

EFFECT OF SOWING DATE, INTRA-ROW SPACING AND BIOPESTICIDE ON THE PRODUCTIVITY OF COWPEA UNDER STRIGA INFESTATION IN KATSINA, SUDAN SAVANNA OF NIGERIA.

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SUMMARY

A field experiment was conducted during the cropping seasons of 2015 and 2016 at the Teaching and Research Farm of College of Agriculture, Hassan Usman Katsina Polytechnic, Katsina, Sudan savanna of Nigeria. The study area lies between Latitudes 12° to 12.98° N and Longitudes 7.36° to 7.60° E, 619 m above sea level. The objective of the research was to evaluate the performance of cowpea under *Striga* infestation as affected by sowing dates (SD), intra-row spacings (SP) and bio-pesticides (B). The experiment was laid out in Split-Split Plot Design with three sowing dates (SD1: 2nd July, SD2: 23rd July and SD3: 13th August) allocated to the main plot, three intra-row spacings (SP1: 75 x 20 cm, SP2: 75 x 30 cm and SP3: 75 x 40 cm) allocated to the sub-plot and bio-pesticides to the sub-sub plot. The treatments were replicated three times. Each plot consisted of 6 ridges of 6 m long and 4.5 m wide. All agronomic practices for successful cowpea production were observed. Data collected were subjected to the analysis of variance and significant means were compared using LSD at 5 % level of probability. The physical and chemical analysis of the soil identified the soil as sandy loam with very low organic carbon (< 4 g kg⁻¹), total nitrogen (< 0.6 g kg⁻¹) and low available phosphorus (3-7 mg kg⁻¹). Lower *Striga* counts were observed on cowpea sown on SD3 (126.81) per cm² which was significantly different ($P \leq 0.01$) from SD1 (335.42) and SD2 (238.31) which were statistically similar. The result of the effect of intra-row

spacing showed that highly significant ($P \leq 0.01$) *Striga* counts were obtained in SP2 (236.56) but were statistically at par with SP1 (236.06). The least *Striga* count was obtained in SP3 (227.92). The area under *Striga* number progress curve (ASNPC) showed that there was up to 6 and 5.8 *Striga* density per m². This implies that there is possibility of 60 and 58% cowpea yield reduction during 2015 and 2016, respectively. Managements which involve early soil testing (prior to sowing) and use of *Striga* resistant variety could give a better control strategy in the study area.

Keywords: *Striga*, *gesnerioides*, infestation, cowpea, productivity, Sudan, savanna

COWPEA (*Vigna unguiculata* L. Walp.), is a dicotyledonous, leguminous plant belonging to the family Fabacea. It is one of the ancient crops known to man. An important crop cultivated by many small-scale farmers as subsistence crop in Africa. The crop originated from Africa and spread through Egypt and domesticated in parts of Southern, Eastern and Western Africa where a large number of primitive cultivars and semi wild forms were found (20). The crop is grown primarily as the most important grain legumes in the savanna regions of the tropics and sub-tropics in Africa, Asia and South America (1, 14, 20 28). One of the limiting factors of sustainable cowpea production is the attack by *Striga* (*Striga gesnerioides* (Wild) Vatke).

The parasitic weed severely damage cowpea plants. Early reports of *Striga* attack by past researchers

described it as an obligate biotic stress, a noxious parasitic weed that attack cowpea reducing its productivity in small holder farming sector (15, 23). Zitta *et al.* (32) and Omoigie *et al.* (30) described *Striga* as root parasitic flowering plant of the family Orobanchaceae, a limiting factor to cowpea production especially in the dry savannas. The effect of this parasitic angiosperm on cowpea starts well ahead before its emergence above the ground (16). Since *Striga* is a parasitic weed the seedlings cannot sustain themselves on their own resources for long after germination. Therefore, they need to find a host root shortly after germination and the germination needs to be perfectly timed with the presence of a host root. Exogenous germination stimulants called *strigolactones* are produced by the host's root and also by some non-host roots (usually referred to as trap crops) (e.g. *Gossypium* spp.). They are plant hormones which inhibit

shoot branching (11) but also signals to seeds of parasitic weeds such as *Striga* to start germination. Strigol, a synthetic compound belonging to the strigolactones, was first isolated from cotton (*Gossypium* sp.) and is used as a germination trigger for *Striga*. Being obligate in its mode of nutrition, when the seed (*Striga*) has started to germinate, the haustorium develops which attaches to the host plant (7). A xylem-xylem connection is created between it and the host plant, in that way the seed can withdraw water and nutrients from the host plant (15), photosynthates (organic compounds) (15, 29).

