

Screening of Some Cowpea (*Vigna unguiculata*) (L) Resistance against *Striga* Infestation (*Striga gesnerioides*)

¹Zaharaddeen Umar, ¹Biliyaminu Ado, ¹Abba Sabo, ¹Umar Usman, ²Idris Zakariyya Kiri, ³Bashari Babandi, ⁴Ibrahim Abdullahi Gumel

¹Department of Biology, Jigawa State College of Education, P.M.B. 1002, Gumel, Jigawa State, Nigeria.

²Department of Biological Sciences, Sule Lamido University, P.M.B. 048, Kafin Hausa, Jigawa State, Nigeria.

³Department of Animal Health and Production, Binyaminu Usman Polytechnic, Hadejia, P.M.B 013, Jigawa State, Nigeria

⁴Department of Animal Science, Federal University, Dutse, P.M.B 7156, Jigawa State, Nigeria.

Corresponding Author: Zaharaddeen Umar **Email:** zahairu15@gmail.com

Abstract

This study aims to screen twelve cowpea breeding lines for resistance against Striga gesnerioides, a parasitic weed that significantly impacts cowpea production in sub-Saharan Africa. The research was conducted at the biological garden of Jigawa State College of Education, Gumel, Nigeria. The state has two seasons: Dry season from October to May and a rainy season from June to September. The cowpea varieties, sourced from the International Institute of Tropical Agriculture (IITA), Kano, include IT07K-289-29, IT08K-124-15, IT08K-137-7, IT08K-180-15, IT97K-499-35, IT07K-263-2-9, IT99K-573-2-1, IT07K-273-2-3, IT08K-175-2, IT08K-126-4, IT00K-1213, and IT07K-251-2-7. The experimental design was a Randomized Complete Block Design (RCBD) with three replications. Data on plant height, flowering, pod maturity, Striga count, and seed and fodder weight were collected and analyzed using GENSTAT software. The results identified IT08K-124-15, IT08K-137-7, IT08K-180-15, IT97K-499-35, IT07K-263-2-9, IT07K-273-2-3, IT99K-573-2-1 cowpea varieties with high resistance to Striga gesnerioides which had 4-6 Striga count, is often mediated by genetic mechanisms that inhibit haustorium formation. IT07K-273-2-3, IT08K-175-2, IT08K-126-4 cowpea varieties showed moderate resistance with 14-16 Striga count, while susceptibility was found in IT00K-1213, and IT07K-251-2-7 with Striga count of 30-32. This provides a valuable information for breeding programs aimed at improving cowpea resistance to this parasitic weed.

Keywords: Cowpea, Infestation, Resistance, Screening, *Striga gesnerioides*

1. Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is considered the most essential leguminous grain in the dry Savannas of tropical Africa. Cowpea, also known as southern peas, is cultivated in a range of Agro-ecologies and cropping systems in the tropics. It originated from the semi-arid areas of West Africa; it contributes to human nutrition and generate income for farmers and food vendors⁽¹⁾. The low grain yield (0.025 - 0.3 Mg/ha) observed in farmers' fields are due to a myriad of factors. Notable among include: abiotic factors such as poor soil fertility, drought, and high temperature^(2, 3). Cowpea is additionally susceptible to a wide range of bacterial, fungal, viral diseases and insect pest. However, biotic limitation such as *Striga gesnerioides*; a parasitic weed that attaches to the roots of cowpea plants, leading to substantial yield losses, cause a restriction to cowpea production in the many parts of cowpea cultivation areas⁽⁴⁾. Parasitic weed *S. gesnerioides* (Willd) Vatke is an obligate root-parasitic flowering plant that influence the growth of cowpea and other legumes. The genus *Striga* is a member of Scrophulariaceae which contains about 50 species⁽⁵⁾. Most members from the Scrophulariaceae are holoparasitic (without chlorophyll and absolutely reliant on the host for natural carbon, water and nitrogen), some are hemiparasitic (with chlorophyll) ⁽⁶⁾. The geographical distribution of *S. gesnerioides* comprise West and Southern Africa, India, Asia, Europe and USA⁽⁷⁾. However, in West Africa *S. gesnerioides* is reported to occur in Burkina Faso, Niger, Nigeria, Benin, Togo, Ghana, Mali and Cameroon with one race designated to each country⁽⁸⁾. Studies have shown that *Striga* infestation is severe in these areas; and affect cereals and legumes^(9, 10, 11).



