PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (7) 2009-2015 July 2024

Post-Emergence *Striga gesnerioides* Damages and Determination of Phosphate Fertilizer Concentration at Low Inoculum Level in Cowpea (*Vigna unguiculata*(L)Walp.)

***OYENUGA, AO; OGUNKANMI, LA; OBOH, B**

Cell Biology And Genetics Department, University of Lagos, Akoka, Nigeria

**Corresponding Author Email: adelekeoyenuga@yahoo.com*
**ORCID: https:/orcid.org/0009-0006-7685-5939*
**Tel: +234 8023261637*

Co-Authors Email: logunkanmi@unilag.edu.ng; boboh@unilag.edu.ng

ABSTRACT: One of Nigerian's preferred crops is cowpea(*Vigna unguiculata*(L)Walp) because it is recognized as a key food and nutritional security legume in Sub Saharan Africa.*Striga gesnerioides*(Willd.)Vatke is a primary biotic constraint of cowpea production in West Africa. There are currently limited sources of resistance in cowpea germplasm and there exists the potential for resistance breakdown . Hence,the objective of this paper was to evaluate post-emergence *Striga gesnerioides* damages and determination of phosphate fertilizer containment concentration at low inoculum level in cowpea (*Vigna unguiculata* (L)Walp.) using appropriate standard method with a bid to meet sustainable development (SD) Goal 2.0 (food security), Twenty five morphological traits comprising seventeen quantitative and eight qualitative traits were evaluated. In this research,assessments of cowpea varieties were carried out to determine phenotypic traits which make them *Striga* resistant/susceptible. *Striga gesnerioides* damage of cowpea was post-emergent and not pre-emergent as commonly reported. Zero *Striga gesnerioides* emergence point was 50 kg/ha TSP.

DOI: https://dx.doi.org/10.4314/jasem.v28i7.11

Cite this Article as: OYENUGA, A.O; OGUNKANMI L. A; OBOH, B. (2024). Post-Emergence *Striga gesnerioides* Damages and Determination of Phosphate Fertilizer Concentration at Low Inoculum Level in Cowpea (*Vigna unguiculata* (L) Walp.). *J. Appl. Sci. Environ. Manage.* 28 (7) 2009-2015

Dates: Received: 21 May 2024; Revised: 17 June 2024; Accepted: 23 June 2024 Published: 02 July 2024

Keywords: cowpea; *Striga gesnerioides*; triple super phosphate; strigolactone; phosphate efficiency

Cowpea (*Vigna unguiculata* (L) Walp.) is an important legume crop with enormous nutritional, agronomic and economic value (Osipitan, 2021). It is a dicotyledonous plant belonging to the family Fabaceae and sub-family, Faboideae. It is grown extensively in the low lands and mid-altitude regions of Africa (particularly in the dry savanna) sometimes as sole crop but more often intercropped with cereals such as sorghum or millet (Agbogidi, 2010) and is an affordable source of quality protein for rural and urban dwellers in Africa (Dube and Fanadzo, 2013). The dry grain protein concentration oscillates from 21 to 33% (Abdulai *et al.*, 2016). Currently cowpea yields are estimated around 300 to 500 kg ha $^{-1}$ on farmer's field in Sub-Saharan Africa (SSA) whereas it's yield potential is up to 3000kg ha $^{-1}$ in optimum growing conditions (Tanzubil *et al.*, 2008, Leandre *et al.*, 2018).

Cowpea witchweed (*Striga gesnerioides* (Willd.) Vatke is a primary constraint of cowpea(*Vigna unguiculata* (L) Walp) production in West Africa (Ohlson and Timko, 2020). Most *Striga* species parasitize grass species (Poaceae), but *Striga gesnerioides* has evolved to parasitize dicotyledonous plants (Spallek *et al.*, 2013). *Striga* affects the life of more than 100 million people in Africa and causes economic damage equivalent to approximately 1

