Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 17 Number 3 (September 2018) pp. 1-6
ISSN 1119-7455

Aeschynomene histrix (Joint Vetch) FALLOW AND NITROGEN FERTILIZER EFFECTS ON *Striga hermonthica* INFESTATION AND MAIZE (*Zea mays*) PRODUCTIVITY IN SOUTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT
Integration of herbaceous legume Aeschynomene histrixinto the farmers' cropping system is one viable option that can improve the nutrition of maize (Zea mays), increase soil physical, chemical and biological properties which can result in sustainable Striga control and crop productivity. This study was conducted to determine the effects of A. histrix fallow and N fertilizer application on Strigainfestation, growth and yield of maize. The study involved the factorial combination of fallow type: natural fallow (NF) and A. histrix fallow (AF), and inorganic N fertilizer application: 0, 30, 60 and 90 kg N ha^{-1} arranged in a split plot in a randomised complete block design and replicated three times. Results show that cropping/maize after A. histrix fallow significantly ($P < 0.05$) delayed Strigaemergence, reduced its virulence on the host crop, increased maize plant height, and grain yield compared to natural fallow. Application of 90 kg N ha^{-1} delayed days to Striga shoot emergence, reduced Striga damage on host crop, and increased plant height of maize. Heavier and higher grain yield of maize were significantly associated with of 60 kg N ha^{-1}. Integrating A. histrix fallow rotations with application of 60 kg N ha^{-1} can provide sustainable Strigacontrol, and A. histrixin combination with 90 kg N ha^{-1} modest yield of maize. This study has shown that farmers in the southern Guinea savanna location of Nigeria can effectively control Striga and obtain better maize yield by integrating A. histrix fallow with the application of N fertilizer.

Key words: *Striga, Aeschynomene histrix*, fallow rotation, nitrogen, maize

INTRODUCTION
Witch weed (*Striga hermonthica* (Del.) Benth.) is a major biotic constraint threatening the production of several cereal crops, in small-holder farmlands in sub-Sahara Africa (Sjogren *et al*., 2010; Jamil *et al*., 2012). The weed is a root hemiparasite claimed to be affecting an estimated 45 million ha of arable farmlands in Africa (Olupot *et al*., 2003). It is known to attach itself to the roots of the host crop, such as maize, sorghum, millet, rice, finger millet, pearl millet, wheat and sugar cane, thereby reducing their productivity. *Striga* infestation and poor soil fertility are among factors that cause severe yield losses in maize production (Sjogren *et al*., 2010; Kamara *et al*., 2012; Uzoh *et al.,* 2015). This implies that maize farmlands are faced with a complex of biotic and abiotic problems (Kamara *et al.,* 2012). For instance, in Africa, an estimated 75,000 ha of smallholder farmlands under maize cultivation are under *Striga* infestation, which is on the increase both in severity and spread due to the continuous depletion of the soil fertility (Sjogren *et al.,* 2010). In Nigeria, over 85% of maize and sorghum farmlands are infested with *Striga* (Kamara *et al.,* 2012), causing severe yield losses to complete crop failure, and in most cases, farmers are made to abandon such infested land (Kolo and Adamu, 2006; Kamara *et al*., 2012).

One feasible and effective method that can be adopted by resource constraint farmers for *Striga* control is integrating management options that include inorganic N-fertilizer application and cultural practices, like crop rotation with herbaceous legumes (Dakora and Keys, 1997). The use of inorganic fertilizer is, however, hampered by its inaccessibility to the majority of the farmers due to high cost in a developing country like Nigeria (Juo *et al.,* 1995). A viable option that is available for the farmer is to integrate herbaceous legumes such as *A. histrix* into the smallholder maize cropping system. This legume has the ability to fix large quantities of N into the cropping system and can improve the nutrition of maize and soil organic matter content (Carsky *et al.,* 2001). In addition to increased soil N supply, legume species can improve the soil physical, chemical and biological properties (Uzoh *et al*., 2017), and as well create a less favourable environment for pests like *Striga*

Please cite as: Usman I., Daniya E. and Kolo M.G.M. (2018). *Aeschynomene histrix* (joint vetch) fallow and nitrogen fertilizer effects on *Striga hermonthica* infestation and maize (*Zea mays*) productivity in southern Guinea Savanna of Nigeria. *Agro-Science*, **17 (3),** 1-6.
DOI: https://dx.doi.org/10.4314/as.v17i3.1

(Sjogren *et al.,* 2010), resulting in high and sustainable crop production.

