ISSN : 2321-9602

Indo-American Journal of Agricultural and Veterinary Sciences

editor@iajavs.com
iajavs.editor@gmail.com

Indo-Am. J. Agric. & Vet. Sci., 2024

ISSN 2321–9602 www.iajavs.com
Vol. 12, Issue 4 Oct 2024

Indo-American Journal of Agricultural and Veterinary Sciences

Genotypic Variation in Late-Set Pigeon Pea (Cajanus cajan L.) Yield Stability

Md. Rifat Ahmed[1], Ayesha Akter Anne[2]

[1]Bako Agricultural Research Center, P. O. Box 03, Bako, Oromia Region, Ethiopia; [2]Dept. of Biochemistry & Molecular Biology, Gono Bishwabidyalay, Dhaka, Bangladesh.

Article Info

Received: 30-09-2024 *Revised: 18-10-2024* *Accepted: 29-10-2024*

ABSTRACT

In order to address the demands of farmers throughout the nation, a new pigeon pea breeding program has just been launched in Ethiopia. The program is actively working to improve the genetic yield potential by introducing new genotypes. The goal of this research was to assess the stability and performance of six late set pigeon pea genotypes, including the standard check, in terms of yield, as genotype performance is dependent on crop genetic potential and growing conditions. During the primary growing seasons of 2021, five sites in western Oromia—Bako, Billo, Gute, Uke, and Chewaka—had their yield performances assessed. There were three replications of the experiment at each site, using a Randomized Complete Block Design. The findings demonstrated that genotype-environment interaction (GEI) had a significant impact on the yield performances of late set pigeon pea genotypes. The effects of GEI on the yield components were substantial. The G + GE sum of squares was partitioned and found to have two significant components, IPCA1 and IPCA2, which contributed 29.72% and 34.86% of the total, respectively. These genotypes were very sensitive to their surroundings, exhibiting adaptation for high performance conditions and providing maximal output when inputs are not constrained. A highly significant mean square was reported for genotypes, genotypes by environment interaction, and environment. The ICEAP 01489 and 01499 genotypes showed good stability and yield performance in all of the tested conditions. Therefore, these two genotypes were chosen as potential candidates to be released the following season in Western Oromia and other regions with comparable agro-ecologies.

Keywords: Yield stability analysis, *Cajanus Cajan*, Genotype x environment, Late set, and Pigeon pea.

INTRODUCTION:

According to Fatokimi and Tanimonure (2021), the pigeon pea (Cajanus cajan L.) was rated sixth on the world stage, behind peas, broad beans, lentils, chickpeas, and common beans. Around the world, 4.49 million tons of it are grown each year on 5.4 million hectares of land. It is cultivated in around 82 countries throughout the globe. About 72% of the pigeon pea growing area is in India (FAO, 2017). In the southern and eastern parts of Africa, About 0.56 million hectares are devoted to growing pigeon peas (Esther and Victoria, 2021). Tanzania, Mozambique, Malawi, and Uganda all rely on pigeon pea as a major crop. It is often grown alongside several crops, including yam, millet, sorghum, and cassava (Egbe and Kalu, 2006). Pulses like this tropical grain legume are essential for human consumption, animal feed, and the enhancement of soil fertility. Rooted and drought-tolerant, this leguminous crop finds usage in a wide variety of dietary protein source in several nations (Troedson et al., 1990). Its seed is a good source of the protein your body needs since it is loaded with protein. According to Padhyaya and Reddy (2006), the protein content of the seed ranges from 18% to 29% by dry weight, which is much higher than cereals' value and somewhat lower than soybeans' 34%. Additionally, the protein is 258 of good quality and has a lot of lysine. Therefore, the crop is a great addition to meals that consist of grain and roots (Varshney et al., 2009).

As a key cash crop in many countries, including India and Malawi, pigeon pea has enormous economic potential (Silim and Mgonja, 2006). It has several applications in the pharmaceutical business and is a protein source for both people and animals (Egbe, 2005). Pigeon pea enhancement program started with germ- plasm introduction from the ICRISAT and neighboring countries to identify high-yielding, disease, and pest- tolerant cultivars. Pigeon pea research in terms of crop improvement is still at its infant stage in Ethiopia. The production of pigeon peas in the present agro-ecolo- gical area is inadequate due to a scarcity of released and widely adapted pigeon pea varieties, which are better in both biotic and abiotic aspects.