According to Amusan *et al* (6), yield losses as a result of *Striga* infestation in Africa depend on the crop cultivar, weather, and degree of infestation. Cowpea yield losses associated with *Striga* infestation is enormous. Depending on the extent of damage and level, *Striga* infestation is often more serious under low soil fertility and increased moisture stress conditions (6). According to Parker (26) problems with *Striga* are generally caused by low economic resources, poor soil fertility, newly infested areas due to unclean sowing materials and cropping of host crops. Emechebe *et al* (9) reported 100% yield loss on farmer's fields in the northern Guinea savanna of Nigeria.

Noubissie *et al* (23) stated that yield loss due to *S. gesnerioides* may be up to 70%. On susceptible cowpea cultivars (16, 17) reported yield loss reaching 100% when *S. gesnerioides* abundance was over 10 per plant. This research was aimed at providing a baseline study on *Striga* control on cowpea as affected by varying sowing dates, intra-row spacings and biopesticides in the study area.

MATERIALS AND METHODS

Study Area

A field experiment was carried out during 2015 and 2016 cropping seasons in Katsina, Latitudes 12° 59' and 12.98° 01' N and Longitudes 7.36° and 7.60° E, 619 m above sea level in the Sudan savanna of Nigeria (19). The experiment was conducted at the Teaching and Research Farm, College of Agriculture, Hassan Usman Katsina Polytechnic during the rainy seasons of 2015 and 2016, respectively. The rainy season in the area starts from May and ends in October with mean annual rainfall of 742 mm. According to Koppen Climate Classification system, Katsina has a hot semi-arid climate. The average temperature is between 33.2- 42.2°C, average relative humidity (at 07:00 LST) is 60%. The major crops grown include maize, sorghum, millet, rice, cotton,

groundnut, sesame, soya bean and cowpea (22).

The experimental site was ploughed, harrowed and ridged using tractor. SAMPEA 7 Cowpea variety was used. Prior to planting, the seeds were dressed with Allstar® 40 SD (20% Metalaxyl, 20% limidacloprid) at the rate of one sachet per 2.5 kg of seeds against soil-borne diseases and insect pests (25). Sowing was carried out at three weeks intervals. Three cowpea seeds were sown per hole and later thinned to two seedlings per stand (18). Single super phosphate fertilizer was applied at the rate of 25 kg P₂O₅ ha⁻¹ to each plot immediately after sowing. Mancozeb 80% as Z-force (family of ethylene Bisdithiocarbamate) at the rate of 0.33 kg a.i. ha⁻¹ was applied against fungal diseases when symptoms were observed associated by appearance of powdery substance, leaf spots, lesions and leaf curl. Weeding was carried out at 3 and 6 weeks after sowing (WAS) (3). Gap filling was done at three weeks after germination (24).

Morphological Characteristics of Test crop, SAMPEA 7

SAMPEA 7 popularly known as IAR 48 was produced from a cross between Ife Brown and Yella (a local variety introduced from Birniwa District in Jigawa State). It was

developed and released by Institute for Agricultural Research, Ahmadu Bello University Zaria, Nigeria in 1986. The crop has large, light brown seeds with a rough seed coat texture. It is medium maturing (90 to 100 days) variety adapted to Savanna and forest zones. The crop has a potential yield output of 1,500 - 2,500 kg ha⁻¹). However, it is susceptible to Scab, Bacterial blight, Septoria leaf spot, Brown blotch, Beetles, Thrips, *Maruca* pod borer, pod sucking bugs, Bruchids and *Striga* (13).

A composite soil sample was collected using soil auger at the depth of 0-15 and 15-30 cm for laboratory analysis. Samples were analyzed in the Soil Science laboratory, Department of Agronomy, Faculty of Agriculture/Institute for Agricultural Research, ABU Zaria, Nigeria.