There is, however, little information on the effect of this legumes species on *Striga* prevalence when fallowed with maize in *Striga* infested land in the southern Guinea savanna of Nigeria. The question we seek to answer is whether planted fallow with herbaceous legume, *A. histrix*, can address the problem of *Striga* infestation and increase maize production. Hence, the present study had two objectives, to:

(i) evaluate the effect of one or two years fallow of *A. histrix* and N-fertilizer application on *Striga* suppression in maize; and
(ii) assess the growth and yield of maize under one or two years fallow of *A.histrix* and N-fertilizer application.

MATERIALS AND METHODS

Experimental Site

Field experiment was conducted from 2010 to 2012 growing seasons at the Federal University of Technology, Gidan Kwano ($09^0$31.860^l N latitude; $6^0$27.244^l 'E longitude; 254 m above sea level), Minna in the southern Guinea savanna of Nigeria. Soil samples at 0-15 cm were taken prior to field establishment with a soil auger from ten different spots from the experimental site. These were bulked and sub-samples were taken and subjected to routine soil analysis for physical and chemical properties (Table 1). The Bouyoucous hydrometer with sodium hexametaphosphate as a dispersing agent was used to determine the soil particle size (Gee and Or, 2002). Soil pH was determined with a glass pH meter in 1:2 (soil: water) ratio. Organic carbon was determined by the Walkley and Black method (Anderson and Ingram, 1993). The macro-kjeldahl method was used to determine the total nitrogen content (Jackson, 1962). The Olsen method was used to determine the available phosphorus, and exchangeable potassium by flame photometer (Okalebo *et al*., 2002).The rainfall pattern in the experimental site is monomial with a mean value that varies from 1103 to 1362mm, concentrated almost entirely in seven months. Rainy season in this location normally starts in April/May and ends in October, with an estimated 74 % of the annual rainfall occurring between June and September with August as the peak rainfall month (Alabi and Ibiyemi, 2000). The experimental site had been under continuous cultivation with arable crops such as maize, sorghum and yam for several years. The site was chosen because of the high prevalence of *Striga* prior to this study.

Treatments and Experimental Design

The treatment was a factorial combination of fallow: natural fallow (NF) and *A. histrix* fallow (AF), and inorganic N application: 0, 30, 60, 90 kg N ha^{-1} arranged as a split-plot in a randomised complete block design with three replications. Fallow type (NF and AF) was assigned to the main plot, while inorganic fertilizer rate was assigned to the subplot. The subplot was 6 x 8 m, separated by an alley of 1m between each treatment plot. There were two types of natural and *A. histrix* fallow (AF): one-year fallowthen succeeded by maize in the second year; and two years fallow then succeeded by maize in the third year.

Agronomic Practices

The experimental field was manually cleared of existing vegetation in the first year, and the AF portion ploughed and evenly broadcast with 20 kg ha^{-1} of *A. histrix* seed mixed with 25 kg soil ha^{-1} as described by Kayeke *et al*. (2007). The NF plot was not manually weeded, while the *A. histrix* plot was weeded by hand-pulling other weeds than *Striga* and *A. histrix*at 3 and 6 WAS during the season. At the end of each fallowperiod, existing vegetation in all the plots was incorporated into the soil by manual ploughing, and ridged at 75 cm apart. A basal application of 60 kg ha^{-1} each of P_2O_5 and K_2O from the single superphosphate and muriate of potash were applied to all the plots. Three seeds of maize (Suwan 1) were sown at a depth of 4cm, at an intra-row spacing of 50 cm. Maize seedlings were thinned to two plants per stand at 2 WAS to give a plant population of 53,000 plants ha^{-1}. One-third of N fertilizer rate from urea was applied at 3 WAS and the remnant two-thirds at 6 WAS by side placement at 5 cm deep and 5 cm away from the base of each plant stand as per the treatment.

Data Collection

Days to first *Striga* shoot emergence was taken by observing from sowing date to days to when *Striga* plants began to emerge per gross plot (eight rows of 6 m × 8 m (48 m^2). *Striga* reaction score on maize was taken by measuring the host damage severity on a scale of 0-9, where 0 - no effect on maize plant (plots with vigorous plants), and 9 - necrosis/dead (plots with completely dead plants) as described by Reinhardt and Tesfamichael (2011). Maize height was taken from ten randomly selected and tagged plants within the plot by measuring each stand from the soil level to the flag leaf using a metre rule at 6, 9 and 12 WAS. Maize grains were obtained from all the harvested and air-dried shell ears from the net plot (two middle rows of 3 m × 8 m (24 m^2) and then expressed in kg $ha^{-1}$to determine the grain yield. For 100-grain weight, 100 grains were taken from each net plotand expressed in grams (g).