**Corresponding Author Email: adelekeoyenuga@yahoo.com*
**ORCID: https:/orcid.org/0009-0006-7685-5939*
**Tel: +234 8023261637*

billion US per year (Labrada, 2008; Waruru, 2013). *Striga gesnerioides* is a key threat to cowpea production throughout West and Central Africa (Omoigui *et al.*, 2017). It is one of the greatest devastating parasitic weeds in most parts of the world (Leandre *et al.*, 2018). In Nigeria, the losses in yield of cowpea grain due to *Striga gesnerioides* ranges between 80 and 100% (Omoigui *et al., 2017).*

Plants absorb Phosphorus (P) from the soil through root hairs and transfer P to various organs or tissues through phosphate transporters,which are precisely controlled at the transcript and protein levels (Wang, 2021). P efficiency is comprised of (i). P acquisition efficency(PAE)-the capacity of a cultivar to extract P from soil (ii). P utilization efficency(PUE)-the capacity of a cultivar to convert the acquired P into biomass/grain yield (Irfan *et al*., 2020). Phosphorus(P) use efficiency in rice is linked to tissue-specific biomass and Phosphorus allocation patterns(Irfan *et al*., 2020). Strigolactones are phytohormones with roles in various developmental processes such as symbiotic mycorrhizal association between fungi and plants (Faizan, 2020).Strigolactones are known to stimulate hyphal branching of arbuscular mycorrhizal fungi(AMF) that establish relationships with plants to exchange soil-derived nutrients such as phosphate and nitrogen with plant derived carbon sources (Ogawa *et al*., 2022).Under P deficient conditions plants increase the uptake of inorganic Phosphate (Pi) to maintain internal concentration. These responses are collectively termed as Phosphate starvation responses /PSRs (Ueda, 2020). Nitrogen (N), mainly as Nitrate (NO_3^-) triggers the PSR gene expression (Wang, 2020). NO_3^- is a nutrient signal that triggers complex regulation of transcriptional networks to modulate growth (Maeda, 2018). Nitrogen (N) fertilization enhances P uptake by cowpea plants (Ngwene *et al*., 2010). Therefore, the objective of this paper was to evaluate post-emergence *Striga gesnerioides* damages and determination of phosphate fertilizer containment concentration at low inoculum level in cowpea (*Vigna unguiculata* (L)Walp.)

MATERIALS AND METHODS

Materials: Fifty (50) cowpea varieties were collected from six(6) different locations in the North East and North West regions of Nigeria (Figure 1).These seeds were subjected to viability tests and fifteen(15) varieties were selected.*Striga gesnerioides* seeds were sourced from the Federal University of Agriculture,Makurdi,Benue State, Nigeria.

