Hindawi
Advances in Agriculture
Volume 2022, Article ID 7013602, 7 pages
https://doi.org/10.1155/2022/7013602

Research Article

Performance Evaluation of Pigeon Pea (*Cajanus cajan* L. Millsp.) Variety for Registration in the Lowland Areas of Ethiopia

Tariku Simion,[1] **Dembele Ersulo**,[1] **and Asnake Fikre**[2]

[1]*South Agricultural Research Institute, Arba Minch Agricultural Research Center, Arba Minch, Ethiopia*
[2]*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT-Ethiopia), Addis Ababa, Ethiopia*

Correspondence should be addressed to Tariku Simion; trk2011smn@gmail.com

Received 16 May 2022; Revised 3 August 2022; Accepted 22 August 2022; Published 22 September 2022

Academic Editor: Othmane Merah

There were few released pigeon pea varieties in Ethiopia. This study was primarily conducted to diversify the availability of varieties, thus addressing socioeconomic cross-cutting issues. From eight pigeon pea genotypes after continuous evaluation, one variety, including the local check, was promoted with the objectives of evaluating the agronomic performance and registering a new variety in lowland areas of Ethiopia. The study was carried out during the main rain seasons of 2018-2019 to enhance pigeon pea productivity in the study area. A plot size of 10 meters by 10 meters was used in six locations. The spacing between rows and plants was 1.2 and 0.5 meters, respectively. Accordingly to the simple descriptive statistics, there were variabilities in the studied traits among the tested pigeon pea genotypes. The yield advantage of 39% was recorded for the test variety, Ashenafi (ICEAP00554), over the local check, which gave an opportunity to select the best-adapted material for the test and similar agroecologies. From the current study, an average yield of 1.83 t/ha was recorded across locations for a candidate variety, Ashenafi (ICP00554). The grain yield of the local cultivar had a mean of 1.04 t/ha. As a variety, Ashenafi (ICP00554) took the shortest duration to 75% flowering and 90% maturity (115 days and 171 days), respectively. In contrast, the local cultivar (Humbo local) took a long duration to 75% flowering and 90% maturity (164 days and 221 days), respectively. As a variety, Ashenafi (ICP00554) had superior performance over the local cultivar in terms of grain yield and earliness for flowering and maturity. Based on the overall performance, Ashenafi (ICP00554) was selected and registered. Therefore, this variety is recommended to popularize and thereby enhance pigeon pea production.

1. Introduction

Pigeon pea (*Cajanus cajan* L.) ranked sixth globally after peas, broad beans, lentils, chickpeas, and common beans [1]. Globally, it is cultivated on a 5.4 million hectare land area with an annual production of 4.49 million tons. It is grown in about eighty-two countries in the world. India accounts for about 72糌 of the area grown for pigeon peas [2]. In Africa (Eastern and Southern), pigeon pea is grown on 0.56 million hectares [3]. Pigeon pea is an important crop in Malawi, Kenya, Uganda, Mozambique, and Tanzania. It is generally cultivated in association with yam, millet, sorghum, and cassava, among other crops [4].

Pigeon pea offers great potential as an economic crop in the economy of some nations, and it constitutes their major cash crop, especially in India and Malawi [5]. It does not only serve as protein for both humans and livestock but also is very useful in the pharmaceutical industry as medicine [6]. Additionally, it is useful in food processing due to its ability to be processed into many forms, such as biscuits, noodles, cookies, flour, and bread, among others [7], thus making it to be highly relevant economically. It is highly attractive to smallholder farmers of rural areas in many developing countries such as Nigeria [8]. This is because pigeon pea can be a source of income for men and women and function as feed for livestock, fencing material for rural dwellers, and uniquely serve as food during the lean period with little or no value addition [9].

