Response of Soybean Genotypes to *Alectra vogelii* Infestation under Natural Field conditions

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Keywords: Soybean- *Alectra vogelii*- Root exudates- Phytoparasitism- Resistance/tolerance

Summary

Field studies were conducted in 1995 and 1996 in the northern Guinea savanna of Nigeria to determine the response of 22 soybean genotypes to Alectra *infestation. Significant differences were observed amongst soybean genotypes in number of* Alectra *shoots that emerged at 9 and 10 weeks after sowing and days to first* Alectra *emergence.* Alectra *emergence occurred later in early maturing soybean genotypes [54 days after sowing (DAS)] while with most late maturing genotypes,* Alectra *emergence started at 50 DAS. Result revealed that sixteen genotypes supported few or no* Alectra *shoots while six were susceptible. Soybean genotypes that supported high numbers of* Alectra *shoots recorded lower grain yields than those with fewer* Alectra *shoots. However, soybean genotypes, SAMSOY2 and TGX1485-1D that significantly supported high numbers of* Alectra *recorded grain yields similar to those of genotypes that supported few or no* Alectra*. These findings may be due to three possible mechanisms of resistance of soybean genotypes to* Alectra *parasitism. The sixteen genotypes, which supported few or no* Alectra *shoots, may have produced lower amounts of root exudates required for stimulation of germination of* Alectra*. They may also have prevented the initiation, attachment, and penetration of haustorium from* Alectra *plants to the roots of the hosts. These mechanism were however, not investigated in this study. Further studies may therefore be necessary to confirm our speculations. Soybean genotypes, SAMSOY2 and TGX1485-1D, which recorded high yield irrespective of high infestation with* Alectra *may exhibit tolerance to the parasite.*

Résumé

Réponse de génotypes de soja à une infestation par *Alectra vogelii* en conditions naturelles de champ

Des études de champ ont été conduites de 1995 à 1996 dans la savane nord-guinéenne du Nigeria afin de déterminer les réponses de 22 génotypes de soja à une infestation par Alectra*. Des différences significatives ont été observées entre les génotypes de soja quant au nombre de pousses d'*Alectra *émergées à 9 et 10 semaines après semis et au nombre de jours à la première émergence d'*Alectra*. L'émergence d'*Alectra *a été retardée sur les génotypes de soya à maturité précoce (54 jours après semi), tandis que pour les variétés à maturité plus tardive,* Alectra *a émergé déjà à partir de 50 jours après semis. Seize génotypes ont montré une faible infestation, parfois inexistante, d'*Alectra *tandis que les six autres étaient fortement parasités. Les génotypes de soja fortement infestés par les pousses d'*Alectra *ont enregistré des rendements inférieurs aux autres variétés. Cependant, SAMSOY2 et TGX1485-ID qui ont supporté une infestation relativement forte d'*Alectra *ont montré des rendements proches des génotypes peu ou non infestés d'*Alectra*. Nos résultats suggèrent trois mécanismes possibles de résistance au parasitisme d'*Alectra *parmi les génotypes de soja. Les seize génotypes peu ou non infestés de pousses* Alectra *pourraient avoir produit une quantité insignifiante d'exsudats de racines nécessaires pour la stimulation de la germination des graines d'*Alectra*. SAMSOY et TGX1485-1D qui ont donné un rendement élevé malgré l'importante infestation d'*Alectra *montreraient ainsi une tolérance au parasite.*

Introduction

Soybean (*Glycine max* (L) Merrill) has become increasingly important in Nigeria, and has spread to large parts of the Guinea savanna zone characterized by mean annual rainfall of 1050 mm distributed over 5 months during the cropping season (35). In addition to its use as a staple food and fodder, soybean can help to improve soil fertility by contributing to soil N through biological nitrogen fixation. This crop's production then becomes more sustainable from an ecological and economic perspective (7). Soybean has been shown to reduce the seed bank of *Striga hermonthica* a semi-parasite weed in cereals such as sorghum and millet, by causing suicidal germination. After induction of germination of *Striga* seeds, it prevents the attachment of the parasite to its roots, which leads to death of the parasite. Therefore most integrated *Striga* control programme use soybean as a trap crop in rotation with cereals (6, 8, 30, 31).