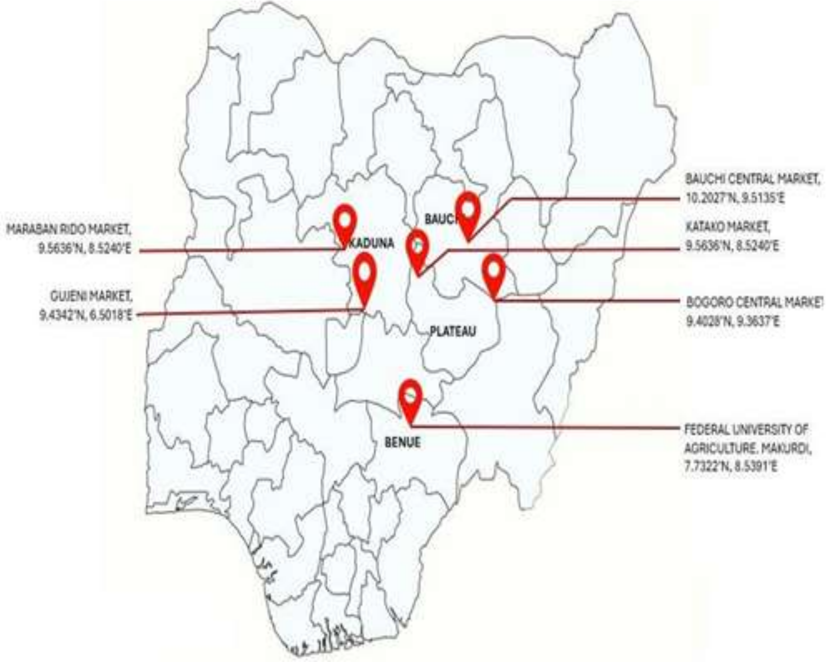

Fig. 1: Map of Nigeria Showing sites of cowpea samples collection

Observation of cowpea plant before (pre) and after (post) Striga gesnerioides emergence: The following symptoms were looked out for: (i).Veinal chlorosis of leaves (ii).Wilting (iii). Stunting (iv). Early Senescence. *Striga* shoots emergence was recorded daily from Day 35 after sowing of cowpea till Day 75 according to the method of Sawadogo *et. al*., 2021**.** Other data collected were the following selected cowpea phenotypic traits: terminal leaflet width,terminal leaflet length, petiolule length,petiole length,rachis length,number of pods per peduncle, pulvin length,number of pods per plant, stipule length, stipule width, pod length, pod width, number of ovules per pod, number of seeds per pod, seed length, seed width and seed weight.

Data collected were subjected to analysis of variance (ANOVA) test using SPSS 26 for windows.

RESULTS AND DISCUSSION

Symptoms of cowpea damage did not appear until after *S.gesnerioides* emergence on day 35 of cowpea growth.Phenotypic changes indicating cowpea damage were veinal chlorosis of leaves, yellowing of leaves, stunted growth and early senescence. Current literature available does not clearly distinguish between low versus high inoculum load of *Striga gesnerioides*. In addition,information regarding damage to cowpea by *S. gesnerioides* is usually unclear-this implies that damage is pre-emergent whilst being silent about post-emergent damage and its implications. This work has been able to emphasise the need to classify *S. gesnerioides* inoculum load into 2 parts (i). Low inoculum load which causes pre-emergence damage and (ii). High inoculum load which causes post-emergence damage. This report is supported scientifically by studies carried out by Williams (1961) on infestation of Sorghum by *Striga senegalensis* at low inoculum. The results were surprising in view of the often encountered statement that *Striga* spp. cause the greatest loss to the host as a total parasite beneath the soil (Williams, 1961).This study has gone a step further in that it has identified the importance of this observation by noting that low inoculum load usually predominates in the earlier infestation stages in the field. Thus, instead of the farmer being taught that there is nothing that can be done once *S. gesnerioides* appears,extension workers should emphasise that instead of abandoning the fields a significant proportion of the harvest can still be realised whilst making plans to integrate other control measures . This work is therefore at variance with earlier reports that *Striga gesnerioides* damages to cowpea plants always begins at the pre-emergence stage (Omoigui *et al.*,2017,IITA,2012,CABI,2012).
The Interaction effect of NPK and TSP on number of seeds per pod of cowpea is shown in Figure 3 above. Statistical analysis revealed significant interaction ($p < 0.01$ at 0.05 Significance level) between NPK and TSP. The highest number of seeds per pod (7.71) was observed in soil treated with 30kg/ha of TSP (P30) with NPK 1.0g; while the lowest (5.66) was recorded in soil treated with 0 kg/ha of TSP (P0) with NPK 1.0g.

Figure 4 is a composite graph showing the effect of fertilization on the emergence and branching of *S. gesnerioides.* In the presence of N (NPK) there was an exponential rise in rate of *S. gesnerioides* emergence and branching from 0 kg /ha TSP to 10kg/ha TSP which decreased from 10 kg/ha TSP to 30 kg/ha TSP and further reduced from 30 kg/ha TSP to 50 kg/ha TSP. In the absence of N fertilizer however, total numbers of emerged and branched *S. gesnerioides* were consistently higher at each P concentration except between 0kg/ha TSP and 10kg/ha TSP for branched *S. gesnerioides*. At 50kg/ha TSP in the presence of N (NPK) fertilizer, rate of *S. gesnerioides* emergence was reduced to zero but with nill/0g NPK, rate of *S. gesnerioides* emergence had reduced to 85 not zero. P levels were found to be inversely proportional to the level of successful *S.gesnerioides* parasitism in susceptible cultivars indicative of a down regulation of strigolactones production (Ayeni *et al.*, 2017).