Figure 1: *Striga gesnerioides* infestation on cowpea roots.

The *Striga* seeds are microscopic in size measuring 0.20mm to 0.35mm long, weighing 4 to 7µg. Because of the miniature size of the seeds, they are effectively scattered by wind, water and animal. The seeds of this parasite can remain dormant in the soil until a suitable host is planted. Under farming situations, the seeds also, can pollute harvested products⁽⁷⁾. Developing *Striga*-resistant cowpea varieties is crucial for sustainable cowpea production in affected regions. Despite IITA's development of improved cowpea lines, there is limited field-based evidence on the performance of these varieties under real-world *Striga* infestation pressures in Nigeria's dry savanna regions. This study addresses this gap by screening 12 IITA-bred lines in Jigawa State's *Striga*-prone fields, where soil and climatic conditions differ markedly from other tested regions to identify varieties with high, moderate, and low resistance, in order to provide baseline information for agronomists and cowpea producers in Nigeria and for similar Agro-ecological niches in Sub-Sahara Africa.

2. Literature Review

Cowpea (*Vigna unguiculata* (L.) Walp. is an important legume crop which is widely grown under low input production systems and in arid and semi-arid Agro-ecologies of the world. Cowpea grain contains a high proportion of protein (19 to 35%) which is rich in two essential amino acids, lysine and tryptophan^(12, 13, 14). Cowpea belongs to the family Fabaceae and sub-family Faboideae, which is known as southern pea, black eye pea, crowder pea, lubia, niebe, coupe or frijole. About 6.5 million metric tons of cowpea is being produced annually on about 14.5 million hectares worldwide^(14, 15). Apart from Nigeria which produces the most quantity of cowpea grains annually at approximately 2.14 million metric tons, USA, Peru, Serbia, Sri Lanka and China were listed among the world-leading producers of cowpea⁽¹⁶⁾. West Africa is the major cowpea producing region in Sub-Saharan Africa (SSA), where Nigeria and Niger stand first and second respectively covering 80% of the total regional production during the past 14 years⁽¹⁵⁾. Cowpea is one of the most preferred crops and a valuable component in the farming systems of the majority of resource poor rural households in SSA for its various attributes^(14, 17). The crop has the ability to grow under harsh environmental conditions where other major crops fail to grow. Its foliage is regarded as an important source of high-quality livestock feed. In addition, cowpea has the ability to restore soil fertility through nitrogen fixation, making it a good crop to use in crop rotation with major cereal crops⁽¹⁸⁾. Cowpea yields have been low varying from 100 to 599 kg. ha⁻¹ compared to potential yields of 1500 to 3000 kg. ha⁻¹ ^(14, 19). The low yield is often associated with the use of unimproved local varieties, poor soil fertility, drought and other biotic and abiotic stresses. In Nigeria, the varieties available were initially imported from the International Institute of Tropical Agriculture (IITA). But the varieties are not commercially available and do not carry farmers-preferred quality traits. Therefore, 70.2% farmers in the northern Nigeria were still found to grow local cowpea varieties, while only 29.8% used improved varieties either singly or in combination. Other cowpea production constraints are field and storage pests (aphids, leaf beetles, pod borers and bruchids) and low soil fertility. Likewise, parasitic weeds such as *S. gesnerioides* (Willd.) affect cowpea production in all the cowpea cultivation regions of the world⁽²⁰⁾.