Compared with other grain legumes, soybean still faces only a limited number of pest problems in the Guinea savanna. However, the parasitic weed *Alectra,*

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which attacks cowpea (*Vigna unguiculata* (L). Walp), groundnut (*Arachis hypogaea* L.), and other tropical grain legumes poses a threat to soybean production in this agro-ecological zone (5, 21, 26). *A. vogelii* is very destructive in the northern Guinea and Sudan savanna agro-ecological zones of West and Central Africa where its damage is aggravated by poor soil and unreliable rainfall (28, 31) so that many farmers' fields are regulary blighted (31). Severe *Alectra* damage can thus cause up to 70 -100% crop loss in cowpea, soybean, and groundnut (5, 21, 26, 29). Many crop fields have been abandoned because of high rates of *Alectra* and the related parasitic weed *S. hermonthica* infestation. Infested fields are difficult to clean due to the species' enormous reproductive capacity. *Alectra* for example, produces 400,000–600,000 viable seeds/plant while *Striga* produces 40,000–60,000 seeds/plant. Moreover, and seeds can persist in the soil for up to 15 years (12, 19, 20). Kureh *et al*. (21) found that 2000 *Alectra* seeds per pot were adequate to parasitize and significantly reduce growth of soybean by over 70%. In another study, Kureh and Alabi (22) reported reduction in growth and nodulation of some soybean genotypes under controlled *Alectra* infestation.

Chemical and cultural methods such as use of clean seeds, adequate application of fertilizer, and optimal crop density have successfully been used to manage parasitic weeds and have proved useful in the control of *Striga asiatica* (L) Kuntze in the USA (7). An integrated approach combining crop resistance with crop management practices such as the use of legume-cereal rotation, application of nitrogen fertilizer, and use of clean seeds for planting probably offers the best solution to control these parasites for resource-poor farmers of the West African savanna. Such an integrated approach has been used in the management of *Striga* in the Guinea savannas of west and central Africa. For effective management of *Striga* in the field, Berner *et al.* (6) recommended the combined use of host plant resistance, crop rotation with non-host nitrogen-fixing legumes selected for efficacy in promoting germination of *Striga* seeds, and other cultural practices such as use of clean seeds and timely application of adequate fertilizers.

Extensive work has been done in west and central Africa in breeding for resistance to parasitic weeds such as resistance/tolerance of maize to *S. hermonthica* (2, 15, 17) and host/plant resistance of cowpea cultivars to *Alectra* (23, 26, 29, 33). Although *Alectra* infestations have been observed on soybean in the Guinea savannas of Nigeria, no information is available on the reaction to *Alectra* of various soybean genotypes bred in the Nigerian savanna. *Alectra* - resistant soybean genotypes can provide an economic means of *Alectra* control and could be important components of integrated *Alectra* management strategies. Information concerning the performance of soybean genotypes under *Alectra* infestation would be valuable to soybean breeders in planning future soybean selection and development programmes aimed at increasing soybean yield in the Guinea savannas of west and central Africa. The purpose of this study therefore was to evaluate soybean genotypes for resistance to *Alectra* infestation under field conditions.

Materials and methods

Field trials were conducted in 1995 and 1996, at two sites, at Samaru (11° 11'N; 7° 38'E; 686 m above sea level) in the northern Guinea savanna zone of Nigeria. Mean annual rainfall at Samaru normally is 1050 mm distributed over 5 months (June-October). Most of the soybean genotypes used in the tests were improved materials derived from the Tropical Glycine Crosses (TGX). These soybean cultivars were developed at the International Institute of Tropical Agriculture (IITA), and have been released in Nigeria and some other countries in the west African sub-region. The widely grown soybean genotypes tested were 9 early maturing (90-105 days) and 13 medium/late maturing (110-130 days) varieties. SAMSOY2, which is widely grown in the northern Guinea savanna zone served as a local check. The soil was a sandy-loam, isohyperthermic Plinthustalf (USDA taxonomy).