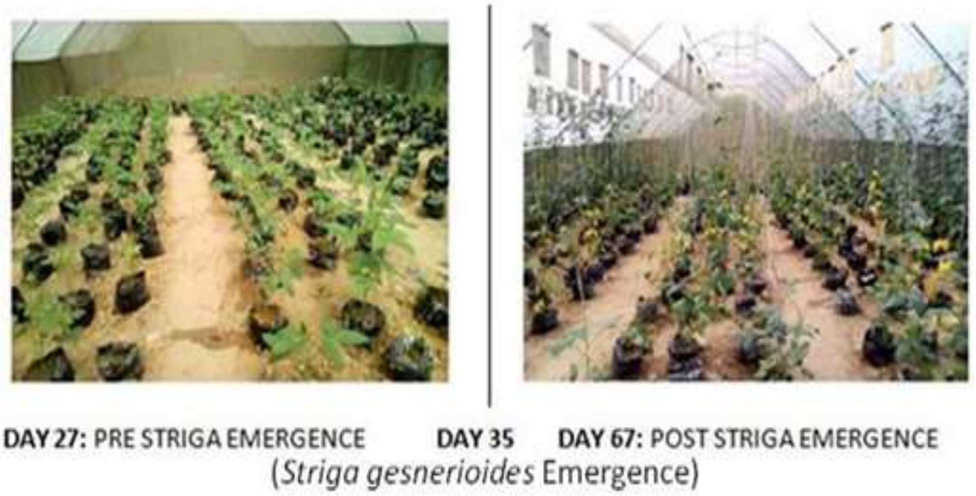

Fig 2 Post-Emergence *Striga gesnerioides* Damage in Cowpea

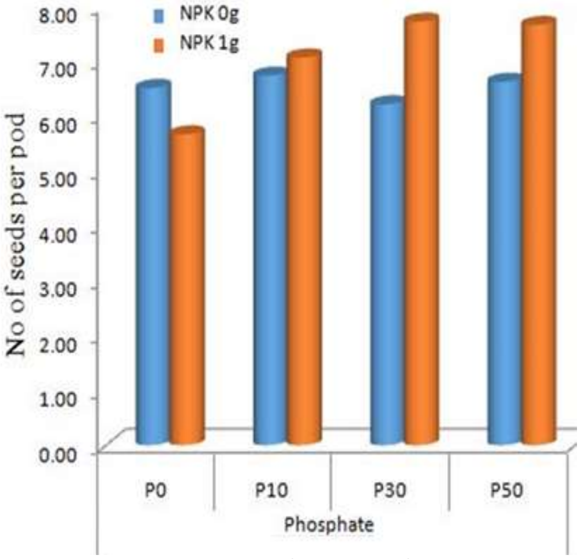

Fig 3. NPK_TSP Interaction for Number of Seeds Per Pod P<0.01 at 0.05 Significance level

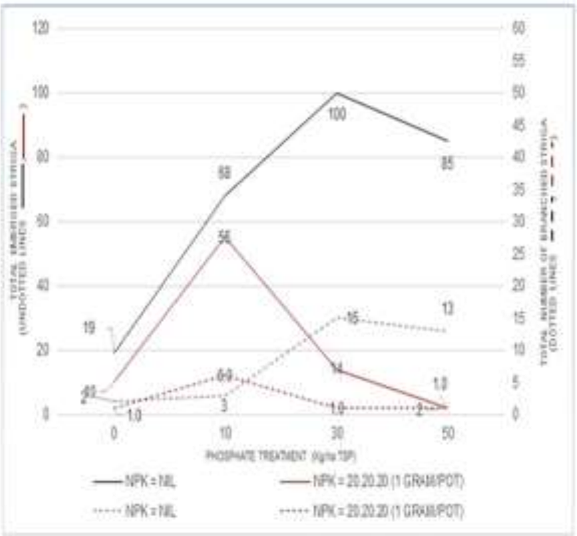

Fig 4: Effect Of Fertilization On The Emergence And Branching Of *S.gesnerioides*