The experiment was carried out during the rainy seasons of 2015 and 2016. Split-split plot design with sowing dates (SD1; 02/07/2015, SD2; 23/07/2015 and SD3; 13/08/2015) allocated to the main plot and intra-row spacing (S1; 75 x 20cm, S2; 75 x 30cm and S3; 75 x 40 cm) allocated to the sub plot and (B0; control, B1; Neem seeds kernel extract (NKE), B2; *Maruca vitrata* Multi-nucleopolyhedrosis virus (MaviMNPV) suspension and B3;

Cyper diforce (30g cypermethrin + 250g dimethoate) allocated to the sub-sub-plot (a total of 36 treatments). The trial was repeated during the same period in 2016. Each plot consisted of six (6) ridges of 6 m long and 4.5 m wide. The ridges were separated by 0.75 m apart. The two middle rows (3rd and 4th) constituted the net plot, 2nd and 5th rows for destructive sampling while rows 1st and 6th constituted borders (20). The blocks were separated by 2 m while 1 m was left between plots. A distance of 1 m was also left between main plots. Data were collected on the following parameters.

Striga Count

Striga count per m² was carried out by counting the number of *Striga* shoots in the net plot at 7th and 10th weeks after sowing (WAS) using a m² quadrant.

Assessment of Area under *Striga* Number Progress Curve

Area under *Striga* number progress curve (ASNPC) which is a measure of the total *Striga* emergence throughout the season and was calculated using successive *Striga* counts described by Haussmann *et al.* (12).

$$ASNPC = \sum_{i=0}^{n-1} \left[\frac{Y_i + Y_{(i+1)}}{2} \right] (t_{i+1} - t_i)$$

Where:

n is the number of dates for the *Striga* that emerged

Y_i *Striga* count at the ith assessment date,

t_i DAS at the ith assessment date

t₀ and Y₀ = 0

Harvesting of dried pods was carried out when about 75 % of the pods in the net plot dried. Subsequently, harvesting was carried out until all the pods were fully harvested. The pods were threshed, winnowed and grains measured using an Electronic Compact Scale (ATOM A-110 model). Plot yields were placed in large envelopes/polythene bags and adequately labelled. Post-harvest operations on the yield were carried out separately for each plot. Yield per plot was extrapolated to kg ha⁻¹ (4). Data obtained were subjected to analysis of variance (ANOVA). Means were separated using LSD at $P \leq 0.05$ probability level using SAS (27) statistical package.

RESULTS

Physical and chemical Soil Characteristics of the Experimental Site

The physical and chemical soil analysis of the experimental site during 2015 and 2016 cropping seasons is presented in Table 1. The results of the analysis showed that, the soil textural class was sandy loam, the soil pH of the location ranged from slightly acidic to neutral. The soil was characterized

by low to moderately organic carbon (1.00 – 1.01%), very low total N (0.14-0.16%) and low to moderate available phosphorus (5.65-5.88 mg kg⁻¹). The exchangeable cations Ca, Mg, K and Na ranged from (0.11-2.50 mg kg⁻¹) and the soil CEC ranged from 3.01-3.02 mg kg⁻¹.

Table 1: Physical and chemical soil characteristics of the experimental site at 0-30 cm depth during 2015 and 2016 cropping seasons

Soil characteristics	2015	2016
Physical Analysis (%)		
Sand	71	74
Silt	20	18
Clay	9	8
Textural class	Sandy loam	Sandy loam
Chemical Analysis		
pH ratio: (1:2.5)		
pH (H ₂ O)	6.92	6.96
pH CaCl ₂ (0.01 M)	5.89	5.98
Organic carbon (%)	1.00	1.01
Nitrogen (%)	0.16	0.14
Phosphorus (mg kg ⁻¹)	5.65	5.88
Exchangeable bases (meq 100 ⁻¹ g)		
Ca	2.42	2.50
Mg	0.35	0.31
K	0.20	0.11
Na	0.16	0.14
CEC (meq 100 ⁻¹ g)	3.01	3.02

Soil samples as analyzed in the Soil Science laboratory, Department of Agronomy, Faculty of Agriculture/Institute for Agricultural Research, ABU Zaria, Nigeria.