Data Analysis

Prior to statistical analysis, data on *Striga* parameters were square root transformed to improve the normality. All the data obtained from the experiment were subjected to the analysis of variance (ANOVA) using the Statistical Analysis System (SAS) (SASInstitute Inc., 2002). The treatment means were separated using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

Initial Soil Physical and Chemical Properties

The initial physical properties of the soil of the experimental site was relatively high in sand content, while the silt and clay contents were low (Table 1). The chemical properties of the soil was slightly acidic, generally low in organic carbon content, with moderate total N content, low available phosphorus and high K content.

Striga Infestation

The results show that *A. histrix* fallow caused significantly longer days to *Striga* shoot emergence compared with natural fallow in the two years of study (Table 2). Application of 60 or 90 kg N ha^{-1} in 2011 (one year fallow), and 90 kg N ha^{-1} in 2012 (two years fallow) produced longer days to first *Striga* shoot emergence than that of the lower N rates. The interaction between two year fallow and N fertilizer application on days to first *Striga* shoot Emergence in 2012 was significant (P < 0.05) (Table 3). Under *A. histrix*fallow, there was no significant response of days to first *Striga* shoot emergence as N fertilizer rate was varied from 0-90 kg^{-1}. However, under natural fallow, number of days to first *Striga* shoot emergence directly increased proportional to increase in N fertilizer rate from 0 - 90 kg^{-1}. The reaction score shows that at 9 and 12 WAS, *Striga* effect on maize was lower in maize plots succeeding *A. histrix* fallow compared to maize following natural fallow in both years of study (Table 4). Application of 90 kg N ha^{-1} at 9 and 12 WAS in 2011 (one year fallow), and at 12 WAS in 2012 (two years fallow) had significantly lower *Striga* reaction than the other treatments, except that with 60 kg N ha^{-1} plots at 12 WAS in both years of the study were at par. The interaction between fallow type and N fertilizer application on *Striga* reaction on maize at 9 WAS in 2011 (one year fallow) showed that there was a significant (P < 0.05) decrease of *Striga* effect on maize as N fertilizer was increased from 0-90 kg ha^{-1} (Table 5). The effect was similar at 90 kg N irrespective of fallow type, while at 0-60 kg N natural fallow was more severely affected than the *A. histrix* fallow

Plant Height

Maize planted after *A. histrix* fallow was significantly taller compared with that planted under natural fallow at 9 and 12 WAS in 2011 (one year fallow) and throughout the sampling periods in 2012 (two years fallow) (Table 6). Application of N fertilizer at 90 kg ha^{-1} had taller plants but at par with plots given 60 kg ha^{-1} at 6 WAS in 2011 (one year fallow) and 2012 (two years fallow). Application of 0 kg N ha^{-1} had the shortest maize plants in both years. The interaction between fallow type and N fertilizer application on maize height at 12 WAS in 2012 (two years fallow) was significant (P < 0.05) (Table 7). In this case, irrespective of the fallow method, there was an increase in height of maize plants as N fertilizer rate was increased from 0 to 90 kg ha^{-1}. The use of *A. histrix* in combination with application of 90 kg N ha^{-1} had the tallest maize plants in this study.

Grain Weight and Yield

Heavier maize grains were recorded in *A. histrix* fallow plots compared with that following natural fallow in both years of study (Table 8). Furthermore, heaviest grains were obtained in plots given 60 kg N ha^{-1}, but similar heaviest grains at 90 kg N ha^{-1} in both years were obtained. The lightest grains were, however recorded in 0 kg N ha^{-1} plots in both years. Grain yield of maize was significantly higher in *A. histrix* fallow plots compared with natural fallow plots in the two years of study (Table 8). Furthermore, application of 60 kg N ha^{-1} had a significantly higher grain yield compared to maize planted in 30 and 0 kg N ha^{-1} plots in both years.