The graphs of NPK_TSP Interaction for Number of Seeds Per Pod of cowpea (Figure 3) , Total Emerged *S. gesnerioides* versus Phosphate Treatment (Figure 4) and Total Branched *S.gesnerioides* (Figure 4) are inter-related**.** An increase in rhizosphere Phosphate concentration led to lowered strigolactone exudation by the cowpea plants which resulted in reduced *Striga* emergence.Thus,rhizosphere Phosphate concentration was inversely proportional to *Striga* emergence. Phosphate Acquisition Efficiency (PAE) is mainly raised by an increase in the number of Phosphate transporters in the plant root hair cells(Wang, 2021). In Figure 3, P0 (P = 0 kg/ha TSP: NPK = 1g ;Red) The mean number of seeds per pod of cowpea is lower for NPK = 1g (Red) than for NPK = Nill/0g (Blue). The reason for this was the higher absorption of available Pi from the rhizosphere by *S.gesnerioides* parasites than cowpea plants growing in the pots containing NPK = 1g .Thus, it can be inferred that *S.gesnerioides* are able to absorb Pi across their body surface which translates to weight increases and branching. Pi was available for absorption by *Striga gesnerioides* at this treatment level due to the fact that Phosphate Acquisition Efficiency (PAE) of the cowpea plants had not attained maximum efficiency because insufficient Phosphate Transporters to achieve maximum PAE had not been synthesised; therefore allowing for competition for free/available Pi between the cowpea plant and *Striga* in the rhizosphere.The higher quantities of Pi nutrient available to the *Striga* parasite at this level were reflected in the exponential rises of emerged and branched *Striga* graph readings for NPK = 1g at P0 (Figure 4) .This resulted in the lower values of the selected trait, number of seeds per pod of cowpea for NPK = 1g relative to NPK = 0g between P0 and P10 Kg/ha TSP (Figure 3) .

Figure 3, P10 – P50 (P =10 kg/ha TSP – P = 50kg/ha TSP: NPK =1g ;Red) . Phosphate Transporters (PHT1s) in the cell membranes of the root hairs had been fully synthesised and operating at maximum efficiency.There was also more Pi available for cowpea growth in the rhizosphere which in turn led to an increase in Pi uptake resulting in a lowering of strigolactone exudation of the cells from the root hairs

Total emerged and branched *Striga* (Figure 4 reached peak values just before P10 (55) and thereafter began to fall which was reflected by an increase in the selected cowpea trait :Number of Seeds Per Pod at P10 (Figure 3).Emerged and branched *Striga* numbers continued reducing from P10 to P30 and then reached a zero emergence point at about P50 (Figure 4). Consequently, there was a corresponding increase in Number of Seeds Per Pod of cowpea from P10 to P30 and then on to P50 (Figure 3). In Figure 3, P10 (P = 10 kg/ha TSP: NPK = 0g ;Blue). There was an inability to attain maximum Phosphate uptake efficiency relative to NPK =1g (Red) because the signalling nutrient NO_3^- was less in the rhizosphere relative to pots with NPK = 1g.Cowpea strigolactone secretion and hence emerged and branched *Striga* numbers continued to increase. P30 (P = 30 Kg/ha TSP: NPK = 0g; Blue): Total Emerged and branched *Striga* (Figure 4) had reached maximum (100 and 15 respectively) thus, there was a marked reduction of nutrients in the rhizosphere available for growth and development.This was reflected in the selected cowpea phenotypic trait:Number of Seeds Per Pod for NPK = 0g/Nill falling to its lowest level at this point (Figure 3). P50 (P = 50 kg/ha TSP: NPK = 0g

;Blue):Total Emerged *Striga* fell from 100 at P30 to 85 at P50 while total branched *Striga* number also reduced from 15 at P30 to 13 at P50(Figure 4), resulting in greater nutrient availability for cowpea growth at P50 than P30 (NPK = 0g/nill) .There was therefore a corresponding increase in the cowpea morphological trait:Number of seeds per pod at P50 for NPK = 0g/nill (Figure 3) .