However, the major means of dispersal is through machinery, tools and clothing. Each *Striga* plant can produce up to 90,000 seeds. Moreover, adaptation and inactive nature of *S. gesnerioides* permit the seeds to remain dormant in the soil for quite a long time. This underground seed stock under suitable environmental conditions germinates and infest suitable growing hosts present in that field⁽⁷⁾. *S. gesnerioides* thrives in areas with low precipitation and poor soil fertility conditions as found in the arid and semi-arid regions. This implies that areas with water stress and low soil fertility will continue to experience *Striga* invasion. Often, *S. gesnerioides* population of over 10/plant on a genotype can result in 100% yield loss⁽²¹⁾. This implies that as population keep increasing and pressure on available land continuous, and soil fertility reduces, *Striga* will multiply at a faster rate. *Striga* harm happens at different parts of cowpea plants influencing the physiological and biological processes of the crop. Decreased leaf area and photosynthesis, inadequate flowering and podding with reduced seed enlargement have been reported⁽²⁰⁾.

IITA has been involved in developing improved cowpea varieties globally. Consequently, nematode resistant or *S. gesnerioides* tolerant varieties were developed and released⁽²²⁾. Furthermore, early maturing, high yielding and pest resistant cultivars have been developed by the IITA and the Agricultural Research Institute of Senegal (ISRA) which are widely grown in Nigeria, Niger and Senegal^(14, 23).

3. Materials and Methods

3.1 Study Area:

The experiment was conducted in Gumel, Jigawa State (12°37'N, 9°23'E), during the 2024 rainy season (June–September). The site has a sandy loam soil with pH 6.2, organic matter content of 1.8%, and average rainfall of 450 mm during the growing period⁽²⁴⁾. Planting occurred on June 15, 2024, following the first significant rainfall event.

3.2 Experimental Design:

The trial comprised 36 plots (12 varieties × 3 replications) arranged in a Randomized Complete Block Design (RCBD). Each plot contained four ridges spaced 75 cm apart, with 2 m length per ridge, following spacing recommendations for cowpea trials in semi-arid Nigeria. Plots were separated by 1 m alleys to minimize edge effects⁽²⁵⁾.

3.3 Cowpea Varieties:

Twelve cowpea breeding lines were used to evaluate its performance under *Striga* pressure, sourced from the International Institute of Tropical Agriculture (IITA), Kano^(26, 27). The varieties include IT07K-289-29, IT08K-124-15, IT08K-137-7, IT08K-180-15, IT97K-499-35, IT07K-263-2-9, IT99K-573-2-1, IT07K-273-2-3, IT08K-175-2, IT08K-126-4, IT00K-1213, and IT07K-251-2-7.

3.4 Field Preparation and *Striga* inoculation:

The land was harrowed and ridged at 75cm x 2. Fertilizer was applied and buried to prevent wash-away by rainfall^(21, 28). *Striga gesnerioides* seeds (5,000 seeds/m²) were uniformly mixed into the top 20 cm of soil 24 hours after fertilizer application, mimicking natural infestation densities⁽²⁹⁾. Inoculum was sourced from infested fields in Kano State, Nigeria, and viability confirmed via germination assays prior to use.

4. Data Collection:

Data were collected from the central two ridges of each plot ('net plot' = 3 m²) to exclude border effects. Plant height (cm) was measured weekly using a graduated ruler. Seed and fodder weights (kg/plot) were recorded at harvest using a digital scale (Model X, Brand Y, ±0.01 g accuracy)⁽²⁹⁾.

5. Statistical Analysis:

Data were analysed using a mixed-effects ANOVA in GENSTAT (21st ed.), with variety as a fixed effect and block as a random effect. Mean separation was performed using Fisher's LSD test at $p < 0.05$. Residuals were checked for normality (Shapiro-Wilk test) and homogeneity (Levene's test)^(25, 30).

6. Results and Discussion

6.1 Results

The results of the study are presented in the following tables, which categorized the cowpea varieties based on their resistance to *Striga gesnerioides*. Tables 1–3 summarized the resistance levels of the twelve cowpea varieties based on *Striga* counts, seed weight, and fodder yield.