Genotypes were arranged in a randomized complete block design and replicated three times. Experiments were established in fields that are naturally heavily infested with *Alectra*, as indicated by high infestation levels in cowpea crops previously grown on the sites (7). The land was ploughed with disc harrow in order to get a fine tilth and ridged with 75 cm between ridges. At site 1, sowing was done on 13 July in 1995 and 28 June in 1996 while at site 2, sowing took place on the 18 July in 1995 and 20 June in 1996, resp. Soybean seeds were drilled on the ridges at a spacing of about 5 cm to achieve a plant population of 266,666 plants/ha. Each plot consisted of four ridges, 5 m long. At planting, phosphorus in the form of single super phosphate (28% P_2O_5) was applied to all plots at 26 kg P/ha. Nitrogen in the form of urea (46% N) was applied two weeks after sowing as starter dose at 20 kg N/ha. Annual weeds, except *Alectra*, were controlled with pre-emergence application of a formulated mixture of metobromuron plus metolachlor (Galex), at 2.5 kg a.i/ha followed by one hoe-weeding at 6 weeks after sowing (WAS). The data on the number of days to first *Alectra* emergence and number of emerged *Alectra* shoots were collected from the two middle rows (7.5 m^2) of each plot at 9 and 10 WAS. Soybean seed yield was determined at physiological crop maturity. For *Alectra* count and soybean yield determination, the two middle rows were sampled in each plot. Soybean was hand-harvested from 7.5 m^2, and allowed to thoroughly air-dry for two weeks before threshing. Seed moisture contents were determined using Dickey John moisture meter (Model 14998, Dickey-John Corporation, Auburn, USA) before weighing. Grain weights were then adjusted to 15% moisture content.

All data were analyzed using the General Linear Model procedure (GLM; SAS Package (34) and significant differences between genotype means were compared using standard error of means. The number of days to *Alectra* emergence and the number of emerged *Alectra* were regressed on grain yield of the soybean genotypes using the regression procedure (SAS Package) (34).

Results

There was no site by genotype interaction for neither of the variables measured. Site results were therefore combined for each year before analysis. Combined analysis showed significant differences amongst genotypes for number of *Alectra* plants emerged at 9 and 10 WAS, days to first *Alectra* emergence, and grain yield of soybean (Table 1).

At 9 WAS, the number of emerged *Alectra* shoots ranged from 0 to 277 per 7.5 m^2 in 1995, whereas in 1996 it ranged from 0 to 145. At 10 WAS, the number of emerged *Alectra* shoots ranged from 0 to 354 in 1995 and from 0 to 214 in 1996, resp.

Six soybean genotypes had significantly higher numbers of emerged *Alectra* shoots than the remaining 16 genotypes. Genotypes that consistently had high numbers of emerged *Alectra* were TGX87D-516, TGX1019-2EB, M-351, TGX849-313D, SAMSOY 2, and TGX1485-1D. *Alectra* emergence occurred later in early maturing soybean genotypes [54 days after sowing (DAS)], which coincided with the beginning of pod stage (R3, 13) than in late maturing genotypes. For most late maturing genotypes, *Alectra* first emerged at 50 DAS just before or around flowering (R1).

Table 1

Alectra* emergence, days to first emergence and grain yield of soybean genotypes under natural field infestation of *Alectra vogelii

