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Reducing *Striga hermonthica* (Del.) Benth. incidence on maize (*Zea mays* L.) using *Mucuna*–maize rotation

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ABSTRACT

Objective: To explore the potential of using *Mucuna* to improve soil fertility and reduce the incidence of *Striga hermonthica* using *Mucuna*- maize rotation without additional inorganic fertilizer application.

Methodology and results: In 2005, 10 *Mucuna* accessions [*M. cochinchinensis*, *M. georgia*, *M. ghana*, *M. jaspaeda, M. pruriens* IRZ, *M. pruriens* var *utilis*, *M. rajada*, *M. veracruz* (black seeded), *M. veracruz* (mottle seeded), and *M. veracruz* (white seeded)], were planted and left on a *Striga*-infested field throughout the year. In 2006, a *Striga* susceptible open pollinated maize variety, TZERS-W, was planted on the *Mucuna* plots without inorganic fertilizer. A plot with conventional recommended rate of inorganic fertilizer and a plot without fertilizer application and without *Mucuna* were included in the design as controls. Germinability, nodulation, leaf area index, dry matter, ground cover and canopy persistence differed significantly ($P \leq 0.05$) between the Mucuna accessions with *M. cochinchinensis, M. veracruz* (black seed) and *M. veracruz* (white seed) being the best three. There were no significant differences in maize growth and yield attributes between the plots with *Mucuna* and the conventional fertilizer plots. Maize grain yields from the plots with *Mucuna: M.cochincninensis* (3.2 tha^{-1}), *M. georgia* (1.9 tha^{-1}), *M. ghana* (2.7 tha^{-1}), *M.jaspaeda* (2.8 tha^{-1}), *M. pruriens* IRZ (3.1 tha^{-1}), *M.pruriens* var *utilis* (2.6 tha^{-1}), *M.rajada* (2.0 tha^{-1}), *M. veracruz* (black)(3.1 tha^{-1}), *M. veracruz* (mottle)(2.6 tha^{-1}), *M. veracruz* (white)(2.4 tha^{-1}) and plots with inorganic fertilizer (2.6 tha^{-1}) were significantly ($P \leq 0.05$) higher than in plots without fertilizer (0.50 tha^{-1}). The mean *Striga* shoot count (4.6 shoots m^{-2}) in plots with *Mucuna* at harvest did not differ significantly from the plots with fertilizer treatment (5 shoots m^{-2}), but were significantly different from plots without fertilizer and *Mucuna* (10 shoots m^{-2}). The weed biomass was significantly lower (137 gm^{-2}) in plots with *Mucuna* compared to 275 gm^{-2} in plots with fertilizer and 550 gm^{-2} for plots without fertilizer and *Mucuna*.

Conclusion and application: Resource-poor farmers in the sub-humid savanna can achieve sustainable maize production by rotating the crop with *Mucuna* to increase soil fertility and cost effectively reduce *Striga* infestation.

Key words: *Striga* incidence, maize production, *Mucuna*-maize rotation, sub-humid savanna

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INTRODUCTION

In many parts of the Sub-humid Savanna (SHS) of West Africa, continuous cropping of cereals and other unsustainable farming practices has resulted in depletion of key nutrients. Nutrient depletion rates are estimated to exceed 26 kg of nitrogen (N), 3 kg of phosphorous (P) and 19 kg of potassium (K) per hectare per year (SP-IPM, 2003). Nutrient-poor soils, exhausted by continuous cropping, favour the build up of parasitic weeds. Yield losses due to *Striga* may be as high as 100% and may lead farmers to abandon such farmlands (Abbasher *et al*., 2002). Sharp decline in maize and sorghum production has been reported in Benue State, Nigeria and is attributed to *Striga* infestation, which is caused by low soil fertility (DFID Weeds Project, 2002; BNARDA, 2005). Most tropical maize varieties grown in Africa are highly susceptible to *S. hermonthica* (Kim *et al*., 1985; Kureh *et al*., 2002).