Effect of Sowing Dates, Intra-Row Spacings and Biopesticides on *Striga* Count and Cowpea performance

The result in Table 2 shows the effect of *Striga* on the performance of cowpea. Although, there was no significant difference between sowing dates and intra-row spacings on effect of *Striga* on cowpea performance in all the years and combine. Lower *Striga* counts were observed during 2016 cropping season. The least (17.22) and highest (21.14) *striga* counts were recorded on cowpea sown on 23rd July (SD2) and 2nd July (SD1), respectively. This showed that delay in sowing to SD2 reduced *Striga* density per unit metre. Similarly, lower *Striga* counts (17.89) was recorded in cowpea spaced at 75 cm x 40 cm (SP3), while the highest (19.64) was recorded on cowpea spaced at 75 cm x 20 cm (SP1). The effect of biopesticides was however, statistically similar except in Cyper diforce treated plots which recorded significantly higher *Striga* counts (552.59) during 2015 cropping seasons.

The result of interaction of sowing dates and intra-row spacings during 2015 cropping season is presented in Table 3. Varying sowing dates was observed to statistically result to

similar interaction effect in all the intra-row spacings except in SD3 with SP2 and SP3 in which the interaction was highly significant. Similar interaction effect was observed among the intra-row spacings in the sowing dates. A highest (1.44) control effect was obtained by SD3 x SP2 and the least (2.44) effect was observed by SD2 x SP1.

Area under *Striga* number progress curve (ASNPC) and Cowpea yield performance

The ASNPC presented in Figures 2 and 3 during 2015 and 2016 cropping seasons showed that there was up to 6 and 5.8 *Striga* per plant, respectively. This implies that there is possibility of 60 and 58 % cowpea yield reduction. The result of the effect of varying sowing dates on total grain weight in Katsina is presented in Figure 3. There was no significant difference in yield by varying sowing dates when results of two years combined. However, varying sowing dates in 2016 significantly increased total cowpea grain weight at $P \leq 0.05$. Statistically similar yields were obtained in SD1 (148.01 kg ha⁻¹) and SD2 (190.83 kg ha⁻¹), respectively. The highest grain weight (252.60 kg ha⁻¹) was obtained in SD3.

Table 2: Effect of Sowing Dates, Intra-Row Spacings and Biopesticides on *Striga* Count on the Performance of Cowpea during 2015 and 2016 Cropping Seasons in Katsina

Treatment	2015	2016	
Combined Sowing date (SD)			
SD1	335.42	21.14	13.26
SD2	238.31	17.22	11.13
SD3	126.81	17.81	10.63
Mean	233.51	18.72	11.67
LSD	255.71	5.255	2.686
Intra-row spacing (cm) (SP)			
SP1; 75 x 20	236.06	19.64	12.42
SP2: 75 x 30	236.56	18.64	11.28
SP3: 75 x 40	227.92	17.89	11.32
Mean	233.51	18.72	11.67
LSD	67.131	3.852	1.880
Biopesticide (B)			
B1: Neem kernels extract	133.26 ^b	17.82	11.17
B2: MaviMNPV suspension	107.22 ^b	18.52	11.46
B3: Cyper diforce	552.59 ^a	18.07	11.44
B0: Control	140.96 ^b	20.48	12.61
Mean	233.51	18.72	11.67
LSD	122.17	4.013	2.009
Interactions SD x SP	**	NS	NS

Means with the same letter(s) in the same column are not significantly different using LSD at 5 % level of probability, NS = Not significant, * = Significant at 5 %, ** = highly significant at 1 %, SD = Sowing date (SD1= 02/07/2015, SD2 = 23/07/2015, SD3 = 13/08/2015); SP = Intra-row spacing,

Table 3: Interaction between sowing dates and intra-row spacings on *Striga* counts on cowpea during 2015 cropping season in Katsina

Sowing dates	Intra-row spacings		
	SP1	SP2	SP3
SD 1	2.40 ^a	2.42 ^a	2.43 ^a
SD 2	2.44 ^a	2.22 ^{ab}	2.33 ^a
SD 3	2.28 ^a	1.44 ^c	2.01 ^b
LSD	0.248		