Hence, considering the importance of pigeon peas in food security and its potential for the future in the Ethiopian economy, it is important to increase its production and productivity through developing new ones. Hence, the current research was started to evaluate introduced pigeon pea genotypes, for releasing and registering improved varieties for production in the Western part of Oromia and areas with similar agro-ecologies (Ray et al., 2022; Mijena et al., 2023).

MATERIALS AND METHODS:

Six late set pigeon pea genotypes including check (**Table 1**) were evaluated at five locations for one year, during 2021 main cropping season. Each plot consisted of four rows of 4- meter length, with 60 cm and 40 cm inter and intra row spacing, respectively. NPS fertilizer was applied at the rate of 100 kg ha-1 at planting time. All other management practices were applied as per recommendation.

Data Analysis

Data Analysis an Additive Main Effects and Multipli- cative Interaction (AMMI) model was used to assess genotype by environment interaction (GEI) pattern.

AMMI model is expressed as:

$$\mathbf{Yger = \mu + ag + ße + ënãgnden + eger + ñge}$$

Where: Yger is the observed yield of genotype (g) in environment (e) for replication (r); µ is the grand mean; ag is the deviation of genotype g from the grand mean, ße is the deviation of environment e; ën is the singular value for IPCA, ãgn is the genotype eigen- vector for axis n, and den is environment eigenvector; eger is error term and ñge is PCA residual.

Accordingly, genotypes with low magnitudes, regard- less of the sign of interaction principal component analysis scores have general or wider adaptability; while genotypes with high magnitudes of IPCA scores have specific adaptability (Gauch, 1992; Umma *et al.,* 2014). Genotype plus genotype by environment variation (GGE) was used to assess the performance of genotypes in different environments. The environmental effects were removed from the data and results obtained from the data were used to calculate envi- ronment and variety scores and these scores were used to plot the standard principal component bi-plots (Yan and Kang, 2003).

Table 1: Pedigree and source of Late set pigeon pea genotypes used for the study.

S. No.	Pedigree	Source of materials	Remark
1	ICEAP 01489	ICRSAT	Line
2	ICEAP 01517	ICRSAT	Line
3	ICEAP 01204	ICRSAT	Line
4	ICEAP 01499	ICRSAT	Line
5	ICEAP 01485	ICRSAT	Line

6	Dursa	OARI	Line

Table 2: The study Environments and their main agro ecological features.

Location	**Longitude**	**Latitude**	**Altitude (m)**	**RF (mm)**	**Soil texture**
Bako	37°09'E	09°06'N	1650	1431	Sandy-clay
Gute	E:036038.196’	N:09001.061’	1915	NI	Clay
Billo	E:037^{0}00.165’	N:09^{0}54.097’	1645	1500	Reddish brown
Chewaka	036.11703’E	09.98285’N	1259	NI	Clay-loam
Uke	E:036032..391’E	N:09025.082’N	1319	NI	Sandy-loam

NI = not identified RF= Rainfall

RESULTS AND DISCUSSION:

Combined analysis of variance there were statistically significant differences (P< 0.01) among late set pigeon pea genotypes, environments and their interaction for grain yield (**Table 3**). This indicates the presence of genetic variation among the late set pigeon pea geno- types and possibility to select high yielding and stable genotype (s); the environments were variable and the responses of pigeon pea genotypes across environ- ments were also variable.

Table 3: Combined analysis of variance for grain yield of six late set pigeon pea genotypes evaluated at parts western Oromia, Ethiopia.

Source	DF	Type III SS	Mean Square
Environments	4	96664800.37	24166200.09**
Genotypes	5	3055106.62	611021.32**
Block within environment	8	162053.22	20256.65*
Interaction	20	4987682.22	249384.11**
CV (%)		5.84	

DF=Degree of freedom Gen=Genotype Loc=Location Rep=Replication **= significant at P = 0.01, *=significant at P=0.05 ns = non-significant

Performance of Genotypes across Environments The result presented in **Table 4** indicates the average mean grain yield of six late set pigeon pea genotypes including standard check evaluated across five envi- ronments in western Oromia in 2021 main cropping season. The pooled mean grain yield ranged from 1508.4 to 2039.3kg ha-1. Among all genotypes, geno- type ICEAP 01204, ICEAP 01517 and ICEAP 01485 was lower yielder at Chewaka and Gute respectively. Higher grain yield was obtained from genotype ICEAP 01499 at Billo, Bako and Uke followed by genotype ICEAP 01489 at the same location while genotype ICEAP 01485 was the highest yield at Uke. This difference could be due to their genetic potential of the genotpes. Hence, genotype 260 ICEAP 01489 was found to be the top yielder at all locations followed by genotype ICEAP 01499 at three locations: Billo, Bako and Uke. The differences in yield rank of late set pigeon pea genotypes across the test environments revealed that there was high genotype by environment interaction in terms of yield.