The statistically significant p value ($p < 0.01$ at 0.05 significance level) observed between NPK and TSP in figure 3 confirms that Nitrate addition aids the uptake of Phosphate in the cowpea trait : Number of seeds per pod.In figure 4 ,there was a reduction of *S. gesnerioides emergence* level to zero at 50 kg/ha TSP in pots where both NPK and TSP were applied. It can thus be inferred that there is reduced production of strigolactones by the cowpea plants in these pots as a result of increased Phosphate uptake.These results are in agreement with the findings of Ayeni *et al.*,2017 which concluded that Phosphate fertilizer alone did not show any significant positive influence on *S. gesnerioides* parasitism however,the combination of Phosphate with Nitrate fertilization effectively down regulated *S. gesnerioides* parasitism.

Conclusion: This study confirmed that at low *Striga gesnerioides* inoculum levels (22 seeds/pot in this paper) / early stages of cowpea field infestation, damage by *S. gesnerioides* is post-emergent and not pre-emergent as commonly reported in many literatures. Thus, even after sighting, containment can be realised if hand-pulling is carried out before *S. gesnerioides* flowering onset.This research also shows that Nitrate enhances Phosphate Efficiency wheareas,number of emerged and branched *Striga gesnerioides* negatively affected Phosphate efficiency in selected cowpea phenotypic trait:number of seeds per pod. This work additionally determined a specific zero *S. gesnerioides* emergence point of 50kg/ha TSP at 22 seeds / pot. Regression analysis which will reduce over-application resulting in increased cost effectiveness and eco-friendliness in low *S. gesnerioides* infested environments can be computed.

Acknowledgements: The authors thank the Central Research Council (CRC), University of Lagos,Akoka and Lagos State Science Research & Innovation Council (LASRIC) for funding this research.

Abbreviations

NPK fertilizer: Nitrogen_Phosphate_Pottasium fertilizer
TSP fertilizer: Triple super phosphate fertilizer
PAE: Phosphate Acquisition Efficiency
PUE: Phosphate Utilisation Efficiency
PSR: Phosphate Starvation Response
AMF: Arbuscular Mycorrhizal Fungi
P: Phosphorus
Pi: Inorganic Phosphate
N: Nitrogen
NO_3^-: Nitrate

REFERENCES

Abdullahi, W. M.; Dianda, M., Boukar, O.; Dieng, I.; Mohammed, G. S.; Belko, N.; Togola, A.; Muhammad, H.; Kanampiu, F.; Giller, K. E.;Vanlauwe, B. (2022). Integrated management of *Striga gesnerioides* in cowpea using resistant varieties, improved crop nutrition and rhizobium inoculants. *Plant Soil*. 473*(*1-2): 197-213.

Abdulai, M.; Seini, S.S.; Haruna, M.; Mohammed, A.M.;Asante, S.K. (2016). Farmer participatory pest management evaluation and variety selection in diagnostic farmer yield flora in cowpea in Ghana. *Afr.J. Agric. Res.*, 11:1765-1771.

Agbogidi, O.M. (2010).Screening six cultivars of cowpea (*Vigna unguiculata*) for adaptation to soil contaminated with spent engine oil. *J. Env. Chem. Toxicol.*.7:103-109.

Ayeni, D. F.; Omoigui, L. D.;Ikwebe, J. (2017). Response of cowpea genotypes to *Striga gesnerioides* infection under varied phosphorus levels. *AASCIT J. Biosci.* 3(5): 40-46.

Beegle, B.D.;Durst, P.T. (2017). Managing phosphorus for Crop Production. Retrieved from https://www.extension.psu.edu. 02/01/2024.

Bolarinwa, K. A.;Ogunkanmi, L. A.;Ogundipe, O. T.;Agboola, O. O.;Amusa, O. D. (2021). An investigation of cowpea production constraints and preferences among small holder farmers in Nigeria. *GeoJ.* 87**(**4): 2993-3005.

Boukar, O.;Togola, S.;Charmathi, S.;Belko, N.;Ishikawa, H.; Suzuki, K. ;Fatokun, C. (2019). “Cowpea (*Vigna unguiculata* (L.) Walp.) breeding,” In Advances in Plant Breeding Strategies: Legumes, Al-Khayri, J., Jain, S. and Johnson, D. Editors, 201-243, Springer International Publishing.

CABI (2012). Plantwise Plus Blog. Stopping *Striga* before it’s started. Retrieved from https:// cabi.org 15/02/2023.

