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

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**ABSTRACT:** One of Nigeria’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.

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Cowpea (*Vigna unguiculata* (L) Walp.) is an important legume crop with enormous nutritional, agronomic and economic value (Ospitan, 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
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 efficiency (PAE)—the capacity of a cultivar to extract P from soil (ii). P utilization efficiency (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 Phosphorus (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](image)

*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.
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 30 kg/ha of TSP (P30) with NPK 1.0 g; while the lowest (5.66) was recorded in soil treated with 0 kg/ha of TSP (P0) with NPK 1.0 g.

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 10 kg/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 0 kg/ha TSP and 10 kg/ha TSP for branched S. gesnerioides. At 50 kg/ha TSP in the presence of N (NPK) fertilizer, rate of S. gesnerioides emergence was reduced to zero but with nil/0 g 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).
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, P0 – P50 (P = 0 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 NO₃⁻ 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

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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) in 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 whereas, 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 50 kg/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.

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Abbreviations
NPK fertilizer: Nitrogen_Phosphate_Pottasium fertilizer
TSP fertilizer: Triple super phosphate fertilizer
PAE: Phosphate Acquisition Efficiency
PUE: Phosphate Utilisation Efficiency

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