Pigeon pea is a tropical grain legume and is among the important pulses grown for food, feed, and soil fertility improvement. It is a deep-rooted and drought-tolerant

leguminous crop used in several countries as a source of dietary protein [10]. Pigeon pea endowed with rich dietary protein in its seed provides the much-needed protein requirements [11]. The seed contains 18–29% protein on a dry weight basis, which is about three times the value found in cereals, and is closer to soybean, which is 34% [12]. The protein is also of excellent quality, being high in lysine. It is used as a contour hedge in erosion control. The crop is, therefore, an important complement to cereal and root-based diets [13].

Despite the attractive attributes and importance of pigeon pea, it is recorded as one of the underutilized crops in Ethiopia. An underutilized crop can be defined as those crops which are marginalized by researchers, farmers, marketers, and consumers due to agronomic, genetic, economic, environmental, and cultural reasons. Underutilized crops might be viewed concerning geographical regions. A crop might be underutilized in some regions but not in others. In Ethiopia, little consideration has been given to the potential of pigeon peas to contribute to the food and income security of poor farming households with insufficient income [14]. There is a dearth of research work on pigeon peas to identify its effective production systems, available modern technology (such as improved varieties with desired traits), nutritional benefits, and value addition. There are limited data sources on its production level in Ethiopia, and hence, no policy framework tailored toward the production of pigeon peas. Meanwhile, pigeon pea is an international good in most Asian countries and constitutes their major staple; but in Ethiopia, it is highly underutilized. One of the identified challenges is the fact that pigeon pea is not competitive compared to the routinely grown legumes such as common bean [15].

The facts of the current production of pigeon peas in the study area are, therefore, necessary because of its increasing demand because of recurrent drought. There is a need to understand the current production levels to harness research and policy efforts in the right direction. This study focused on providing information on the current prospects of pigeon pea adaptation and production potential in Ethiopia. It is expected to provide information regarding whether the farmers will cultivate more or reduce the land allotted to pigeon pea production [16]. Although there is no systematic scoring and a national database, it is distributed all over the geographies in the North (Wollo), South East (Bale), Southern Region, Western regions, and central parts of Ethiopia, growing in patches and intercropped [17].

The pigeon pea enhancement program started with germplasm introduction from the ICRISAT and neighboring countries to identify high-yielding, disease, and pest-tolerant cultivars. The pigeon pea research in terms of crop improvement is still at a low level in Ethiopia. The production of pigeon peas in the present agroecological area is inadequate due to a scarcity of widely adapted better pigeon pea varieties, both biotic and abiotic aspects, and insufficient scale-up and/or popularization of pigeon pea varieties. Consequently, the evaluation of introduced pigeon pea varieties, particularly for the study area, can be taken as one key step in tackling the shortage of improved pigeon pea varieties and technologies.

Hence, considering the importance of pigeon peas in food security and its potential for the future Ethiopian economy, it is important to increase its production and productivity through adaptation and diversifying varieties [18]. Hence, the current research was started to evaluate the adaptation of the introduced pigeon pea varieties, thereby registering in the areas for yield and yield components.

2. Materials and Methods

2.1. Description of the Study Sites. The experiment was conducted in six locations, Arba Minch, Boreda, Mirab Abaya, Humbo, Dirashe, and Konso, in 2018 and 2019 during the main cropping seasons. The descriptions of experimental locations are summarized (Table 1).

2.2. Experimental Materials. Eight pigeon pea accessions were acquired from an International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, and evaluated for two cropping seasons in six locations in South Ethiopia. The best-performing accession was selected and advanced for further registry evaluation. The National Variety Releasing Committee of Ethiopia (ENVRC) evaluated the variety of field conditions (Figure 1). According to their evaluation result, the best-performing variety, Ashenafi (ICEAP 0055), was officially released in 2020 to be utilized by various end-users in the lowland areas. The mean performance for yield and other agromorphological characters of the candidate variety and the standard check is presented in Tables2, 3, 4, 5, and 6. Based on the performance evaluation, ICEAP 00554 was selected and registered. The morphological characteristics of the variety are summarized in Table 7.