Table 1: Physical and chemical properties of the soil at the experimental site (0-15 cm) prior to field establishment

Parameter	Value
Sand (g kg^{-1})	645
Silt (g kg^{-1})	65
Clay (g kg^{-1})	93
Textural class	Loamy
pH(water)	6.6
Organic carbon (g kg^{-1})	0.6
Total N (g kg^{-1})	0.13
Available P (mg kg^{-1})	4.30
Exchangeable K (cmol kg^{-1})	1.05

Table 2: Days to first *Striga* shoot emergence as affected by fallow type and N fertilization

	Days to first *Striga* shoot emergence	
Treatment	One year fallow	Two years fallow
Fallow Type (F)		
A.histrix	54.1a	58.9a
Natural	44.9b	45.2b
SE ±	0.5	0.8
Nitrogen (N) (kg ha^{-1})		
0	45.2c	50.0b
30	49.0b	50.3b
60	50.6a	52.2b
90	53.2a	60.0a
SE ±	0.7	1.1
Interaction		
F × N	NS	*

Means followed by the same letter in the same treatment column are not significantly different at P ≤ 0.05 according to Duncan Multiple Range Test

Table 3: Interaction between fallow type and N fertilization on days to first *Striga* shoot emergence in 2012 (two years fallow)

	Nitrogen (kg ha^{-1})			
Fallow Type	0	30	60	90
A.histrix	60.3a	58.0a	58.3a	59.0a
Natural	39.7d	42.7cd	46.0c	52.3b
SE ±	4.12			

Means followed by the same letter(s) in a row and between columns are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

Table 4: *Striga* reaction score as affected by fallow type and N fertilization

	Striga reaction score					
	One year fallow			Two years fallow		
	Weeks after sowing			Weeks after sowing		
Treatment	6	9	12	6	9	12
Fallow Type (F)						
A. histrix	0.2a	2.0b	3.1b	0.2a	1.4b	2.5b
Natural	0.3a	3.2a	5.4a	0.3a	4.3a	5.2a
SE ±	0.1	0.2	0.3	0.1	0.4	0.3
Nitrogen (N) (kg ha^{-1})						
0	1.0a	4.0a	6.2a	0.7a	3.7a	5.5a
30	0.0b	2.5b	4.3b	0.2b	3.0a	4.2ab
60	0.0b	2.2b	3.7bc	0.0b	2.3a	3.0bc
90	0.2ab	1.3c	2.8c	0.0b	2.3a	2.7c
SE ±	0.2	0.3	0.3	0.1	0.6	0.5
Interaction						
F × N	NS	*	NS	NS	NS	NS

Means followed by the same letter in the same treatment column are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

Table 5: Interaction between fallow type and N fertilization on maize *Striga* reaction score at 9 WAS in 2011 (one year fallow)

		Nitrogen (kg ha^{-1})		
Fallow Type	**0**	**30**	**60**	**90**
A.histrix	2.7b	1.7c	1.7c	1.3c
Natural	5.3a	3.3b	2.7b	1.3c
SE ±	0.3			

Means followed by the same letter(s) in a row and between columns are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

The significant interaction between fallow type and N fertilizer application rate on maize grain yield in 2011 (one year fallow) showed an increase in grain yield as N rate was increased from 0 kg N ha^{-1} irrespective of the fallowtype (Table 9). Application of 90 kg N ha^{-1} in combination with *A.histrix*fallow had the highest grain yield of maize in this study.

DISCUSSION

The low silt and clay content ratio of the soil suggests low degree of weathering of the soil as earlier reported by Afolabi *et al*. (2014) in the same location. The low level of organic carbon is an indication of rapid organic matter breakdown, removal of crop residues and poor soil management by the farmer (Afolabi *et al*., 2014). Also, the moderate level of total N content having low available P and cation exchangeable capacity of the soil according to the rating by the FMARD (2012) suggests that the soil in the site cannot sustain crop growth without the addition of external inputs like inorganic N and organic N through fallow. Planted *A. histrix* fallow delayed days to *Striga* shoot emergence and *Striga* damaging effect on maize, suggesting that *A. histrix* affected some inhibitory properties on *Striga* seed germination and/or seedling development. Our results are consistent with the findings of Kim *et al*. (1997), Lagoke *et al*. (1997) and Botanga *et al*. (2002) who reported that cultivating maize after a legume fallow, like *A. histrix* fallow, is an effective means of suppressing *Striga* emergence through suicidal *Striga* seed germination. Also, the practice of *A. histrix* fallow increased plant height, grain weight and yield of maize in our study. The increase in growth and yield of maize was due to inhibition of *Striga* development, in addition the shading effect of *A. histrix* legume canopy on *Striga* which could change temperature and humidity of the farmland (Sjogren *et al*., 2010). In our study, application of 90 kg N ha^{-1} reduced *Striga* emergence and its damage on maize as N application depressed *Striga* infestation. This finding is in agreement with the work of Sarmiso (2016) who reported that increasing N level from 0 to 92 kg N ha^{-1} decreased *Striga* emergences compared to plots without N application. The production of consistently tallest maize plants in plots treated with 90 kg N ha^{-1} was attributed to the efficient inhibition of *Striga* growth by the application of a high dose of N, which in turn translated into rapid growth and development of maize.