Dube, E.; Fanadzo, M. (2013). Maximising yield benefits from dual purpose cowpea. *Food Sec.* 5: 769-779.

Faizan, M. F.;Faraz, A.;Sami, F.;Siddiqui, H.;Yusuf, M.;Gruszka, D.; Hayat, S. (2020). Role of strigolactones: Signaling and crosstalk with other phytohormones. *Open Life Sci.* 15(1): 217-228.

Gruszka, D. ;Hayat, S. (2020). Role of strigolactones: Signaling and crosstalk with other phytohormones. *Open Life Sci.* 15**:** 217-228.

Horn, L. N.;Nghituwamata, S. N.; Isabella, U. (2022). Cowpea production challenges and contribution to livelihood in Sub-Saharan region. *Agric. Sci.* 13**:**25-32.

IITA. (2012). Saving Africa's maize and cowpea from the violet vampire. Retrieved from https://www.iita.org/news-item. 15/02/2023.

Irfan,M.;Aziz,T.;Maqsood,M.A.;Bilal,H.M.;Siddique ,K.H.M.;Xu.,M.(2020).Phosphorus (P) use efficiency in rice is linked to tissue-specificc biomass and Phosporus allocation patterns.*Scient. Rep.*10:4278-4291.

Jamil, M.; Kountche, B. A.;Al-Babili, S. (2021). Current progress in *Striga* management. *Plant Physiol.* 185***(***4):1339-1352.

Kouakou, A. G.; Ogundapo, A.; Smale, M.; Jamora, N.; Manda, J.;Aberton, M. (2022). IITA's gene bank,cowpea diversity on farms,and farmers welfare in Nigeria. *CABI Agric. Biosci*.3**:**14-29.

Labrada, R. (2008). Farmer training on parasitic weed management. In: *Progress on farmer training in Paras. Weed Manag.* (Labrada, R., ed.), pp. 1-5. Rome: FAO.

Leandre, S.P.; Francis, K.; Richard, A.; Joseph, B.; Jean Baptiste T.; Ouedraogo, J.T.; Patrick, A.; Close T.J.; Roberts, P.A. (2018). Screening for resistance to *Striga gesnerioides* and estimation of yield loss among cowpea (*Vigna unguiculata* (L.) walp)) progenies in the upper East Region of Ghana. *Afr. J. Agric. Res.*13(28): 1430-1442

Maeda, Y.; Konishi, M.; Kiba, T.; Sakuraba, Y.; Sawaki, N.; Kurai, T.; Ueda, Y.;Sakakibara, H.; Yanagisawa, S. (2018). A NIGT1-centred transcriptional cascade regulates nitrate signalling and incorporates phosphorus starvation signals in Arabidopsis. *Nature Comm.* 9(1): 1376-1389.

Makaza, W.; En-nahli, Y.; Amri, M. (2023). Harnessing plant resistance against *Striga* spp. parasitism in major cereal crops for enhanced crop production and food security in Sub-Saharan Africa: A review. *Food Sec.*. 15: 1127-1149.

Manda, J.;Abberton, M. (2022). IITA'S genebank, cowpea diversity on farms, and farmers' welfare in Nigeria. *CABI Agric. Biosci.* 3**:**1-16.

Mutsvanga, S.; Gasura, E.; Setimela, P. S.; Nyakurwa, C. S. ;Mabasa, S. (2022). Nutritional management and maize variety combination effectively control *Striga asiatica* in Southern Africa. *CABI Agric. Biosci.* 3***:*** 47-60.

Ngwene, B.;George, E.;Claussen, W.;Noumann,E.(2010).Phosphorus uptake by cowpea plants from sparingly available or soluble sources as affected by nitrogen form and arbuscular-mycorrhiza-fungal inoculation.*J.plant nutri. soil sci*.173:353-359.

Ogawa,S.;Cui,S.;White,A.R.F.;Nelson,D.C.;Yoshida, S.;Shivasu,K.(2022).Strigolactones are chemoattractants for host tropism in Orobanchaceae parasitic plants.*Nature Comm.*13:4653 - 4663.