2.3. Experimental Design, Data Analysis, and Field Layout. Two pigeon pea varieties were evaluated against the local check (farmer cultivar) at Arba Minch, Mirab Abaya, Konso, Dirashe, Boreda, and Humbo locations during the 2020 main cropping season in Ethiopia. A large plot size without replicates was used. The plot size was 10 m x 10 m of 1.2 m between rows and 0.5 meters between plants. A seed amount of 3 kg ha^{-1} and fertilizer rate of 100 kg ha^{-1} NPS were used. Data on days to 75% flowering and days to 90% maturity were measured on a plot base. Plant height and panicle length were measured in centimeters on five randomly selected plants base per plot. Grain yield produced per plot. A thousand seeds' weight was measured by randomly taking a thousand seeds from a plot after threshing. The *t*-test was applied to compare the average performance varieties. The analysis was conducted using GenStat 18^{th} edition version software.

3. Results and Discussion

The mean performance of the varieties for all locations is presented (Tables 2–6). The result revealed that the variety, Ashenafi (ICEAP00554), was superior to the local cultivar (Humbo local) in all locations for yield and other studied traits. An average grain yield of 1820 kg ha^{-1} was recorded

Table 1: Description of the study locations.

Sites	Average temperature and rainfall		Average elevation (m.a.s.l)	Soil type
	Temperature (°C)	Rainfall (mm)		
Dirashe	25.68	952.10	1253.00	Clay-loam
Arba Minch	27.50	1000.00	1216.00	Sandy-loam
Mirab Abaya	20.00	1000.00	1190.00	Sandy-loam
Humbo	20.24	1175.00	1401.00	Clay
Konso	27.80	800.00	1189.00	Sandy-loam
Boreda	21.11	164.94	1531.00	Clay-loam

Source: Zonal Administration Office of Gamo and Konso.

Figure 1: Field performance of pigeon pea adaptation trail.

Table 2: Yield performance (kg ha^{-1}) of pigeon pea genotypes across locations during the 2018 and 2019 cropping seasons, South Ethiopia.

S. No.	Locations	Locations mean of local cultivar (Humbo local) for 2018 and 2019 years			Locations mean of the proposed variety (ICEAP 00554) for 2018 and 2019 years			The yield advantage over local cultivar (%) for the 2018 and 2019 years		
		2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
1	Dirashe	1250	1200	1225	1960	2000	1980	36.8	39.3	38.1
2	Arba Minch	1050	1030	1040	1470	1800	1635	28.57	27.7	28.1
3	Mirab Abaya	950	780	865	1760	1600	1680	46.0	51.1	48.6
4	Humbo	1170	620	895	1620	1320	1470	27.7	53	40.4
5	Konso	1500	1020	1260	1800	2500	2150	16.6	59.2	37.9
6	Boreda	1400	580	990	2300	1700	2000	30	52.45	41.2
Mean		1220	870	1050	1820	1830	1820	30.9	47.1	39.0
t-value		3.01	—	—	2.22	—	3.40	—	3.7	2.2
SE		32.2	31.3	30.8	37.6	42.5	42.9	45.5	32.2	31.3
P value		<0.001	—	—	<0.01	—	0.002		0.003	0.01

SEM, mean standard error.

for a variety, Ashenafi (ICEAP00554), over locations. The grain yield of the local cultivar (Humbo local) ranges from 870 to 1220 kg ha^{-1} (Table 2).

The information generated from the simple descriptive statistics revealed that there were variabilities in the studied traits among the tested pigeon pea genotypes. The yield advantage of 39% was recorded for the test variety, Ashenafi (ICEAP00554), over the local check, which gave an opportunity to select the best-adapted material for the test and similar agroecologies.

The result of this study revealed the new variety had a grain yield advantage over the poor-performing local variety (Humbo cultivar). The number of average seeds per plant varied from 4.39 for Humbo local to 5.9 for ICEAP00554 (Table 3), and the average hundred seeds weight ranged from 16.7 g for Humbo cultivar to 17.5 g for Ashenafi (ICEAP00554) (Table 4). Numerous authors also reported the variance performance of genotypes in different and alike/similar locations for different traits for various crops [19, 20]; [17, 21, 22].