Key: SP1: 75 x 20, SP2: 75 x 30; SP3: 75 x 40 cm, SD = sowing date, SD1; 02/07/2015, SD2; 23/07/2015, SD3; 13/08/2015

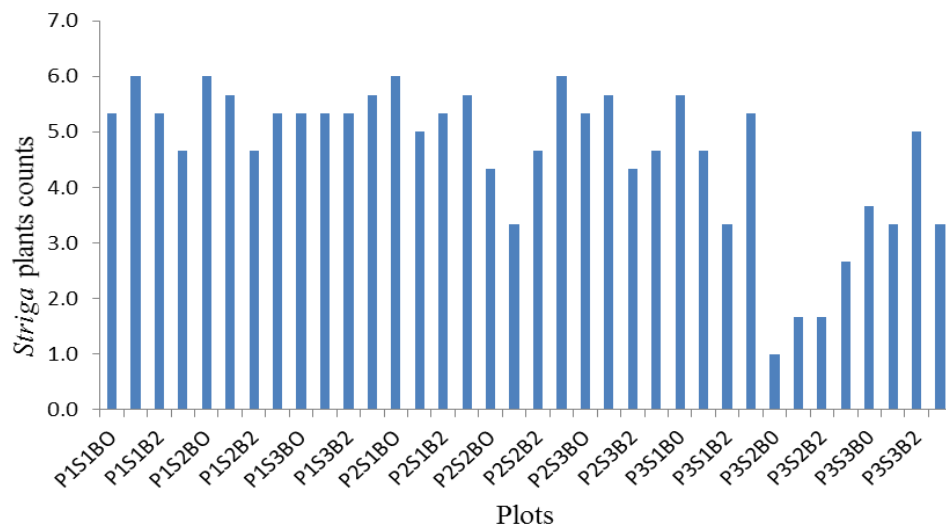


Figure 1: Area under *Striga* number progress curve for *Striga* counts per plot during 2015 cropping season

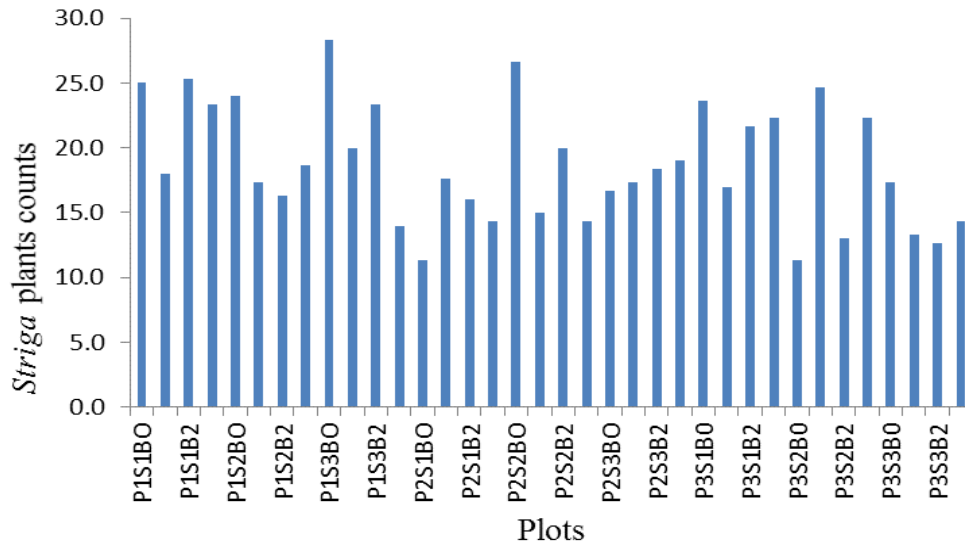


Figure 2: Area under *Striga* number progress curve for *Striga* counts per plot during 2016 cropping season