Maize (*Zea mays* L.) has replaced the more traditional crops, such as sorghum and millet, in the farming systems of West and Central Africa. It is important especially in the SHS, where it is one of the two major crops covering about 40% of the area under agricultural production (Smith *et al*., 1992). In Nigeria, maize has gained prominence in the savanna as the most important cereal (Lagoke *et al*., 2002).

One important characteristic of maize is its high and relative rapid nutrient requirement. The soils, for example, must supply about 50-60 kg N (usually nitrate) and 30 kg Pha^{-1} in plant available forms for each ton of grains produced (Weber, 1996). Most often these requirements are not met because farmers do not apply the required amounts of inorganic fertilizer, mainly due to high cost and shortages. Green manure cover crops (GMCC), e.g. *Mucuna* species, can be used as a low-input technology in traditional cropping systems to improve soil through N fixation and production of large quantities of residual biomass and also to suppress germination of *Striga* seeds (Pesch & Pieterse, 1982; Olaniyan *et al.,* 1991).

Mucuna has been the most researched GMCC for the tropics (Buckles, 1995). It grows well in diverse environments, usually producing a lot of biomass (Carsky *et al*., 2001); has very positive impacts on the main crop yield (Carsky *et al*., 1998) and on weed incidence, as it suppresses even the most noxious ones such as *Imperata cylindrica* (Chikoye & Ekeleme, 2001). In Kenya, farmers ranked *Mucuna* as the best GMCC (Mureithi *et al*., 2000). In Nigeria, various accessions of *Mucuna* have been screened in the forest zone for their growth characteristics and weed suppressing ability (Chikoye & Ekeleme, 2001).

Several studies indicate that leguminous cover crops can improve the nitrogen status of soils and even reduce the fertilizer N requirement of succeeding non-leguminous crops (Asibuo & Osei-Bonsu, 1999). *M. pruriens* and *M. cochinchinensis* increased maize grain yield by 98% without inorganic fertilizer application (Codjia, 1996), which indicates the possibility of growing a non-leguminous crop successfully without inorganic fertilizer if done in rotation with an appropriate leguminous cover crop. This paper reports on the effect of *Mucuna* cover crop, grown in rotation with maize, on soil fertility and *S. hermonthica*.

MATERIALS AND METHODS

Experimental site: The trials were conducted in 2005 and 2006 on an abandoned *Striga*-infested field at the Experimental Station of the University of Agriculture, Makurdi (7°41'N, 08°37'N, and 94 m above sea level). The area is located in the Sub-humid savanna (SHS) ecological zone, which has a bimodal rainfall distribution pattern. Total rainfall received from May to October at the site was 1247 mm in 2005 and 1401 mm in 2006. The soil type is sandy loam. Soil samples were taken before and after *Mucuna* planting and analyzed for changes in physical and chemical properties.

Collection of *Mucuna* accessions and maize: Seeds of 10 *Mucuna* accessions (Table 1) were obtained from the International Institute of Tropical Agriculture (IITA), I badan, Nigeria, while those of the open pollinated *Striga* susceptible maize variety TZESR-W were obtained from the National Cereal Research Institute (NCRI), Yandev sub-station, in Benue State, Nigeria.

Table 1: The 10 *Mucuna* accessions grown in 2005 at the Experimental Station of the University of Agriculture Makurdi, Nigeria

Treatment code	*Mucuna* accession
T1	*Mucuna cochinchinensis*
T2	*Mucuna georgia*
T3	*Mucuna ghana*
T4	*Mucuna jaspaeda*
T5	*Mucuna pruriens* IRZ
T6	*Mucuna pruriens var utilis* (control)
T7	*Mucuna rajada*
T8	*Mucuna veracruz* (black seed)
T9	*Mucuna veracruz* (mottled seed)
T10	*Mucuna veracruz (white seed)*

Source: IITA, Ibadan, Nigeria, 2005

Experimental design: In 2005, the treatments, which included *Mucuna pruriens* var *utilis* as control, were arranged in a randomized complete block (RCB) design with four replications, in plots measuring 5 m x 4 m. In early April, the vegetation was slashed with a machete and then ploughed and harrowed in May. *Mucuna* seeds were soaked in warm water to improve germination (Chee & Chiu, 1997) and treated with Apron Plus (Metalaxyl) to protect them from pests. Three seeds (about 30 kg ha^{-1}) were planted per hill at 100 cm x 25 cm in mid-May when rain stabilized and later thinned to one seedling to give 40,000 plants ha^{-1}. Each plot was weeded twice at 2 and 4 weeks after planting (WAP) to enable *Mucuna* seedlings to develop and establish under weed free conditions (Versteeg & Koudokpon, 1990).