Ohlson, E.;Timko, M. (2020). Race structure of cowpea witchweed (*Striga gesnerioides*) in West Africa and its implication for *Striga* resistance breeding of cowpea. *Weed Sci.* 68(2): 125-133.

Omoigui, L. O.; Kamara, A. Y.; Moukoumbi, Y. D.; Ogunkanmi, L. A.; Timko, M. P. (2017). Breeding cowpea for resistance to *Striga gesnerioides* in the Nigerian dry savannas using marker-assisted selection. *Plant Breed.* 136 **(**3):393-399.

Omoigui, I. O.; Ishiyaku, M. F.; Gowda, B. S.; Kamara, A. Y.;Timko, M. P. (2015). Suitability and use of two molecular markers to track race-specific resistance to *Striga gesnerioides* in cowpea (*Vigna unguiculata* (L.) Walp.). *Afr. J. Biotech.*. 14(27): 2179-2190.

Omoigui, L. O.; Kamara, A. Y.; Ishiyaku, M. F.; Boukar, O. (2012). Comparative responses of cowpea breeding lines to *Striga* and *Alectra* in the dry savanna of northeast Nigeria. *Afr. J.Agric. Res.* 7(5):747-754.

Osipitan, O. A.;Fields, J. S.;Cuvaca, I. (2021). Production systems and prospects of cowpea

(*Vigna unguiculata* [L.] Walp.) in the United States. *Agronomy.* 11**:** 2312-2321.

Sawadogo, P.; Ouedraogo, T.J.; Dieni, Z.; Batieno, T.B.J.; Sawadogo, N.; Poda, S.L.; Zongo, H.; Gnankambary, K.; Tignegre, J.B.S. ;Sawadogo, M. (2021). Differential and comparative screening of cowpea varieties to *Striga gesnerioides* (Willd.) Vatke for race specific identification in Burkina Faso.*Afr. Crop Sci. J*. 29(1):101-118.

Spallek, T.; Mutuku, J. M.;Shirasu, K. (2013). The genus *Striga*: A witch profile. *Mol. Plant Path.* 14(9): 861-869.

Tanzubil, P.B.; Zakariah, M. ;Alem, A. (2008). Integrating Host Plant Resistance and Chemical Control In The Management of Cowpea Pests. *Austtral. J. Crop Sci.* 2(3): 115-120.

Tsuchiya, Y.; Yoshimura, M.; Hagihara, S. (2018). The dynamics of strigolactone perception in *Striga hermonthica*: A working hypothesis. *J. Exp. Bot*. 69(9): 2281-2290.

Ueda, Y.; Kiba, T. ;Yanagisawa, S. (2020). Nitrate-inducible NIGT1 proteins modulate phosphate uptake and starvation signalling via transcriptional regulation of SPX genes. *Plant J.* 102(3):448-466.

Ueda, Y.; Nosaki, S.; Sakuraba, Y.; Miyakawa, T.; Kiba, T. ;Tanokura, M. (2020). NIGT1 family proteins exhibit dual mode DNA recognition to regulate nutrient response-associated genes in Arabidopsis. *PLOS Gen.* 16(11):1-27.

Wang, Y.; Wang, F.; Lu, H.; Liu, Y.; Mao, C. (2021). Phosphate uptake and transport in plants: An elaborate regulatory system. *Plant Cell Physiol.* 62(4): 564-572.

Wang, X.; Wang, H.; Chen, Y.;Sun, M.; Wang, Y.; Chen, Y. (2020). The transcription factor NIGT 1.2 modulates both phosphate uptake and nitrate influx during phosphate starvation in Arabidopsis and maize. *Plant Cell.* 32: 3519-3534.

Waruru, M. (2013). Deadly *Striga* weed spreading across Eastern Africa. Available at: http://www.scidevnet/en/Sub-Saharan-Africa/news/deadly-*Striga*-weed-spreading-across-eastern-africa**.**html: SciDev.Net [accessed on July 2, 2013]. *Weeds,* Cordoba, Spain.

Williams, C. N. (1961). Effect of inoculum size and nutrition on the host/parasite relations of *Striga senegalensis* on sorghum. *Plant Soil.* XV(1): 1-12.