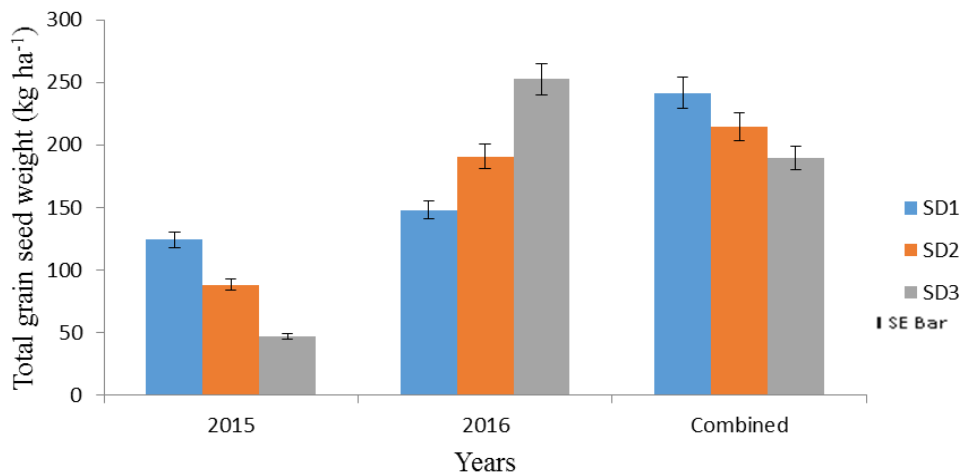


Figure 3: Grain yield of cowpea (kg ha^{-1})

SD1; 02/07/2015, SD2; 23/07/2015, SD3; 13/08/2015 during 2015 and 2016 cropping seasons

DISCUSSION

The results of the analysis of physical and chemical characteristics of the experimental site showed that these C, N and P nutrients are deficient and generally characterized by very low organic carbon ($< 4 \text{ g kg}^{-1}$) and total nitrogen ($< 0.6 \text{ g kg}^{-1}$) and low available phosphorus ($3\text{-}7 \text{ mg kg}^{-1}$) according to [10]. Soil organic carbon gives an indication of soil organic matter content. This is consistent with the findings of Kamara *et al.* 2014 (17) who observed that low level of P and organic matter are common in sandy Sudan savanna of Jigawa state. The *Striga* infestation observed could be attributed due to low level of N and P in the soil. This finding corroborates the report of Kamara *et al.* (17) and Yoneyeme *et al.* (31) who stated that the low level of N and P could have implications for *Striga* infestation in cereal crops and that under N and P deficient conditions, cereal such as sorghum, maize and rice were reported to produce high amount of *Strigolactones* (SLs) that ultimately stimulate germination of *Striga* seeds in the soil. Lopez-Obando *et al* (21) reported Cook *et al.* (8) that '*strigolactones*' came from the first identified role of these compounds as stimulants of seed germination in species of the parasitic weed such as

Striga. Zwanenburg *et al.* (33) regarded SLs as germination stimulants for parasitic plants. Cowpea host reaction due to *Striga* infestation could be observed inform of stunted growth, chlorosis (yellowing), necrosis (death), delay in flowering and pod formation and overall yield reduction (17).

Furthermore, the poor performance could also be attributed partly due to heavy *Striga* infestation as well as to the activities of insect pests. These findings corroborate the findings of Kamara *et al.* (17) who stated that 10 *Striga* plant⁻¹ can cause 100 % yield reduction in cowpea.

CONCLUSION

It can be concluded from the results obtained that *Striga* infestation on cowpea in the ecological zone constitutes threat to cowpea productivity. Varying sowing dates and intra-row spacings did not have any effect on *Striga* performance on cowpea. Sowing cowpea at 23rd July and at wider spacing of 75 x 40 cm reduces effect. The variety used in this study performed below its potential yield capacity according to IAR (13). Hence, efforts should be geared towards its management in order to reduce cowpea yield loss for an overall increase in food security.