In 2006, the treatments, which comprised fertilizer free *Mucuna* plots, a plot with conventional fertilizer treatment and a *Mucuna* free/fertilizer free plot as control, were arranged in a RCB design with four replications. The land was ploughed and harrowed and maize seed planted at 75 cm x 25 cm in May. Fertilizer was applied at 100 kg N, 58 kg P_2O_5 and 40 kg K_2O or 500 kg (10 bags) of NPK 20: 10:10-2 S-1Zn ha^{-1} at 3 WAP. All the plots were carefully weeded with a hoe at 3 and 6 WAP, exempting visible *Striga* stands.

Data collection: *Mucuna* germination was evaluated 1 week after planting (WAP) by counting emerged seedlings in all plots. Ground cover of each accession was assessed by the beaded string method (Sarrantino, 1991) from 4 to 24 WAP. Canopy duration was derived from ground cover measurement and is defined as the time when *Mucuna* covers at least 40% of the ground. Mean nodulation was assessed at 4 and 8 WAP by carefully digging out 5 plants selected at random per plot and counting the total number of nodules per plant. Dry matter (DM) was estimated at 24 WAP by harvesting both the above and underground parts in a $1m^2$ quadrat in all treatments and oven-drying them at 80°C for 48 hours. The rest of the *Striga* plants were left *in situ* until the end of the growing season.

Maize plant height was measured with a meter rule at 6 and 9 WAP as the distance between the soil surface and the tip of the last formed leaf. Cob weight was measured with a beam balance after sun drying of the cobs after harvest. Grain yield was determined from the harvest of a 2 x 2 m net plot and converted to t/ha. Three batches of 100 sun-dried maize seeds were weighed and the mean weight was multiplied by 10 to get the 1000 seed weight. Emerged *Striga* plants were also counted at 6 and 9 WAP.

Data analysis: The data were analyzed using GenStat Release 7.2 DE (LAT, 2007). Means were separated using the Duncan's New Multiple Range Test (DNMRT) at 5% level of probability.

RESULTS

Germinability differed significantly ($P \leq 0.05$) between the *Mucuna* accessions from 49% in *M. georgia* to 93% in *M. cochinchinensis* (Table 2). When ranked based on germinability M. *cochinchinensis* > *M .jaspaeda* > *M. pruriens* var. *utilis* > *M. veracruz* (black seeded) > *M.veracruz* (white seeded), > *M.veracruz* (mottle seeded) > *M. ghana* > *M. pruriens* IRZ > *M.rajada* > *M. georgia*. Nodulation ranged from 16/plant (*M. georgia*) to 32.2/plant (*M. cochinchinensis*) but on average did not differ significantly among the accessions. *M. cochinchinensis* had the highest number of nodules and LAI, which was, however, not significantly different when compared to *M. veracruz* (black seeded) and *M. veracruz* (white seeded). *M. georgia* had 62% less LAI than *M. cochinchinensis*.

Table 2: Characteristics of 10 *Mucuna* accessions grown in 2005 at the Experimental Station of the University of Agriculture, Makurdi, Nigeria.