	1995				1996			
	Emergence (plants/7.5 m^2)		Days to first emergence	Grain yield (kg/ha)	Emergence (plants/ 7.5 m^2)		Days to first emergence	Grain yield (kg/ha)
Genotypes	9 WAS	10 WAS			9 WAS	10 WAS		
Early Maturing								
TGX1660-15F	4.4	7.5	50.0	1934	2.4	6.0	55	1340
TGX1485-1D	14.7	25.7	53.5	1289	22.4	39.4	55	1140
TGX1649-11F	1	1.4	57.5	2037	0.5	0.7	60	1427
TGX1681-3F	0.9	1.2	53.0	1867	0.5	1.2	53.5	1530
TGX1674-3F	0.2	0.9	59.5	1878	0.0	0.0	.	1544
TGX1519-1D	1.9	3	51.0	1282	3.7	4.9	52	1187
TGX1740-7F	0.9	1.7	54.0	1639	0.7	0.8	55	1523
TGX1740-2F	0.0	0.0	.	1864	0.5	0.7	57.5	1567
TGX849-313D	53.5	80.0	51.5	930	12.7	18.5	50	987
Late Maturing								
TGX1019-2EB	32.2	52.2	47.0	937	103.4	130.9	49	923
TGX923-2E	8	11.5	48.0	1400	2.4	3.8	48	1333
SAMSOY 2	30.2	37.4	45.0	1815	14.3	19.7	37	1730
M-351	50.2	77.7	50.0	789	12.2	20.7	48.5	1040
TGX 1448-2E	1.7	2.9	51.5	1304	3.5	6.2	50	1274
TGX1440-1E	2.9	4.0	53.0	1293	2.0	3.7	51	1294
TGX1479-1E	3.7	5.4	55.5	1239	1.7	2.7	57.5	1274
TGX1670-1F	0.4	0.5	55.0	1872	0.2	0.4	61	1520
TGX87D-516	276.5	353.9	41.0	904	144.5	214.2	40.5	1027
TGX1670-3F	0.4	1.0	52.5	1812	0.3	0.7	54.5	1564
TGX1660-19F	0.7	0.7	61.5	1185	0.2	0.2	59	1600
536-02D	6.9	10.9	52.0	1411	5.8	9.0	49.5	1367
TGM 344	4.2	6.9	45.5	797	9.2	14.8	47	1054
MEAN	22.5	31.2	51.5	1431	15.6	22.7	51.5	1329
S.E.	12.6	16.2	2.3	87	7.7	10.9	1.5	49

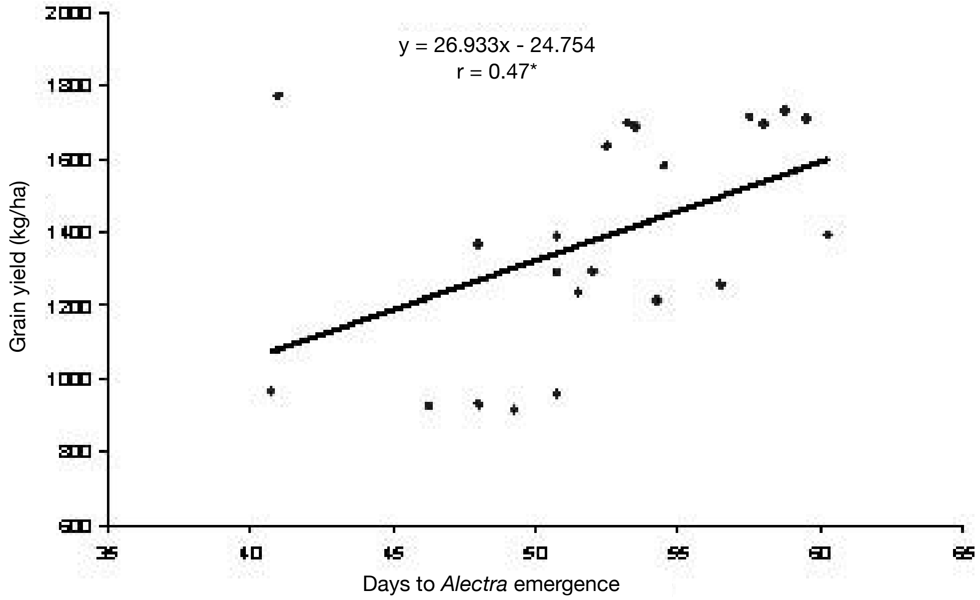

Figure 1: Relationship between days to first *Alectra* emergence and grain yield (kg/ha) of soybean.

