19813	3
11	DA2020-1	0.83728	14	0.48607	12
12	Pusa195	0.98683	7	1.05374	4
13	Pusa197	1.09185	3	0.93459	7
14	MAL53	1.09175	4	0.34135	14

In order to conserve resources, genotypes that are widely adaptable and with reliable performance across environments need to be identified through analysis and utilization of GEI. Several statistical methods (non-parametric and parametric) have been proposed for studying the GEI (Lin *et al.,* 1986). These include the biological or static concept, where the ideal genotypes would be those presenting minimum variation across environments, showing constant performance in any area (minimum statistical variance), as well as the agronomic or dynamical concept, where the objective is to obtain an increase in yields in response to environmental improvements (Becker and Leon, 1988). To analyze genotype × environmental interactions, it is important to integrate both yield and stability of genotype performances across environments using reliable stability statistics (Kang, 1993). Rao and Prabhakaran (2005) developed combined or simultaneous selection indices by giving weights to the different parameters.

The simultaneous selection index for the fourteen entries was computed as described by Rao and Prabhakaran (2005) using SAS (Statistical Analysis System) code (Table 2). The present analysis was done by retaining maximum principal components so that >90% of total variations were captured by the AMMI model. The entry IPA18-33 with 2.0941 index value was found the best entry followed by IPA203 with index value 1.2477 and KA18-1 with index value 1.0745 in Model-I wherein stability component w2=0.5 and yield component w1=0.5 were given equal weights (Table 2). Whereas, in Model-II, the stability component (w2=0.20) and yield component (w1=0.80) were given 20:80 weights respectively recorded that the entry IPA18-33 with 1.4274 index value was found best entry followed by IPA203 with index value 1.0853 and DA2020-2 with index value 1.0613 (Table 2). Hence, these genotypes (IPA18-33, IPA203, KA18-1, and DA2020-2) may be used by the pigeon pea breeder for developing high-yield and stable pigeon pea lines on AMMI-based simultaneous selection for yield and stability.

Table 2. Combined index and corresponding rank of entries

S. No.	Entries	Model-I Yield: Stability=50:50		Model-II Yield: Stability=80:20	
		Index	Rank	Index	Rank
1	Bahar	0.9830	8	0.9990	8
2	MA6	0.8877	9	0.9786	9
3	IPA203	1.2477	2	1.0853	2
4	Pusa196	0.7788	11	0.8777	12
5	IPA19-55	0.8613	10	0.9092	11
6	DA2020-2	1.0145	5	1.0613	3
7	IPA18-33	2.0941	1	1.4274	1
8	IPA19-6	0.6591	14	0.8411	13
9	IPA19-26	0.9876	7	1.0508	5
10	KA18-1	1.0745	3	1.0003	6
11	DA2020-1	0.6617	13	0.7670	14
12	Pusa195	1.0203	4	1.0002	7
13	Pusa197	1.0132	6	1.0604	4
14	MAL53	0.7166	12	0.9417	10

CONCLUSION

The present study describes a new approach for selecting superior genotypes of pigeon pea through AMMI analysis based on yield performance and stability of the genotypes under multi-environment trials. The model was able to identify genotypes namely IPA18-33, IPA203, KA18-1, and DA2020-2 with higher yield and stable performance over locations by giving 50:50 and 80:20 weights for yield: stability respectively. The present study can lead to the identification of stable genotypes as future varieties which will provide much-needed stability in yield performance. The model has a scope of similar utilization in other pulse crops as well where higher genotypes × environment interactions are present.

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REFERENCES

Becker HC and Leon J. 1988. Stability analysis in plant breeding. Plant Breeding **101**(1): 1-23.

Ceccarelli S. (1989). Wide adaptation: How wide? Euphytica **40**(3): 197-205.

Deepak Pal, Verma SK, Gaur AK, Chauhan C, Karn A, Yadav H and Harshdeep. 2020. Stability Analysis in Pigeonpea (Cajanus cajan (L.) Millspaugh) Genotypes for Yield and its Component Traits. International Journal of Current Microbiology and Applied Sciences **9**(9): 264-271.

Eisemann R L, Cooper M and Woodruff DR. 1990. Beyond the analytical methodology, better interpretation and exploitation of GE interaction in plant breeding. In Genotype-by-environment Interaction and Plant Breeding, Kang MS (Ed.). Louisiana State Univ. Agric. Center, Baton Rouge, LA. Pp. 108-117

Hill J. 1975. Genotype-environment interactions-a challenge for plant breeding. Journal of Agricultural Science **85**(3): 477-493.

Hemant Kumar, Dixit GP, Srivastava AK and Sing NP. 2020. AMMI-based simultaneous selection for yield and stability of chickpea genotypes in south zone of India. Legume Research **43**(5): 742-745

Kang MS. 1993. Simultaneous selection for yield and stability in crop performance trials: Consequences for growers. Agronomy Journal **85**(3): 754-757.

Mekbib F. 2002. Simultaneous selection for high yield and stability in common bean (Phaseolus vulgaris) genotypes. The Journal of Agricultural Science **138**(3): 249-253.

Ramesh S Muniswamy and Praveenkumar B. 2017. stability analysis for yield and its components in pigeonpea [*Cajanus cajan* (L.) Mill sp.] under rainfed conditions. International Journal of Current Microbiology and Applied Sciences **6**(5): 1134-1144.

Rao AR and Prabhakaran VT. 2005. Use of AMMI in simultaneous selection of genotypes for yield and stability. Journal of the Indian Society of Agricultural Statistics **59**: 76-82.

Rao AR and Prabhakaran VT. 2005. Use of AMMI in simultaneous selection of genotypes for yield and stability. Journal of the Indian Society of Agricultural Statistics **59**: 76-82.

Sawargaonkar SL, Saxena KB, Madrap IA and Rathore A. 2011. Stability analysis of yield and related traits in pigeonpea hybrids. Journal of Food Legumes **24**(3): 184-193.

Singh Ja , Kumar A, Abdul Fiyaz R and Singh MK. 2018. Stability analysis of pigeonpea genotypes by deployment of AMMI model under rainfed environment. Legume Research **41**(2): 182-188.

Tukamuhabwa P, Oloka HK, Sengooba T and Kabayi P. 2012. Yield stability of rust-resistant soybean lines at four mid-altitude tropical locations. Euphytica **183**: 1-10.

Lin CS, Binns MR and Lefkovitch LP. 1986. Stability analysis: where do we stand. Crop Science **26**: 894-900.