The result from this study indicated the various performance of varieties from location to location and from year to year. The yield performance of the local variety ranged from 580 kg ha^{-1} at Boreda in 2019 to 1500 kg ha^{-1} at

Table 3: Number of seeds per pod of pigeon pea genotypes across locations during 2018 and 2019 cropping seasons, South Ethiopia.

S.No.	Location	Locations mean of local cultivar (Humbo local) for 2018 and 2019 years			Locations mean of proposed variety (ICEAP 00554) for 2018 and 2019 years		
		2018	2019	Mean	2018	2019	Mean
1	Dirashe	4.72	4.44	4.58	5.76	5.80	5.78
2	Arba Minch	4.84	4.84	4.84	5.76	5.56	5.66
3	Mirab Abaya	4.44	4.25	4.345	6.16	6.52	6.34
4	Humbo	4.48	3.10	3.79	6.00	5.63	5.815
5	Konso	4.52	4.24	4.38	6.04	5.88	5.96
6	Boreda	4.52	4.33	4.425	6.08	5.66	5.87
Mean		4.58	4.20	4.39	5.96	5.84	5.90
t-value		3.01	-	5.2	2.22	9.2	3.40
SE		1.7	1.4	5.2	2.8	9.9	1.7
P value		<0.001	-	0.03	<0.01	0.012	0.002

SEM, mean standard error.

Table 4: Hundred seed weight (gm) of pigeon pea genotypes across locations during the 2018 and 2019 cropping seasons, South Ethiopia.

S. No.	Location	Locations mean of local cultivar (Humbo local) for 2018 and 2019 years			Locations mean of proposed variety (ICEAP 00554) for 2018 and 2019 years		
		2018	2019	Mean	2018	2019	Mean
1	Dirashe	17	16.8	16.9	17	17	17
2	Arba Minch	14	15	14.5	17	16.7	16.85
3	Mirab Abaya	15	13	14	16	16	16
4	Humbo	15	13.4	14.2	18	16	17
5	Konso	17	17.1	17.05	14	17	15.5
6	Boreda	17	16	16.5	18	17	17.5
Mean		15.83	15.21	15.52	16.66	16.61	16.64
t-value		3.0	5.1	4.1	2.22	6.7	3.40
SE		2.1	3.21	1.20	2.0	4.21	5.2
P value		0.003	0.02	0.04	0.03	0.021	0.002

SEM, mean standard error.

Table 5: Days to 75% flowering of pigeon pea genotypes across locations during 2018 and 2019 cropping seasons, South Ethiopia.

S. No.	Location	Locations mean of local cultivar (Humbo local) for 2018 and 2019 years			Locations mean of proposed variety (ICEAP 00554) for 2018 and 2019 years		
		2018	2019	Mean	2018	2019	Mean
1	Dirashe	156	158	157	116	118	117
2	Arba Minch	155	178	166.5	95	105	100
3	Mirab Abaya	159	165	162	116	118	117
4	Humbo	162	170	166	118	120	119
5	Konso	160	168	164	115	114	114.5
6	Boreda	172	176	174	127	124	125.5
Mean		160.7	169.2	164.9	114.5	116.5	115.5
t-value		—	—	3.01	2.22	—	3.40
SE		12.1	3.21	1.20	2.0	4.21	5.2
P value			—	<0.001	<0.01	—	0.002

SEM, mean standard error.

Konso in 2018. While the new variety ranged from 1320 kg ha^{-1} at Humbo to 2500 kg ha^{-1} at Konso in 2019. From the current result, we can conclude that the locations and the years had various effects on the performance of varieties. Other researchers also reported the effect of environments and years on the performance of genotypes for different traits for various crops [17, 22].

There was a considerable difference for days to 75% flowering, 90% maturity, and average grain yield among studied varieties, indicative of vital selection in the future improvement and breeding program (Figure 2).