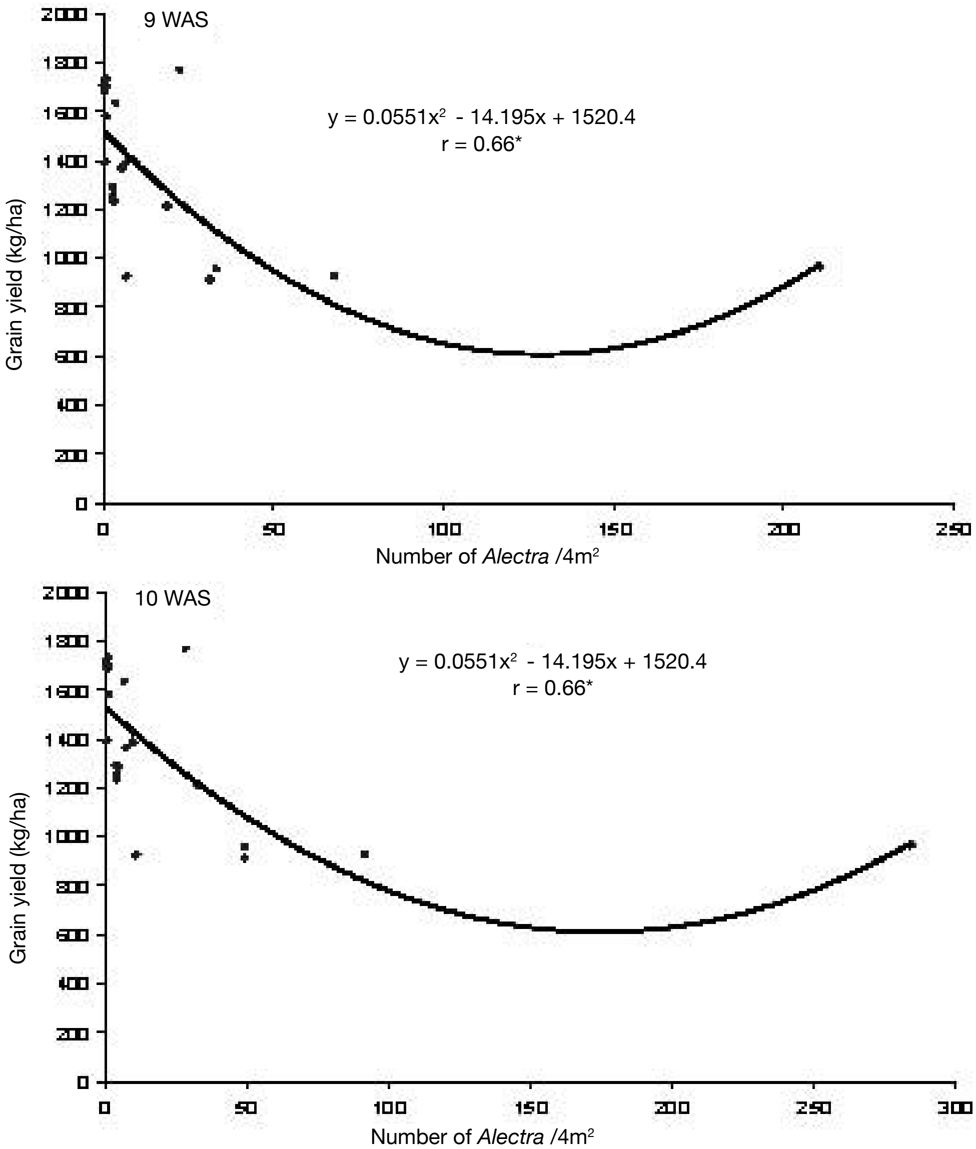

Figure 2: Effect of number of emerged *Alectra* plants and grain yield of soybean at 9 and 10 weeks after sowing (WAS) soybean.

Alectra infestation significantly reduced grain yield of the four most susceptible genotypes (TGX87D-516, TGX1019-2EB, M-351, and TGX849-313D). Reduction in grain yield was significant even at lower levels of infestation. Grain yield reduction by as few as 20 emerged *Alectra* shoots/plot was similar to grain yield reduction by 200 emerged *Alectra* shoots/plot (Figure 2).

Two genotypes (SAMSOY 2, and TGX1485-1D), which had high number of emerged *Alectra* shoots recorded grain yields similar to those of genotypes that had few or no emerged *Alectra* shoots. Grain yields of late maturing genotypes appeared to be more affected than those of early maturing genotypes. There was a significant and positive correlation (r= 0.47*) between days to first *Alectra* emergence and grain yield (Figure 1). Generally, there was a significant negative correlation (r= -0.66* for 9 WAS; r= -0.69* for 10 WAS) between number of emerged *Alectra* shoots and grain yield at both 9 and 10 WAS (Figure 2).