Table 4: Mean grain yield for late set Pigeon pea for individual and across location.

Genotypes	**Grain yield kg ha^{-1}**					**Comb. GY (kg ha^{-1})**	**Yield Adv. (%) check**
	Bako	**Uke**	**Chewaka**	**Gute**	**Billo**		
ICEAP 01489	1321.3	2649.1	1136.1	997.2	2902.5	1801.2	19.4 %
ICEAP 01517	1126.8	2813	470.4	437.97	2893.1	1548.3	
ICEAP 01204	1325.9	2987.1	393.5	471.3	2830.5	1601.7	
ICEAP 01499	1845.4	3045.4	736.1	709.3	3860.2	2039.3	35.2 %
ICEAP 01485	1377.8	3243.5	387.9	492.6	2479.5	1596.3	
Dursa	1588^{b}	2297.2	569.4	350.9	2736.5	1508.4	
Mean	1430.9	2839.2	615.6	576.6	2950.4	1682.5	

LSD (0.05)	233.8	271.5	66.9	76.8	144.3	72	
CV (%)	9.1	5.3	6.1	7.3	2.7	5.8	
P-value	**	**	**	**	**	**	

AMMI analysis

An output of the ANOVA table of AMMI model analysis of variance for grain yield is presented in **Table 5**. This analysis also revealed the presence of highly significant (P< 0.01) differences among late set pigeon pea varieties for grain yield. From the total treatment sum of squares, the largest portion (92.3%) was due to the environment's main effect; followed by genotype's main effect (63.35 %) and the effect of genotype by environment interaction was 25.9 %.

Table 5: Partitioning of the explained sum of square (SS) and mean square (MS) from AMMI analysis for grain yield of six late set pigeon pea genotypes used as testing materials.

Source of variation	Degree of freedom	SS	Explained SS (%)	MS
Total	89	105360555		1183826
Treatments	29	104707648		3610609**
Genotypes	5	3055200	2.9	611040**
Environments	4	96664674	92.3	24166169**
Interactions	20	4987773	4.8	249389**
Block	10	170655		17065ns
IPCA1	8	2293213	45.98	286652**
IPCA2	6	2017093	40.44	336182**
Residuals	6	677468		112911
Error	50	482252		9645

ns= non- significant, **= significant at 1% and *= significant at 5% probability level. SS= sum of square, MS= mean square

A large yield variation explained by the environments indicated the existence of both spatial and temporal diversity in test-environments, with large differences among environmental means that caused most of the variation in grain yield. In line with this result Tolessa and Gela, (2014) reported large yield variation of common bean genotypes due to environments. This also indicates the existence of a considerable amount of deferential response among the 261 evaluated pigeon pea genotypes to changes in growing environ- ments and the differential discriminating ability of the test environments. Substantial percentage of G × E interaction was explained by the IPCA-1 (45.98%); followed by IPCA-2 (40.44 %) and, therefore, used to the plot a two-dimensional GGE biplot. Amare and Tamado, (2014) and Temesgen *et al.* (2014) suggested the most accurate model for AMMI could be predicted by using the first two IPCA.

AMMI biplot analysis

AMMI biplot graphs with X-axis plotting IPCA1 (52.96 %) and Y-axis plotting IPCA2 (26.13 %) scores illustrate stability and adaptability of late set pigeon pea genotypes to tested environments (**Fig. 1**). The more the IPCA scores approximate to zero, the more stable or adapted the genotypes are over all the environments sampled. The variation of seed yield for each genotype was significant in the different environ- ments. G4 was specifically adapted to high yielding environments (**Fig. 1**). G5, G6, G3 and G2 were the most unstable genotypes and also adapted to low yielding environments and not stable. Billo, Uke and Bako locations were the potentially environmentally friendly than other testing locations (**Fig. 1**). G4 had the highest seed yield followed by G1. G4 had higher GEI in the environments of Bako and Billo. It has been reported that the genotypes that have the lowest IPCA score in AMMI biplot are an indication of the stability or adaptation over environments (Dolinassou *et al.,* 2016). It is further stated that the greater the IPCA scores, negative or positive, the more specific adapted genotypes to certain environments.

GGE biplot analysis

In GGE biplot (**Fig. 2**), IPCA1 and IPCA2 explained 52.98 and 26.13 %, respectively, of the pigeon pea genotypes by environment interaction and made a total of 79.1%.