The average mean number of seeds per pod significantly varies from 4.39 for Humbo local to 5.90 for ICEAP 00554. This indicated the varieties are not similar in their performance for the studied traits (Table 2). Other authors also reported different ranges of performance of varieties for the number of seeds per pod [17]. The performance of the local variety ranged from 4.44 in 2018 to 4.84 in 2019 at Mirab

Table 6: Days to 90% maturity of pigeon pea genotypes across locations during the 2018 and 2019 cropping seasons, South Ethiopia.

S. No.	Location	Locations mean of local cultivar (Humbo local) for 2018 and 2019 years			Locations mean of proposed variety (ICEAP 00554) for 2018 and 2019 years		
		2018	2019	Mean	2018	2019	Mean
1	Dirashe	201	204	202.5	161	162	161.5
2	Arba Minch	205	210	207.5	150	155	152.5
3	Mirab Abaya	219	225	222	176	179	177.5
4	Humbo	210	235	222.5	178	180	179
5	Konso	210	248	229	175	178	176.5
6	Boreda	242	240	241	187	180	183.5
Mean		214.5	227	220.6	171.2	172.3	171.8
t-value		—	—	3.01	2.22	—	3.40
SE		2.1	3.21	1.20	2.0	4.21	5.2
P value		—	—	<0.001	<0.01	—	0.002

SEM, mean standard error.

Table 7: Morphological characteristics of the variety Ashenafi (ICEAP 0055).

S. No.	Morphological characteristics	Measurements or description
1	Species name	*Cajanus cajan*
2	Common name	Pigeon pea
3	Variety name	ICEAP 00554 (Ashenafi)
4	Plant growth habit	Nondeterminate and semi-spreading. Under intercropping, the plants remain tall and compact, but when grown under a low population, additional branches develop, giving a semi-spreading appearance.
5	Stem color	Green.
6	Leaves	Green in color and medium in size.
7	Plant height	Significantly influenced by temperature. Under warm environments, the plants grow tall but shorter under cool environments.
8	Days to flowering and maturity	Temperatures above 24°C delay flowering and maturity. At optimum temperature for growth, it flowers and matures in about 95–127 days and 150–187 days, respectively.
9	Flower color of base petal	Yellow.
10	The pattern of streaks on a standard petal	No streaks.
11	Immature pods	Color: dark to pale green with no stripes, shape: long and slightly curved, pod constriction: slight, and seeds per pod: 5–7 seeds
12	Seed size	Large with a 100-seed mass of 14–18 g.
13	Seed color	White/cream and uniform in pattern.
14	Suitability to shelling	The shellability of green pods is excellent, making them highly preferred by farmers.
15	Dehulling %	It has an excellent dehulling quality of up to 85% and is, therefore, suitable for processing.
16	Potential yield	Immature and dry grain is 6–10 $t\,ha^{-1}$ and 1.8–3.4 $t\,ha^{-1}$, respectively.
17	Suitability to ratoon	Suitable.
18	Target areas of production	Variety ICEAP 00557 (Ashenafi) is widely adapted across semiarid environments. It is recommended for cultivation in areas with an annual rainfall of (400–900) mm. It grows well at an altitude between 400 and 1800 m above sea level.
19	Source of breeder's seed	ICRISAT Nairobi, P O Box 39063, Nairobi-00623

Abaya. The performance of the new variety ranged from 5.56 in 2019 at Arba Minch to 6.52 in 2019 at Mirab Abaya.

The average hundred seed weight also varies from genotype to genotype. The performance varies from 15.52 for Humbo local to 16.64 for ICEAP 00554. This indicated the variability of performance for these traits (Table 3). A similar, significantly different genetic variability study of pigeon peas was reported by another author [17].

Days to flowering and maturity, in addition to grain yield, are important characteristics of crops that are considered before the release of a variety. Early flowering, maturity, and grain yield performance of the crops ensure the advantage of a given variety in the crop production system. The development of early maturing variety is not only important for pigeon pea crop improvement but also for climate mitigation as a drought escaping mechanism for areas with marginal rainfall patterns [23]. In the present study, the variety Ashenafi (ICEAP00554) showed significantly the shortest duration of flowering (115 days) and maturity (171 days) compared to the local cultivar (Humbo local), which takes 164 and 221 days to flower and mature, respectively.