Discussion

This study showed significant differences to exist amongst soybean genotypes in their performance under *Alectra* infestation. These differences occurred in the number of days to first *Alectra* emergence, number of emerged *Alectra* shoots and grain yield of soybean, lower soybean grain yield with number of emerged *Alectra* shoots, shows that *Alectra* infestation reduced grain yield of soybean genotypes. Similarly, Alonge *et al.* (3) found that *Alectra* reduced grain yield, number of pods, pod weight, and number of seeds per pod in cowpea. This was attributed to reduced leaf area and photosynthetic activity of parasitized cowpea plants. They also found genotypic differences among cowpea varieties in their response to *Alectra*. Another report showed delayed onset of flowering, reduced number of flowers and pods and reduced weight of pods and seeds in cowpea due to *Alectra* infestation (27). In our study, grain yields of soybean genotypes that had early emergence of *Alectra* were lower than those which had delayed emergence. This may be due to the fact that by late emergence of *Alectra*, the sensitive growth stages of soybean would have been completed before the parasite became effective thereby escaping *Alectra* damage. Likewise, in maize, a *Striga*-resistant genotype (Across 97 TZL COMP1) in which *Striga* emergence is delayed until after the maize has silked, grain yield was not affected by *Striga* infestation (J.G. Kling, personal communication).

Host plants can respond differently to parasitic weed infestation because the ability of host plants to tolerate these weeds involves a number of different mechanisms (9, 10, 11, 14, 15, 16). In cowpea, vertical resistance occurs based on a single gene that inhibits *Striga* germination or attachment (32). In the present study, three different mechanisms of resistance may be involved. Sixteen genotypes had few or no emerged *Alectra* shoots at 9 and 10 WAS. This low emergence may be due to low production of germination stimulants by these genotypes or to host plant-parasite incompatibility whereby the initiation of haustoria, and subsequent attachment and penetration are all inhibited. Similarly, inhibition of *Striga* germination through low host plant production of germination stimulants, prevention of haustoria initiation, attachment to and penetration of host plants are found to confer resistance of some genotypes of cereals to *Striga* (10, 11, 24, 28). However, these possible mechanisms of resistance were not investigated in the present study. Therefore there is a need for further research to confirm these speculations.

Two genotypes, SAMSOY 2 and TGX1485-1D, which had high numbers of emerged *Alectra* shoots, recorded yields similar to those genotypes that had fewer or no emerged *Alectra* shoots. Probably these two genotypes exhibited tolerance to *Alectra*. Kim *et al.* (18) noted that tolerance to *Striga* in maize often did not involve a reduction in the number of *Striga* seedlings that were able to emerge from infested hosts. In their study, they found a *Striga*-tolerant inbred to support a high number of parasites.

There was a significant negative correlation between number of emerged *Alectra* plants and grain yield of soybean. These findings are, however, different from those of Adetimirin *et al*. (2) who found little correlation between *Striga* emergence counts and the tolerance of maize cultivars at Mokwa and Abuja in Nigeria.

As few as 20 emerged *Alectra* plants per 7.5 m^2 induced yield reductions, similar to those caused by 200 or more emerged *Alectra* plants (Figure 2). This shows that beyond a certain threshold that may be as few as 20 *Alectra* plants/7.5 m^2, yield reduction may no longer depend on number of emerged *Alectra* plants but probably on the susceptibility of the soybean genotype to *Alectra*. This is in agreement with Kim *et al*. (18) who observed one highly susceptible inbred line of maize that hosted very few *Striga* but reacted with reduction in root biomass and evidently senescing rapidly. While *Alectra* infestation was found to reduce soybean grain yield, the *Alectra* seed bank of the study area was not investigated. Generally, field screening relies on the previous knowledge of the level infestation of a field as shown through attacks on susceptible hosts.

Conclusions

Soybean is increasingly becoming popular in the Guinea savannas of west and central Africa. This crop is attractive to farmers because of its high economic value and the belief that it does not require many external inputs as it is relatively free of pests and fixes its own nitrogen, a nutrient deficient in savanna soils. Given the devastating effects of *Alectra* on grain legumes in this region, the threat posed by this parasitic weed should not be underestimated. Combining several control methods, as in the management of *Striga* spp. should be a sustainable option. Our study has confirmed that it is possible to exploit host plant resistance as part of control options in the management of *Alectra* in soybean. This is because significant differences were found among soybean genotypes in their reaction to *Alectra* infestation. Also *Alectra* emergence was significantly and negatively correlated with grain yield of the soybean genotypes. Possible mechanisms of resistance may be low stimulant production by host plant roots to induce germination of *Alectra*, prevention of haustoria initiation by *Alectra* and subsequent attachment and penetration of host plant, and also tolerance of soybean to *Alectra* infestation. These mechanisms were, however, not investigated in this study. Therefore there is a need for further investigation to confirm these speculations. Such information would be valuable for breeding efforts to develop or select *Alectra*-resistant soybean genotypes.