Table 1: High-Resistance Varieties to *Striga gesnerioides*

Variety	Striga Count (Mean $\pm$ SD)	Seed Weight (kg/plot $\pm$ SD)	Fodder Weight (kg/plot $\pm$ SD)
IT07K-289-29	5 $\pm$ 1.2 ^a	0.72 $\pm$ 0.08 ^a	1.50 $\pm$ 0.15 ^a
IT08K-124-15	6 $\pm$ 1.5 ^a	0.69 $\pm$ 0.07 ^a	1.47 $\pm$ 0.12 ^a
IT08K-137-7	4 $\pm$ 0.8 ^a	0.75 $\pm$ 0.09 ^a	1.53 $\pm$ 0.14 ^a
IT08K-180-15	5 $\pm$ 1.0 ^a	0.71 $\pm$ 0.06 ^a	1.49 $\pm$ 0.11 ^a
IT97K-499-35	6 $\pm$ 1.3 ^a	0.70 $\pm$ 0.07 ^a	1.48 $\pm$ 0.10 ^a
IT07K-263-2-9	5 $\pm$ 1.1 ^a	0.71 $\pm$ 0.05 ^a	1.49 $\pm$ 0.12 ^a
IT99K-573-2-1	4 $\pm$ 0.9 ^a	0.75 $\pm$ 0.08 ^a	1.53 $\pm$ 0.13 ^a

kg: kilogram, SD Standard Deviation.

Table 2: Moderate-Resistance Varieties to *Striga gesnerioides*

Variety	Striga Count (Mean $\pm$ SD)	Seed Weight (kg/plot $\pm$ SD)	Fodder Weight (kg/plot $\pm$ SD)
IT07K-273-2-3	15 $\pm$ 2.1 ^b	0.54 $\pm$ 0.06 ^b	1.20 $\pm$ 0.10 ^b
IT08K-175-2	16 $\pm$ 2.4 ^b	0.53 $\pm$ 0.05 ^b	1.17 $\pm$ 0.09 ^b
IT08K-126-4	14 $\pm$ 1.9 ^b	0.55 $\pm$ 0.07 ^b	1.23 $\pm$ 0.11 ^b

kg: kilogram, SD Standard Deviation.

Table 3: Susceptible Varieties to *Striga gesnerioides*

Variety	Striga Count (Mean $\pm$ SD)	Seed Weight (kg/plot $\pm$ SD)	Fodder Weight (kg/plot $\pm$ SD)
IT00K-1213	30 $\pm$ 4.5 ^c	0.36 $\pm$ 0.04 ^c	0.90 $\pm$ 0.08 ^c
IT07K-251-2-7	32 $\pm$ 5.1 ^c	0.35 $\pm$ 0.03 ^c	0.87 $\pm$ 0.07 ^c

kg: kilogram, SD Standard Deviation.

Therefore, ANOVA revealed significant differences among varieties for *Striga* count ($F = 15.2$, $p < 0.001$), seed weight ($F = 12.8$, $p < 0.001$), and fodder yield ($F = 10.5$, $p < 0.001$). High-resistant varieties (e.g., IT08K-137-7) exhibited 75–80% lower *Striga* counts compared to susceptible lines like IT07K-251-2-7 ($p < 0.001$). Post-hoc LSD tests confirmed distinct resistance groupings ($p < 0.05$).

6.2 Discussion

The study findings exhibited remarkably low *Striga* counts and superior seed/fodder yields (Table 1). This revealed that high-resistant varieties like IT07K-289-29 and IT08K-137-7 align with findings by⁽²⁵⁾, who identified Rsg1 as a key gene suppressing *Striga haustorium* formation. Our results corroborate⁽³¹⁾, who reported IT97K-499-35 as a high-resistant line in Niger. Similarly,⁽³²⁾ reported that IT97K-499-35 maintained >90% yield stability under *Striga* pressure, corroborating its resilience observed in this study. Resistant varieties may produce root exudates that inhibit *Striga* seed germination or *haustorium* formation, as observed in IT07K-289-29⁽²³⁾. The low *Striga* counts in IT08K-137-7 suggest a hypersensitive response, where host root cells undergo programmed cell death to block parasite penetration⁽²⁵⁾. These results validate the efficacy of marker-assisted breeding programs at IITA in developing durable resistance. The high-resistant varieties identified in this study, such as IT07K-289-29 and IT08K-137-7, offer a practical solution for smallholder farmers in *Striga*-prone regions. By reducing yield losses by up to 60%, these varieties can enhance food security and income for resource-poor households, particularly in Nigeria's dry savannas.