There was a considerable variance for days to 90% maturity and 75% flowering among the varieties, suggesting the variety Ashenafi (ICEAP00554) is grouped under a short

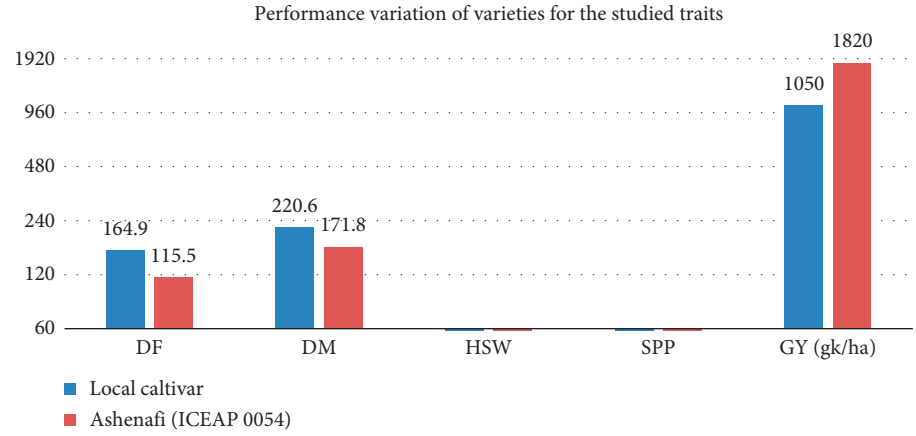

Figure 2: Comparison of important traits of pigeon pea varieties. DF, days to 75% flowering; DM, days to 90% maturity, HSW (gm), hundred seed weight; SPP, number of seeds per pod; GY (kg ha^{-1}), grain yield measured in kg.

maturity and flowering duration type and early-type variety (Tables 5 and 6) and can be used in different resource shortage areas. Comparable results by Zeru et al. [17] were reported for the differential performance of pigeon pea varieties for different traits in different environments. A large variation in the performance of different traits explained among varieties indicated that the varieties were diverse.

Days to 90% maturity were affected by environmental and year variation. This study indicated the different performances of varieties from location to location and from year to year. The days to 90% maturity of the local variety ranged from 201 days at Derashe in 2018 to 229 at Konso in 2019. While, the new variety ranged from 161 days at Derashe in 2018 to 187 days at Boreda in 2018. From the current result, we can conclude that the environmental variation had effects on the varieties. Other researchers also reported the effect of environments on maturity [24].

4. Conclusion

This research was conducted to evaluate the performance of the pigeon pea varieties for registration purposes. A local cultivar (Humbo local) was included for comparison for grain yield and other agronomic performance. This is to enhance pigeon pea productivity in the study areas and other similar agroecologies. The variety Ashenafi (ICEAP00554) showed superior performance in overall studied traits. It was better performed in grain yield with a yield advantage of 39% and earliest compared with local cultivars. Based on the results obtained, it is registered and recommended for demonstration and popularization to increase pigeon pea production. Due to the multiuse nature of pigeon peas (foodstuff, forage, firewood, fence, and soil fertility improvement), research and development should work as a basic issue of the lowland pulses research program. Genetic resources are prerequisites to be exploited for further characterization and identification of useful traits in pigeon pea improvement programs. Hence, the introduction, validation, and commercialization are suggested in diverse areas for commercial production and upcoming improvement of pigeon peas and its final influence on the livelihood of farmers and stakeholders in the country [25–28].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

South is highly appreciated for the technical and financial assistance. The Arba Minch Agricultural Research Center is recognized for its overall encouragement in carrying out this experiment. The authors are also thankful to the ICRISAT, specially Asnake Fikire (Dr), for their collaborative works and seed provision. The authors acknowledge that this study is a dedication to former researcher Mr. Ashenafi Dana who was eager to see the success of this variety registry but passed without seeing it.