Literature

1. Adetimiri V.O., 1995, Inheritance of resistance in maize (*Zea mays* L.) to *Striga hermonthica* (Benth). PhD Thesis, Dept. of Agronomy, University of Ibadan. Nigeria, pp. 251.

2. Adetimiri V.O., Kim S.K. & Aken'ova M.E., 2000, Expression of mature plant resistance to *Striga hermonthica* in maize. Euphytica, 34, 1-10.

3. Alonge S.O., Lagoke S.T.O. & Ajakaiye C.O., 2001, Cowpea reactions to *Alectra vogelii* I: effect on growth. Crop Protection, 20, 281-290.

4. Atokpe I.D.K., Singh B.B., Emechebe A.M., 1995, Genetics of resistance to Striga and Alectra in cowpea. Journal of Hereditary, 86, 45-59.

5. Bagnall-Oakeley H., Gibberd V. & Nyongesa T.E., 1991, The incidence and control of *Alectra vogelii* in Embu District, Kenya. Proceedings of the fifth International Symposium of Parasitic Weeds. J.K. Ransom, L.J. Musselman, A.D., Worsham and C. Parker (eds.), CIMMYT, Nairobi, Kenya. Pages. 340-345.

6. Berner D.K., Carsky R., Dashiell K., Kling J. & Manyong V.M., 1996, A land management based approach to integrated *Striga hermonthica* management in Africa. Outlook on Agriculture, 25, 157-164.

7. Carsky R.J., Abaiido R., Dashiell K. & Sanginga N., 1997, Effect of soybean on subsequent grain yield in the Guinea savanna zone of west Africa. African Crop Science Journal, **5**, 1, 33-38.

8. Dogett H., 1988, Witch weed (Striga). *In*: Sorghum, Second edn. G. Wrigley, pp 368- 404. Longman Scientific and Technical. London, UK: Longman.

9. Efron Y., 1993, Screening maize for tolerance to *Striga hermonthica*. Plant Breeding, 112, 192-200.

10. Ejeta G. & Butler L.G., 1993a, Host plant resistance to *Striga*. Pages 561-569, *In*: International Crop Science 1. Crop Science Society of America., Madison, WI, USA.

11. Ejeta G. & Butler L.G., 1993b, Host-parasite interactions throughout the *Striga* life cycle, and their contributions to *Striga* resistance. African Crop Science Journal, **1,** 2, 75-80.

12. Emechebe A.M., Singh B.B., Leleji O.I., Atokpe I.D.K. & Adu J.K., 1991, Cowpea *Striga* problems and research in Nigeria. Pages 22-24, *In*: Kim S.K. (ed.). Combating Striga in Africa. Proceedings of a workshop held in Ibadan, August, 1988, IITA, Ibadan, Nigeria.

13. Fehr W.R. & Caviness C.E., 1977, Stages of soybean development. Ames, IA: Agriculture and Home Economics Experiment Station and Cooperative Extension Service, Iowa State University. Special Report 80. 11 p.

14. Kim S.K., 1991, Breeding maize for *Striga* tolerance and the development of field infestation technique. Pages 96-108, *In*: S.K. Kim (ed.) Combating Striga in Africa. International Workshop by IITA, ICRISAT and IDRC. IITA. Ibadan, Nigeria.

15. Kim S.K., 1994, Genetics of tolerance of maize to *Striga hermonthica*. Crop Science, 34, 900-907.

16. Kim S.K., 1996, Horizontal resistance: core to a research break-through to combat Striga in Africa. Integrated Pest Management Review, 1, 229-246.