Treatment	Germination (%) (1 WAP)	Nodulation (No/plant) 8 WAP	LAI (12 WAP)	Dry Matter (t/ha) (12WAP)
Mucuna cochinchinensis	93ab	33	18.5a	6.8a
Mucuna georgia	49c	16	7.1d	2.6c
Mucuna ghana	64abc	31	11.0cd	3.8bc
Mucuna jaspaeda	88ab	29	10.3cd	4.4bc
Mucuna pruriens IRZ	60bc	26	9.7d	3.6bc
**M. pruriens* var *utilis*	86abc	28	12.2bcd	4.6abc
Mucuna rajada	59bc	27	8.7d	3.6bc
Mucuna veracruz (black)	83ab	31	16.1ab	5.5ab
Mucuna veracruz (mottle)	66abc	27	7.7d	3.0c
Mucuna veracruz (white)	80abc	29	15.1abc	4.7abc

*=Control; Means within a column followed by same letter(s) do not differ significantly at $P \leq 0.05$ (DNMRT)
NS = Not significantly different at $P \leq 0.05$; WAP = Weeks after planting

Table 3: Physico-chemical properties of soil before and after planting *Mucuna* in 2005 at the Experimental Station of the University of Agriculture, Makurdi, Nigeria.

Property	Before *Mucuna*	After *Mucuna*	Change (%)
Particle size Distribution (%)			
Clay	12	13	+8
Silt	14	16	+14
Sand	74	71	- 4
Soil acidity			
pH (H_2O)	6.2	6.0	-3
pH ($Cacl_2$)	5.4	5.1	- 6
Organic Matter (%)	0.77	0.81	+5
Total N (%)	0.14	0.18	+29
Available P (ppm)	4.0	6.0	+50
Exchangeable cations (Cmol/kg)			
Ca	2.6	2.8	+8
Mg	2.2	2.0	-9
Ka	0.3	0.5	+7
Na	0.05	0.1	+100
Cation Exchange Capacity (Cmol/kg)	8.4	9.0	+7

M. cochinchinensis, *M. veracruz* (black seeded), and *M. veracruz* (white seeded) had the highest DM, which was not significantly different from *M. pruriens* var. *utilis* (control). The rest of the accessions produced less DM than the control. The *Mucuna* accessions exhibited differences in canopy development (Figure 1). All the accessions, except *M. georgia*, covered over 50% of the ground by 6WAP and all attained 100% ground cover at 12 WAP. *M. cochinchinensis* attained 100% ground cover earlier at 10WAP. The canopies (except *M. georgia*) covered the ground at 100% till 16WAP and diminished thereafter. The canopies of *M. cochinchinensis*, *M. veracruz* (black seeded), *M. veracruz* (white seeded) and *M. pruriens* var. *utilis* (control) persisted longer compared to the other accessions (Figure 2).

The physical and chemical properties of the soil were improved by planting *Mucuna* compared to soils that were not planted with the cover crop (Table 3). Particle size distribution was altered with decrease in sand and increases in clay and silt particles. The pH decreased, the organic matter increased by 5%, total N (29%) and available P (50%). All the exchangeable cations, except Mg, increased with substantial increase of 100% in Na. The Cation Exchange Capacity of the soil increased by 7%.