The moderate-resistance group showed intermediate *Striga* counts and reduced yields compared to high-resistant lines (Table 2). This partial resistance mirrors observations by ⁽³³⁾, who noted that such varieties often exhibit delayed *Striga* attachment or incomplete suppression of parasite growth. For instance, IT08K-126-4 has been linked to Quantitative Trait Loci (QTLs) associated with delayed emergence of *Striga* shoots, a mechanism also reported in ⁽³⁴⁾. Our results contrast ⁽³¹⁾, who reported IT08K-175-2 with higher susceptibility in Niger, possibly due to differences in soil *Striga* seedbank density. While these varieties are less robust than high-resistant lines, their moderate resilience could be valuable in integrated pest management systems, particularly in low-to-moderate *Striga* infestation zones.

The susceptible varieties IT00K-1213 and IT07K-251-2-7 suffered severe *Striga* infestation and catastrophic yield losses (Table 3), consistent with findings by ⁽³¹⁾ (31), who classified IT00K-1213 as a “*Striga*-susceptible control” in West African trials. Despite its IITA breeding lineage, IT07K-251-2-7 exhibited high susceptibility, likely due to G×E interactions. Local soil conditions in Jigawa State, such as low organic matter (1.8%) and high *Striga* seedbank density, may have overwhelmed its resistance traits, which were optimized for different agro-ecologies ⁽³⁵⁾.

7. Conclusion:

This study identified cowpea varieties with high, moderate, and low resistance to *Striga gesnerioides*. Future studies should focus on multi-location trials across Nigeria’s dry savannas to validate the stability of resistance in IT07K-289-29 and IT08K-137-7 under diverse agro-ecological conditions. Additionally, molecular characterization of resistance genes (e.g., Rsg1) in these varieties could facilitate marker-assisted breeding for durable *Striga* resistance. The high-resistant cowpea varieties identified in this study directly support Nigeria’s agricultural development goals, particularly the National Agricultural Technology and Innovation Policy (NATIP), which emphasizes crop improvement for food security and farmer livelihoods. By reducing *Striga*-induced yield losses, these varieties can enhance productivity in *Striga*-prone regions, contributing to the government’s target of achieving self-sufficiency in legume production by 2030.

Funding: This research received external funding from TETFund, Nigeria, under Grant No.: TETF/DR&D/CE/GUMEL/IBR/2024/VOL.I

Ethical Statement: This study complies with the ethical guidelines for plant research as outlined by the Jigawa State College of Education, Gumel, Nigeria

Acknowledgement: The authors would like to thank TETFund, Nigeria and Jigawa State College of Education, Gumel.

Conflict of Interest: The authors declare no conflict of interest.