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REFERENCES

1. African Agricultural Technology Foundation (AATF). 2011. Pod-borer Resistant Cowpea Project, www.aatf-africa, retrieved 18/01/2014, Pp 6.
2. African Agricultural Technology Foundation (AATF). 2014. Pod-borer resistant cowpea project partnership- developing a pod-borer resistant cowpea. www.aatf-africa.org
3. Aghali A.M. 1993. Intercropping as a component in insect pest management for grain cowpea, *Vigna unguiculata* (Walp) production in Nigeria. *Journal of Tropical Insect Science*. 14(1): 50-52.
4. Ahmed, B.I., Onu, I. and Mudi, L. 2009. Field Bioefficacy of Plant Extracts for the Control of Post Flowering Insect Pests of Cowpea, *Vigna unguiculata* (L.) Walp. in Nigeria. *Journal of Biopesticides*. 2(1), 37-43.
5. Aliyu, M., Ladan, T., Ahmed, B.I. and Abdullahi, J. 2007. Studies on the efficacy of black soap and kerosene on the control of pod sucking bugs (*Clavigralla tomentosicollis* Stal.) on Cowpea (*Vigna unguiculata* (L.) Walp.). *Emirate Journal Food Agriculture*.19(2), 08-12.
6. Amusan, I.O., Patrick, J.R., Abebe, M., Thomas, H. and Gebisa, E. 2008. Resistance to *Striga hermonthica* in a maize inbred line derived from *Zea diploperennis*. *New Phytologist*, 178: 157–166. doi: 10.1111/j.1469-8137.2007.02355.x
7. Cardoso, C., Ruyter-Spira, C., Bouwmeester, H.J. 2010. Strigolactones and root infestation by plant-parasitic *Striga*, *Orobanche* and *Phelipanche* spp. *Plant Science* 180 (2011) pp. 414- 420.
8. Cook, C.E., Whichard, L.P., Turner, B., Wall, M.E. and Egley, G.H. 1966. Germination of witchweed (*Striga lutea* Lour): isolation and properties of a potent stimulant. *Science*, 154, 1189-1190.
9. Emechebe, A.M., Ellis-Jones, Schulz, J.S., Chikoye, D., Douthwaite, Kureh, B., Tarawali, I.G., Hussaini, M.A., Kormawa, P. and Sanni, A.

2004. Farmers' Perception of the *Striga* Problem and its Control in Northern Nigeria, *Expl Agric.* 40, 215–232.
10. **Federal Fertilizer Department (FFD) 2011.** Fertilizer use and management practices for crops in Nigeria 4th Ed., In V.O. Chude, S. O. Olayiwola, A. O. Osho and C. K. Daudu (Eds.). Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja. Nigeria, 215pp
11. **Gomez-Roldan, V., Fermas, S., Brewer, P.B., Puech-Pagès, V., Dun, E.A., Pillot, J.P., Letisse, F., Matusova, R., Danoun, S., Portais, J.C., Bouwmeester, H., Bécard, G., Beveridge, C. A., Rameau, C., Rochange, S.F. 2008.** "Strigolactone inhibition of shoot branching". *Nature* 455(7210): 180–194.
12. **Hausman, B.I.G., Hess, D.E., Web, H.G. and Geiger, H.H. 2000.** Improved methodologies for breeding *Striga*-resistant sorghums. *Field Crops Research*, 66: 195-211.
13. **Institute for Agricultural Research (IAR). 2015.** IAR released variety descriptors. Institute of Agricultural Research, Samaru, Federal Ministry of Agriculture and Rural Development, Zaria, Ndahi press Zaria, Nigeria, 85pp.
14. **International Institute of Tropical Agriculture (IITA). 1990.** Cowpea, *Vigna unguiculata* crop, Ibadan, Nigeria. www.iita.org. Sourced on 18/01/2014.
15. **International Institute of Tropical Agriculture (IITA). 2016.** About *Striga* and *Alectra*, publication of Integrated *Striga* Management in Africa (ISMA), IITA. <http://www.iita.org/web/striga>. Sourced on 28/09/2016.
16. **Kamara, A. Y., Chikoye, D., F., Ekeleme, L. Omoigui, O. and Dugje, I. Y. 2008.** Field performance of improved cowpea varieties under conditions of natural infestation by parasitic weed *Striga gesnerioides*. *International Journal Pest Management*. 54(3), 189-195.
17. **Kamara, A.Y., Ekeleme, F., Jibrin, J.M., Tarawali, G. and Tofa, I. 2014.** Assessment of level, extent and factors influencing *Striga* infestation of cereals and cowpea in a Sudan Savanna ecology of northern Nigeria. *Agriculture, Ecosystem and Environment*. 188: 111-121. Available online www.elsevier.com/locate/agee