Table 6: Plant height of maize as affected by fallow type and N fertilization

	Maize plant height (cm)					
	One year fallow (WAS)			Two years fallow (WAS)		
Treatment	6	9	12	6	9	12
Fallow Type (F)						
A. histrix	109.4a	167.7a	192.1a	115.3a	178.9a	201.1a
Natural	101.0a	145.0b	173.5b	104.3b	146.9b	155.9b
SE ±	2.8	3.3	4.0	2.4	2.2	1.8
Nitrogen (N) (kg ha^{-1})						
0	93.5c	121.5d	144.0d	99.0c	127.5d	138.3d
30	101.7bc	138.5c	168.2c	105.2bc	143.5c	160.3c
60	108.3ab	173.0b	200.2b	113.2ab	178.3b	196.7b
90	117.3a	192.3a	218.8a	122.0a	202.3a	218.7a
SE ±	1.6	1.9	2.3	3.4	3.0	2.5
Interaction						
F × N	NS	NS	NS	NS	NS	*

Means followed by the same letter in the same treatment column are not significantly different at P ≤ 0.05 according to Duncan Multiple Range Test

Table 7: Interaction between fallow type and N fertilization on maize plant height at 12 WAS in 2012 (two years fallow)

	Nitrogen (kg ha^{-1})			
Fallow Type	0	30	60	90
A.histrix	156.7f	187.7d	225.0b	235.0a
Natural	120.0h	133.0g	168.3e	202.3c
SE ±	3.54			

Means followed by the same letter(s) in a row and between columns are not significantly different at P ≤ 0.05 according to Duncan Multiple Range Test

Table 8: Grain weight and yield of maize as affected by fallow type and N fertilization

	100- grain weight (g)		Grain yield (kg ha^{-1})	
Treatment	One year fallow	Two years Fallow	One year fallow	Two years Fallow
Fallow Type (F)				
A. histrix	27.8a	29.8a	4046.0a	4844.0a
Natural	22.5b	22.8b	2676.0b	2947.0b
SE ±	0.4	0.3	86.9	45.8
Nitrogen (N) (kg ha^{-1})				
0	21.2c	22.7d	1747.0c	2530.0c
30	25.1b	25.7c	2601.0b	3001.0b
60	26.6a	27.6b	4640.0a	4690.0a
90	27.7a	29.1a	4999.0a	4818.0a
SE ±	0.5	0.4	122.8	64.8
Interaction				
F × N	NS	NS	**	NS

Means followed by the same letter in the same treatment column are not significantly different at P ≤ 0.05 according to Duncan Multiple Range Test

Table 9: Interaction between fallow type and N fertilization on maize grain yield in 2011 (one year fallow)

	Nitrogen (kg ha-1)			
Fallow Type	0	30	60	90
A.histrix	2156.0e	3187.0d	5181.0ab	5661.0a
Natural	1337.0f	2014.0e	4099.0c	4336.0b
SE ±			173.7	

Means followed by the same letter(s) in a row and between columns are not significantly different at P ≤ 0.05 according to Duncan Multiple Range Test

Our result is consistent with previous studies in which the application of N fertilizer at 90 kg N ha^{-1} enhanced plant growth in maize production (Dugje *et al*. 2008). The delay in *Striga* shoot emergence and reduced syndrome reaction score on maize of interaction between *A. histrix* fallow and N fertilizer application was due to higher soil nitrogen. This is consistent with the findings of Sjogren *et al.* (2010) who noted that fodder legumes can reduce *Striga* infestation as trap crops, and application of high N rates reduced *Striga* infestation and increased crop growth and yield.

CONCLUSION

This study has shown that farmers in the southern Guinea Savanna of Nigeria can suppress *Striga* infestation by practising *A. histrix* fallow in combination with application of 60 kg N ha^{-1}, and natural fallow with application of 90 kg N ha^{-1} for maize production. Increased growth and yield of maize can be realized in this agro-ecology with *A. histrix* fallow in combination with 90 kg N ha^{-1}.

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