17. Kim S.K., Robinson R.A., Atkinson K., Adetimirin V.O., The C. & Salle G. (eds.), 1998, Combating parasitic weeds through horizontal resistance. International Agricultural Research Inst., Kyungpook National University, Taegu, Korea. 66 pp.

18. Kim S.K., Akintunde A.Y. & Walker P., 1999, Responses of maize inbreds during development of *Striga hermonthica* infestation. Maydica, 44, 333-339.

19. Kroschel J., 1998, *Striga*: How will it affect African agriculture in the future? An ecological perspective PLITS, 16, 137-158.

20. Kroschel J., 1999, Analysis of the Striga problem, the first step towards future joint action. *In*: Kroschel, J.H. Mercer-Quarshie, J. Sauerborn (eds). Advances in Parasitic Weed control at on-farm level. Vol **1**. Joint action to Control Striga in Africa. Margraf Verlag, Weikersheim, Germany.

21. Kureh I., Katung P.D. & Orakwue F.C., 1999, Reaction of soybean varieties to preconditioning and concentration of seed inoculum of *Alectra vogelii* (Benth). Science Forum, Journal of Pure and Applied Science, **2**, 1, 116-124.

22. Kureh I. & Alabi S.O., 2003, The parasitic angiosperm *Alectra vogelii* (Benth) can influence the growth and nodulation of host soybean (Glycine max (L) Merril). Crop Protection, 22, 361-367.

23. Lane J.A., Bailey J.A. & Tery P.J., 1991, An *in-vitro* growth of system for studying the parasitism of cowpea (*Vigna unguiculata)* by *Striga gesneroides*. Weed Research, 31, 211-217.

24. Lynn D.G. & Change M., 1990, Phenolic signals in cohabitation: implication for plant development. Annual Review of Plant Physiology, 41, 497-526.

25. Magani I.E., Lagoke S.T.O, Emechebe A.M., Singh B.B. & Adu J.K., 1991, Reaction of cowpea varieties to *Alectra* in northern Guinea Savanna. Paper presented at the 19 Annual Conference of the Weed Science Society of Nigeria. ABU, Zaria, Nigeria, 1-10.

26. Magani I.E., 1994, Effects of fertilizers and herbicides on the reaction of cowpea (*Vigna unguiculata* (L.) Walp) varieties to *Alectra vogelii* Benth. PhD Thesis, Department of Agronomy, Ahmadu Bello University, Zaria, Nigeria, 165 pp.

27. Mugabe N.R., 1983, Effect of *Alectra vogelii* Benth on cowpea (*Vigna unguiculata* (L.) Walp) I: Some aspects on reproduction of cowpea. Zimbabwe Journal of Agricultural Research, **21**, 2, 135-147.

28. Olivier A., Benhamon N. & Leroux G.D., 1991, Cell surface interactions between sorghum roots and the parasitic weed *Striga hermonthica* cytochemical aspects of cellulose distribution in resistant and susceptible host tissues. Canadian Journal of Botany, 69, 1679-1690.

29. Parker C., 1991, Protection of crops against parasitic weeds. Crop Protection, 10, 6-13.

30. Parkinson V., Kim S.K., Efron Y., Bello L. & Dashiell K., 1987, Trap crops as a cultural measure in Striga Control in Africa. FAO Plant Protection Bulletin No. 35 (Rome: FAO), pp. 51-54.

31. Salle G. & Raynal-Roques A., 1989, Le Striga. La Recherche, 20, 44-52.

32. Singh B.B. & Emechebe A.M., 1990, Inheritance of *Striga* resistance in cowpea genotype B301. Crop Science, 30, 879-881.

33. Singh B.B. & Emechebe A.M., 1997, Advances in research on cowpea *Striga* and *Alectra*. Pages 215-224 *In*: Singh, B.B., Mohan Raj., D.R. Dashiell, K.E., and Jackai, L.E.N. (eds.), Advances in cowpea research. Co-publication, IITA and JIRCAS. IITA, Ibadan, Nigeria.

34. SAS, 1990, SAS/STAT User's Guide. Version 6, 4th edn. SAS Institute Inc. Cary, USA.

35. Smith J., Woodworth J.B. & Dashiell K.E., 1993, Government policy and farm-level technologies. The expansion of soybean in Nigeria. Agricultural Systems in Africa, 3, 20-32.

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