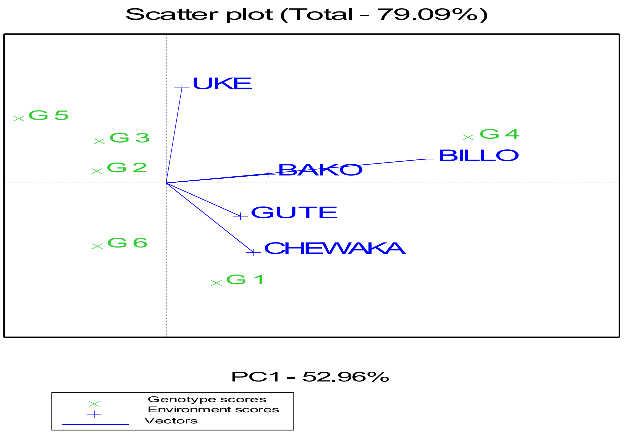

Fig. 1: Biplot of interaction principal component axis (IPCA1) against interaction principal component axis (IPCA2) of late set pigeon pea genotypes evaluated across environments.

Other studies conducted on groundnut by Amare and Tamado, (2014) and white lupines by Atnaf *et al.* (2017) explained an interaction of 81.8 and 63.4%, respectively, extracted from IPCA1 and IPCA2. An ideal genotype is defined as genotype which has the greatest IPCA1 score (mean performance) and with zero GEI, as represented by an arrow pointing to it (**Fig. 2**). A genotype is more desirable if it is located closer to the ideal genotype. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. In this study, genotype 4 which fell closest to the ideal genotype was identified as the most desirable genotypes as compared to the rest of the tested late set pigeon pea genotypes (**Fig. 2**). Similar results were reported by Dabessa *et al.* (2016) for groundnut.

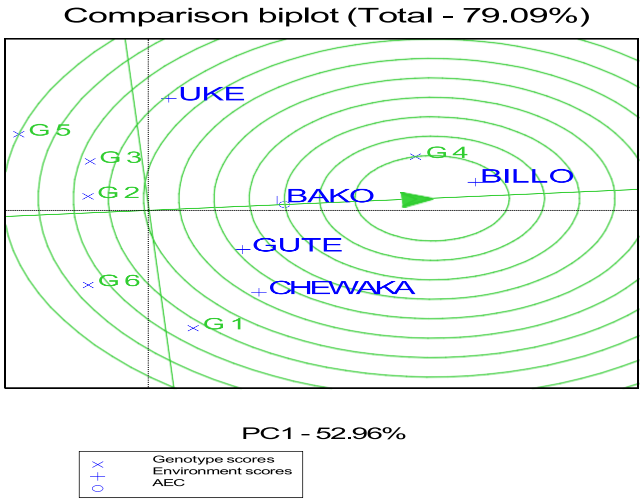

Fig 2: GGE-biplot based on genotype-focused scaling.

CONCLUSION AND RECOMMENDATIONS:

Environment, variety, and GEI had a significant impact on the grain yield performances of the late set pigeon peas that were examined, according to the combined analysis of variance. This suggested that various genotypes may react differently to a given environment or that certain genotypes might not perform consistently under all environments.

There was a very significant interaction impact between genotype and environment, as well as a main effect between variety and environment, in the case of late set pigeon pea genotypes. Grain yield fluctuation was largely caused by environmental factors. To evaluate the remaining late-set pigeon pea genotypes in western Oromia, genotype 4 may be used as a benchmark since it was closer to the optimal genotype. Genotype 4 was suggested for further investigation under variety verification experiment as the best late set pigeon pea genotype when mean yield and stability were considered together.

REFERENCES:

1) 1) In 2014, Amare and Tamado... Groundnut (Arachis hypogaea L.) top breeding lines in Eastern Ethiopia: genotype by environment interaction and pod yield stability. Vol. 3, Issue 1, pages 43–46, Star Journal. The link to the article is https://doi.org/10.4314/star.v3i2.6.

2) In 2017, Atnaf, Dagne, and Tesfaye published a study. Landraces of Ethiopian White Lupin (Lupi- nus Albus L.) Variegated by Genotype and Environmental Factors Influencing Stable Grain Yield. Research in the field of agricultural sustainability. Thirdly, in 2016, Dabessa, A., Abebe, Z., and Lule, D. Groundnut (Arachis hypogaea L.) variety stability in kernel yield and genotype-environment interaction in Western Oromia, Ethiopia. In the Journal of Agriculture and Crops, volume 2, issue 11, pages 113–120. 113–120 (https://ideas.repec.org/a/arp/jacarp/2016p113-120.).