References

[1] E. O. Fatokimi and V. A. Tanimonure, "Analysis of the current situation and future outlooks for pigeon pea (Cajanus Cajan) production in Oyo State, Nigeria: A Markov Chain model approach," *Journal of Agriculture and Food Research*, vol. 6, p. 100218, 2021.

[2] FAO, *Statistics Pigeon Producing Countries. Production and Area Harvested*, Food and Agriculture Organization of the United Nations, Rome, Italy, 2017.

[3] O. Esther and A. Victoria, "Analysis of the current situation and future outlooks for pigeon pea (Cajanus Cajan) production in Oyo State, Nigeria: a Markov chain model approach (2021)," *Journal of Agriculture and Food Research*, vol. 6, Article ID 100218, 2021.

[4] O. M. Egbe and B. A. Kalu, "Farming systems study: participatory rural appraisal of pigeon pea cropping systems in

southern Guinea savanna of Nigeria," *The Review*, vol. 5, no. 1, pp. 37–47, 2006.

[5] E. T. Gwata, S. N. Silim, and M. Mgonja, "Impact of a new source of resistance to Fusarium wilt in pigeon pea," *Journal of Phytopathology*, vol. 154, no. 1, pp. 62–64, 2006.

[6] O. M. Egbe, *Evaluation of Some Agronomic Potentials of Pigeonpea Genotypes for Intercropping with Maize and Sorghum in Southern Guinea Savanna*, University of Agriculture, Makurdi, Nigeria, 2005.

[7] E. T. Gwata and S. N. Silim, "utilization of landraces for the genetic enhancement of pigeon pea in Eastern and Southern Africa," *Journal of Food Agriculture and Environment*, vol. 77, 2009.

[8] S. R. Kaoneka, R. K. Saxena, S. N. Silim et al., "Pigeonpea breeding in eastern and southern Africa: challenges and opportunities," *Plant Breeding*, vol. 135, no. 2, pp. 148–154, 2016.

[9] M. A. T. Ayenan, K. Ofori, L. E. Ahoton, and A. Danquah, "Pigeonpea [(Cajanus cajan (L.) Millsp.)] production system, farmers' preferred traits and implications for variety development and introduction in Benin," *Agriculture & Food Security*, vol. 6, no. 1, p. 48, 2017.

[10] R. J. Troedson, E. S. Wallis, and L. Singh, *Pigeon Pea Adaptation*, CAB International, Wallingford, UK, 1990.

[11] D. Hari, K. N. Upadhyaya, and L. L. Reddy, "Patterns of diversity in pigeon pea Cajanuscajan (L.) germplasm collected from different elevations in Kenya," *Journal of Genetic Research Crop Evolution*, vol. 54, pp. 1787–1795, 2006.

[12] L. J. Reddy, J. M. Green, S. S. Bisen, U. Singh, and R. Jambunathan, "Seed protein studies on *Cajanus cajan* L, and some hybrid derivatives," *Seed Protein Improvement in cereals and grain legumes*, vol. 2, pp. 105–117, 1979.

[13] R. K. Varshney, R. V. Penmetsa, S. Dutta et al., *Pigeon Pea Genomics Initiative (PGI): An International Effort to Improve Crop Productivity of Pigeon Pea (Cajanus Cajan L.)*, Springer, Berlin, Germany, 2009.

[14] R. L. Domoguen, K. B. Saxena, M. G. Mula, F. Sugui, and W. D. Dar, *The Multiple Uses of Pigeon Pea*, 2010, https://www.sunstar.com.ph/article/175414/the-multiple-uses-of-pigeonpea.

[15] S. K. Yadav, N. Kumar, H. C. Lal, K. Prasad, C. S. Mahto, and S. Sen, "Assessment of morphological variation for different qualitative characters in pigeon pea [Cajanus cajan (L.) Millsp.] germplasm," *Journal of Food Legumes*, vol. 32, no. 1, pp. 60–63, 2019.