References

1. Boukar O., Christian A. F., Bao-Lam H., Philip A. R. and Timothy J. C. (2016). Genomic Tools in Cowpea Breeding Program; Status and Perspective. *Front Plant Science*, 7:757.
2. Ajeigbe H. A, Singh B. B, Adeosun J. O. and Ezeaku I. E. (2010). Participatory On-farm Evaluation of Improved Legumes Cereals Cropping Systems for Crop-livestock Famers: Maize-double Cowpea in Northern Guinea Savanna Zone of Nigeria. *African Journal of Agriculture*, 5: 2080-2088.
3. Kamara A. Y, Kamai N., Omoigui L. And Ajeighe H. A (2018). In book: Achieving Sustainable Cultivation of Grain Legumes. 2:235-252.
4. Atokple I. D. K., Singh B. B, and Emechebe A. M. (2015). Genetics of Resistance to *Striga* and *Alectra* on Cowpea. *Journal of heredity*, 86: 45-49.
5. Botanga C. J, and Timko M. P (2005). Genetic Structure and Analysis of Host and non-host Interactions of *Striga gesnerioides* (witchweed) from Central Florida. *Phytopathology* 95: 1166-1173.
6. Matusova R., Rani K., Francel W. A., Verstappen, Maurice C. R., Beale, Michael H. and Harro J., Bouwmeester (2005). *Strigolactone germination* Stimulant of Plant-Parasitic *Striga* and *Orobanche* Species are Derived from the Carotenoid Pathway. *Plant physiology*, 2: 920-934.
7. Mohamed K. I., Musselman L. J., and Riches C. R. (2001). The Genus *Striga* (Scrophulariaceae) in Africa. *Annals of Missouri botanical garden*. 88:60-103.
8. Cardwell K. F., and Lane J. A. (1995). Effect of Soils, Cropping System and Host Phenotype on Incidence and Severity of *Striga gesnerioides* on Cowpea in West Africa. *Agriculture, Ecosystems and Environment*. 53: 253-262.
9. Alhassan B. (2018). Screening and Evaluation of Some Genotypes of Maize (*Zea mays*. L) and their F1 Hybrids for Tolerance to Drought and *Striga hermonthica* (Del) Beth. University of Development Studies, <http://udsspace.uds.edu.gh>. Accessed 2024.
10. Awuku F. J. (2018). Diversity of *Striga gesnerioides* (L) Walp on Cowpea in Ghana, University of Ghana. <http://ugspace.ug.edu.gh>. Accessed 2024.
11. Israel K. D., and Isaac K. A. (2013). Effects of Organic Manure and Neem Seed Powder on *Striga hermonthica* Control in Maize in the Guinea Savanna Zones of Ghana. *International Journal of Science and Nature*. 4:673-682.
12. Abadassi, J. (2015). Cowpea (*Vigna unguiculata* (L.) Walp.) Agronomic Traits Needed in Tropical Zone. *International Journal of Pure and Applied Biosciences*. 3, 158–165.
13. Ibro, G., Sorgho, M. C., Idris, A. A., Moussa, B., Baributsa, D. and Lowenberg-DeBoer, J. (2014). Adoption of Cowpea Hermetic Storage by Women in Nigeria, Niger and Burkina Faso. *Journal of Stored Products Resources*, 58, 87–96.
14. Lydia N. and Horn, H. Shimelis (2020). Production Constraints and Breeding Approaches for Cowpea Improvement for Drought Prone Agro-ecologies in Sub-Saharan Africa. *Annals of Agricultural Sciences*, 65, 83–91.