18. **Komolafe M.F., Adegbola A.A., Are L.A., Ashaye T.I. 1985.** *Agricultural science for West African Schools and colleges*, 2nd Edition, University press, Ibadan, Nigeria.
19. **Kowal J.M. and Knabe, O.T. 1972.** *An Agroclimatological Atlas of the Northern States of Nigeria with explanatory notes*, Ahmadu Bello University Press, Zaria, Nigeria, 111 pp. 1972.
20. **Kwaifa, N.M., Ibrahim, N.D., Dike, M.C. and Abubakar, M.G. 2012.** Bioefficacy of Neem and Mahogany extracts for control of Cowpea flower Thrips, *Megaluthrips sjostedti* Trybom [Thysanoptera: Thripidae] and Grasshopper, *Ailopus simulatrix* Walker [Orthoptera: Pyrgomorphidae] in Sudan Savannah, Nigeria. *Nigerian Journal of Entomology*. 29, 31-42.
21. **Lopez-Obando, M., Ligerot, Y., Bonhomme, S., Boyer, F. and Rameau, C. 2015.** Strigolactone biosynthesis and signaling in plant development. *The Company of Biologists Ltd Development*, 142, 3615-3619. doi:10.1242/dev.120006.
22. **MOANR, 2013.** Agriculture in Katsina State an overview, a publication of Katsina State Ministry of Agriculture and Natural Resources, Lamp Printing Press, 21 pp.
23. **Noubissie Tchiagam, J.B., Bell, J.M., Guissai Birwe, S., Gonne, S. and Youmbi, E. 2010.** Varietal Response of Cowpea (*Vigna unguiculata* (L.) Walp.) to *Striga gesnerioides* (Willd.) Vatke Race SG5 Infestation. *Not. Bot. Hort. Agrobot. Cluj*, 38 (2), 33-41. Special Issue. Available online at www.notulaebotanicae.ro
24. **Ogah, E.O. 2013.** Field Evaluation of Plant Extracts in the Management of *Megalurothrips sjostedti* and *Maruca vitrata* of Cowpea in Southeastern Nigeria. *World Essays Journal*.1 (1):11-17. Available online at www.worldessaysj.com
25. **Oparaeke A.M. 2005** Studies on the insecticidal potential of extracts of *Gmelina arborea* products for control of field pests of cowpea, *Vigna unguiculata* (L.) Walp and *Clavigralla tomentosicollis*. *Journal of Plant Protection Research*. 45(1): 1-7.
26. **Parker, C. 2008.** Observations on the current status of *Orobache* and *Striga* problems worldwide. *Pest Manag Sci* 2009; 65: 453-459.
27. **SAS. 2000.** SAS Users Guide; version 606, Cary, NC: SAS Institute. 2000

28. Singh, S.R. 1990. Insect pests of tropical food legumes, Chinchester, Wiley, 451pp.
29. Teka, H.M. 2014. Advance research on *Striga* control: a review. *African Journal of Plant Science*. 8(11), 492-506. <http://www.academicjournals.org/AJPS>. DOI: 10.5897/AJPS2014.1186.
30. Omoigui, L.O., Kamara, A.Y., Ishiyaku, M.F. and Boukar, O. 2012. Comparative responses of cowpea breeding lines to *Striga* and *Alectra* in the dry savanna of northeast Nigeria, *African Journal of Agricultural Research*. 7(5), 747-754. DOI: 10.5897/AJAR11.1341
31. Yoneyeme, K., Xie, X., Kim, H.I., Kisugi, T., Nomura, T., Sekimoto, H., Yokota, T. and Yoneyama, K. 2012. How do nitrogen and phosphorus deficiencies affect strigolactone production and exudation? *Plant*, 235 (6): 1197-1207. <http://dx.dot.org/1007/s00425-011-1568-8>
32. Zitta, C., Magani, E.I. and Ahom, R.I. 2014. Effects of varying levels of *Parkia* husk powder for the control of *Striga gesnerioides* in Cowpea (*Vigna unguiculata*). *World Journal of Agricultural Sciences*. 2 (6), 155-162. Available online at <http://wsrjournals.org/journal/wjas>
33. Zwanenburg, B., Pospíšil, T. and Čavar Zeljković, S. 2016. Strigolactones: new plant hormones in action. *Planta*. 243(6):1311-1326. doi: 10.1007/s00425-015-2455-5. Retrieved on 08/10/2017.