[16] D. Tulu, W. Endalkachew, A. Makka, F. Asnake, A. Tilahun, and O. Chris, "Morphophysiological diversity of rhizobia nodulating pigeon pea (Cajanus cajan L. Millsp.) growing in Ethiopia," *African Journal of Biotechnology*, vol. 17, no. 6, pp. 167–177, 2018.

[17] Y. Zeru, Y. Wasihun, F. Asnake, D. Tulu, and R. Ganga, "Large-plot-based performance evaluation of pigeon pea (*Cajanus cajan* L. Millsp.) Varieties for grain yield and agronomic traits under irrigation conditions in Mandura District, North-West, Ethiopia," *International Journal of Research in Agronomy*, vol. 3, no. 1, pp. 08–12, 2020.

[18] P. R. Manju and I. Sreelathakumar, "Genetic variability, heritability, and genetic advance in hot chili (Capsicumchinense)," *Journal of Tropical Agriculture*, vol. 40, pp. 4–10, 2002.

[19] F. N. Hendrie, R. F. F. Francisco, Q. R. Valdenir, and L. F. G. Regina, "Grain yield adaptability and stability of blackeyed cowpea genotypes under rainfed agriculture in Brazil," *African Journal of Agricultural Research*, vol. 9, no. 2, pp. 255–261, 2014.

[20] G. Santos, E. V. Rodrigues, P. A. Teodoro et al., "Adaptability and stability of cowpea genotypes to Brazilian Midwest," *African Journal of Agricultural Research*, vol. 10, no. 41, pp. 3901–3908, 2015.

[21] G. Tilahun, F. Mekbib, A. Fikire, and M. Eshete, "Genotype x environment interactions and stability analysis for yield and yield-related traits of Kabuli-type Chickpea (*Cicer arietinum* L.) in Ethiopia," *African Journal of Biotechnology*, vol. 14, no. 18, pp. 1564–1575, 2015.

[22] T. Simion, S. Markos, and T. Samuel, "Evaluation of midland maize (*Zea mays* L.) varieties in selected districts of southern Ethiopia," *Cogent Food and Agriculture*, vol. 5, no. 1, Article ID 1704136, 2019.

[23] D. Hanumanthappa, S. N. Vasudevan, N. M. Shakuntala, N. M. Muniswamy, S. I. Maacha, and U. Hiremath, "Evaluation of pigeonpea genotypes for growth and yield characters," *International Journal of Current Microbiology Applied Science*, vol. 9, no. 4, pp. 2625–2637, 2020.

[24] A. Bhartiya, J. P. Aditya, G. Singh, A. Gupta, P. K. Agrawal, and J. C. Bhatt, "Assessment of genetic variability of agronomic characters in an indigenous and exotic collection of black soybean (Glycine max (L.) Merrill.)," *SABRAO Journal of Breeding and Genetics*, vol. 43, no. 1, pp. 81–90, 2012.

[25] A. Choudhary, S. Kumar, B. S. Patil et al., "Narrowing yield gaps through genetic improvement for Fusarium wild resistance in three pulse crops of the semi-arid tropics," *SABRAO Journal of Breeding and Genetics*, vol. 45, pp. 341–370, 2013.

[26] A. K. Choudhary, M. A. Iquebal, and N. Nadarajan, "Protogyny is an attractive option over emasculation for hybridization in pigeon pea," *SABRAO Journal of Breeding and Genetics*, vol. 44, no. 1, pp. 138–148, 2012.

[27] M. G. Mula and K. B. Saxena, *Lifting the Level of Awareness on Pigeon Pea-A Global Perspective*, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Telangana, 2010.

[28] N. C. Onwubiko, "Phenotypic variability in cowpea (Vigna unguiculate L. Walp) genotypes was assessed with quantitative and qualitative characters," *SABRAO J Breed Genet*, vol. 52, no. 2, pp. 191–201, 2020.