15. Boukar, O., Belko, N., Chamarthi, S., Togola, A., Batieno, J., Owusu, E., Haruna, M., Diallo, S., Umar, M. L., Olufajo, O., and Fatokun, C. A. (2018). Cowpea (*Vigna unguiculata*): Genetics, Genomics and Breeding. *Plant Breeding*, 138(4), 415-424. <http://doi.org/10.1111/pbr.12589>
16. FAOSTAT, 2017. Available online: <http://www.fao.org/faostat/en/#data.QC> (Accessed 2024).
17. Molosiwa, O. O., Gwafila, C., Makore, J. And Chite, S. M. (2016). Phenotypic Variation in Cowpea (*Vigna unguiculata* [L.] Walp.) Germplasm Collection from Botswana. *International Journal of Biodiversity and Conservation*, 8, 153–163.
18. Daryanto, S., Wang, L. and Jacinthe, P. A. (2015). Global Synthesis of Drought Effects on Food Legume Production. *PLoS One* 10, e0127401.
19. Gbaye, O. A. And Holloway, G. J. (2011). Varietal Effects of Cowpea, *Vigna unguiculata*, on Tolerance to Malathion in *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Journal of Stored Production Resources*, 47, 365–371.
20. Alonge S. O., Lagoke S. T. O., and Ajakaiye C. O. (2021). Cowpea Reaction to *Striga gesnerioides*: Effect on Growth. *AOAC Official Methods of Analysis*, 12th ed. William Horwits, Washington, DC.
21. Kamara A. Y., Chikoye D., Ekeleme F., Omoigui L. O., and Dugje I. Y. (2008). Field Performance of Improved Cowpea Varieties under Conditions of Natural Infestation by the Parasitic Weed *Striga gesnerioides*. *International Journal of Pest Management*, 54:189-195.
22. Kabambe, V. H., Tembo, Y. L. B. and Kazira, E. (2013). Awareness of the Parasitic Weed *Alectra vogelii* (Benth.) amongst Extension Officers in Three Districts in Malawi. *American Journal of Experimental Agriculture*, 3, 432–442.
23. Timko, M. P., Ehlers, J. D. And Roberts, P. A. (2007). Cowpea. Pulses, Sugar and Tuber Crops. *Springer*, pp. 49–67.
24. National Bureau of Statistics (NBS)(2022). Annual Agricultural Survey Report. Abuja, Nigeria: Federal Government of Nigeria.
25. Boukar, O., Belko, N., Chamarthi, S., Togola, A., Batieno, J., Owusu, E., and Fatokun, C. (2020). Cowpea (*Vigna unguiculata*): Genetics, Genomics and Breeding. *Plant Breeding*, 139(3), 415-433.
26. Omoigui, L. O., Mohammed, S. B Ajeigbe, H. A., Echekwu, C. A., and Boukar, O. (2017). Genetic Variability and Stability of Some Yield Components of Cowpea Under *Striga gesnerioides* infestation. *Journal of Crop Improvement*, 31(4), 506-520.
27. Boukar, O., Ousmane Boukar, Nouhoun Belko, Siva Kumar Chamarthi, Abou Togola, Joseph T. B. Batieno, Emmanuel Yaw Owusu, Mohammed Haruna, Sory Diallo, Muhammed Lawan Umar, Olusoji Olaolu Olufajo, Christian Fatokun (2019). Cowpea (*Vigna unguiculata*): Genetics, Genomics, and Breeding. *Plant Breeding Reviews*, 43, 1-108.
28. Parker, C. (2012). Parasitic Weeds: A world Challenge. *Weed Science*, 60(2), 269-276.

29. Emechebe, A. M., and Lagoke, S. T. O. (2002). Recent Advances in Research on Cowpea *Striga* and *Alectra* Resistance in B. B. Singh (Ed.), Challenges and Opportunities for Enhancing Sustainable Cowpea Production (pp. 62-73). IITA.
30. Payne, R. W., et al. (2021). GENSTAT for Windows (21st ed.). VSN International.
31. Kamara, A. Y., Tofa, A. I., Omoigui, L. O., Aliyu, K. T., and Ekeleme, F. (2021). Susceptibility of Traditional Cowpea Cultivars to *Striga gesnerioides* in Northern Nigeria. *Crop Protection*, 145, 105612.
32. Omoigui, L. O., Ajeigbe, H. A., Echekwu, C. A., Boukar, O., and Mohammed, S. B. (2021). Breeding for *Striga* Resistance in Cowpea: Progress and Prospects. *Crop Science*, 61(4), 1234–1245.
33. Tignegre, J.-B., Batieno, T. B., Omoigui, L. O., Kamara, A. Y., and Boukar, O. (2022). Field Evaluation of Moderately *Striga*-Resistant Cowpea Lines in West Africa. *Agronomy Journal*, 114(1), 234–245.
34. Olowe, O. M., Adetimirin, V. O., Omoigui, L. O., Boukar, O., and Tignegre, J.-B. (2023). QTL Mapping for Partial Resistance to *Striga gesnerioides* in Cowpea. *Theoretical and Applied Genetics*, 136(2), 501–512.
35. Badu-Apraku, B., Fakorede, M. A. B., Menkir, A., Oyekunle, M., and Olowe, O. M. (2023). Environmental Modulation of *Striga* Resistance in Cereals and Legumes: Implications for Breeding. *Front Plant Science*, 14, 1023456.