4) In 2016, the authors Dolinassou, S., Djirantal, A. K., and Njintang, Y. N. Kernel yield stability and the interplay between genotype and environment in groundnut (Arachis hypogaea L.) in northern Cameroon. Vol. 4, Issue 1, Pages 001-007, Journal of Applied Biology and Biotechnology.

5) O. M. Égbe (2005). At the University of Agriculture in Makurdi, Nigeria, researchers assessed the agronomic potential of several pigeonpea genotypes for intercropping with maize and sorghum in the Southern Guinea Savanna.

6) In 2006, Egbe and Kalu published a paper. "Collaborative rural evaluation of pigeon pea cropping systems in the southern Guinea savanna of Nigeria: a farming systems study," The Review, 5(1), pp. 37-47. 2007; Victoria A. and Esther O. The present state of pigeon pea (Cajanus cajan) production in Oyo State, Nigeria, and its potential future outcomes: a Markov chain model study, The citation is from the Journal of Agriculture and Food Research, volume 6, article number 100218 from the year 2021. Access it at: https://doi.org/10.1016/j.jafr.2021.100218 on Google Scholar.

No. 8: FAO, 2017. Countries that produce pigeons data. The United Nations Food and Agriculture Organization is located in Rome, Italy, and it oversees production and area harvested crops.

In 2021, Fatokimi and Tanimonure published a paper. "Determining the present state of pigeon pea (Cajanus cajan) production in Oyo State, Nigeria: A Markov Chain model approach to analysis," Scientific Reports in Agriculture and Food, volume 6, page 100218. 66654323210204 https://www.sciencedirect.com/science/article/pii/S2

Gauch, G. (1992). (10). Regional yield trials statistical analysis: AMMI factorial design analysis. Published by Elsevier Science Publishers in Amsterdam, the Netherlands. On page 11, you may find the work of Gwata, Silim, and Mgonja (2006). "Fusarium wilt resistance in pigeon pea: the effects of a novel source," Citation: Journal of Phytopathology, 154(1), pages 62–64.

12-Hari, D. K. N. U padhyaya, and L. L. Reddy (2006). "Pigeon pea variety patterns Cajanus cajan (L.) seed stock from several Kenyan altitudes Pages 1787–1795 of the Journal of Genetic Research on Crop Evolution, volume 54. In 2023, Mijena, Getiso, Islam, and Shafi published a study (https://oar.icrisat.org/481/13). Assessing the

herbage production of several genotypes of Pennisetum purpureum grass. Pages 64–74 of the International Journal of Agricultural and Veterinary Science, volume 5, issue 4. DOI: 10.34104/ijavs.023.064074
Raymond BP, U.K. Nath, and M.A. Azad (2022). Examining the genetic makeup of rice genotypes with submergence tolerance using marker assay and introgression of the Sub1 QTL to the Indica HYV in breeding populations (F2). The citation is from the American Journal of Pure and Applied Science, volume 4, issue 1, pages 10-21. "https://doi.org/10.34104/ajpab.022.010021" referenced in the article.
In 2014, Temesgen, Mammo, and Lule published a study. Genotype by Environment Interaction (G x E) and Grain Yield Stability Analysis of Ethiopian Linseed and Niger Seed Varieties. J. of Applied Biosciences, 80(1), pp.7093-7101.
16) Tolessa, T.T. and Gela, T.S., (2014). Sites regression GGE biplot analysis of haricot bean (Phaseolus vulgaris L.) genotypes in three contrasting environments. World J. of Agricultural Research, 2, pp.228-236.
17) Troedson R. J., E. S. Wallis, and L. Singh, (1990). Pigeon Pea Adaptation, CAB Inter, Wallingford, UK. https://doi.org/10.1017/S0014479700020688

18) Umma, K., Jamil, H., and Niaz, F. R., (2014). "Stability for BRRI developed Promising Hybrid Rice for Yield and its related traits." J. of Applied Science and Agriculture, 9, pp. 56-62.
19) Varshney R. K., R. V. Penmetsa, S. Dutta. (2009). Pigeon Pea Genomics Initiative (PGI): An International Effort to Improve Crop Productivity of Pigeon Pea (Cajanus cajan L.), Springer, Berlin, Germany.
20) Yan W. and Kang M.S (2003). GGE Biplot Analysis. A Graphical Tool for Geneticists, Breeders and Agronomists. CRC Press, Boca Raton, FL.