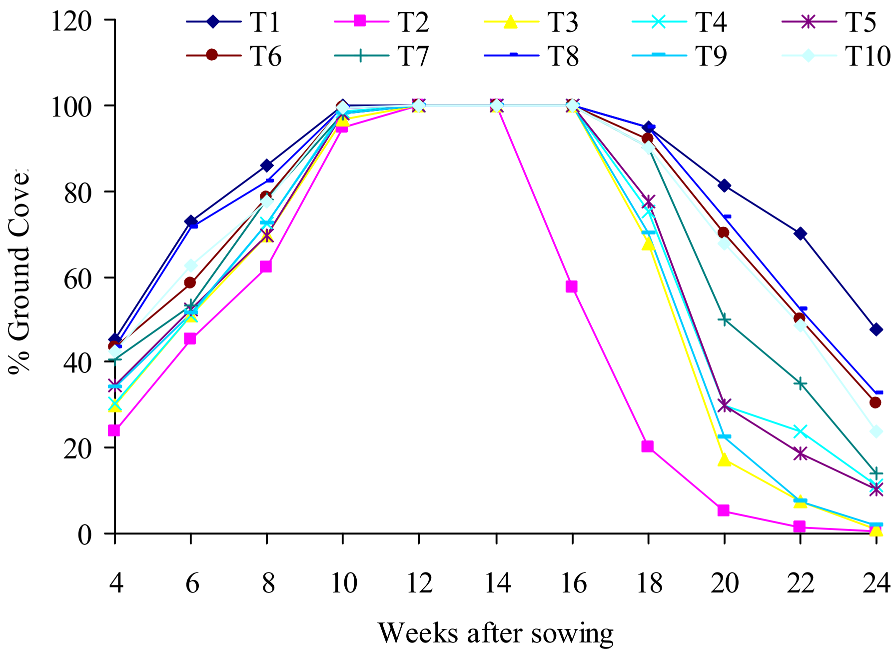

Figure 1: Canopy development of 10 *Mucuna* accessions ((T1= *Mucuna cochinchinensis*, T2 = *M. georgia*, T3 = *M. ghana*, T4 = *M. jaspaeda*, T5 = *M. pruriens* IRZ, IRZ, T6 = *M. pruriens* (var. utilis), T7 = *M. rajada*, T8 = *M. veracruz* (black seeded), T9 = *M. veracruz* (mottled seed), T10 = *M. veracruz* (white seed) grown in Makurdi during the 2005 cropping season.

In 2006 there were no significant differences in maize growth and yield attributes among the plots with *Mucuna* accessions and between the accessions and the conventional method (Table 4*). M. pruriens* IRZ, *M. jaspaeda* and *M. georgia* produced 8, 23 and 27% lower maize grain yield, respectively, than the conventional method (No *Mucuna* but with fertilizer). However, *M. veracruz* (white seed), *M. rajada*, *M. ghana, M. pruriens* var *utili*s and *M. cochinchinensis* produced 4, 7, 16, 16 and 19% higher grain yield, respectively, than the conventional method. Maize growth and agronomic yields were signif icantly lower in unfertilized plots. The grain yield margin s over unfertilized plots with no *Mucuna* were 620-1270% higher and greatly increased the benefit-cost ratio (Table 5).

Striga reduction: *Striga* shoot count did not differ significantly among the *Mucuna* accessions and between them and the conventional method (Table 6). Nonetheless, the conventional method had slightly higher mean *Striga* shoot count. Similarly, the mean weed weight (137 g/m^2) was significantly ($P \leq 0.05$) lower in plots with *Mucuna* compared to 275 g/m^2 in plots with conventional fertilizer, which had significantly lower weed weight than the plots without *Mucuna* and fertilizer (550 g/m^2).

T able 4: Effects of *Mucuna* on growth of maize in *Mucuna*-maize rotation in 2006 at the Experimental Station of the University of Agriculture, Makurdi, Nigeria (WAP = Weeks After Planting).

Treatment	Plant height (cm) 9 WAP	Cob weight (t/ha)	Grain yield (t/ha)	Shelling (%)	1000 seed weight (g)
M. cochinchinensis	200.00a	4.1a	3.2a	78.1a	259.0a
M. georgia	162.5a	2.6a	1.9a	73.1a	258.0a
M. ghana	175.0a	3.8a	2.7a	71.1a	253.2a
M. jaspaeda	187.5a	3.5a	2.8a	80.0a	251.2a
M. pruriens IRZ	190.0a	3.7a	3.1a	83.8a	254.7a
M. p. var *utilis*(control),	191.0a	3.5a	2.6a	74.3a	258.7a
M. rajada	181.0a	2.7a	2.0a	74.1a	257.2a
M. veracruz (black),	199.0a	4.1a	3.1a	75.6a	238.0a
M. veracruz (mottle),	197.5a	3.5a	2.6a	73.4a	262.2a
M. veracruz (white),	197.5a	3.9a	2.4a	61.6a	261.5a
No *Mucuna* + *fertilizer*	188.5a	3.4a	2.6a	76.5a	255.0a
No *Mucuna* + no fertilizer	125.0b	1.0b	0.5b	50.0b	150.4b

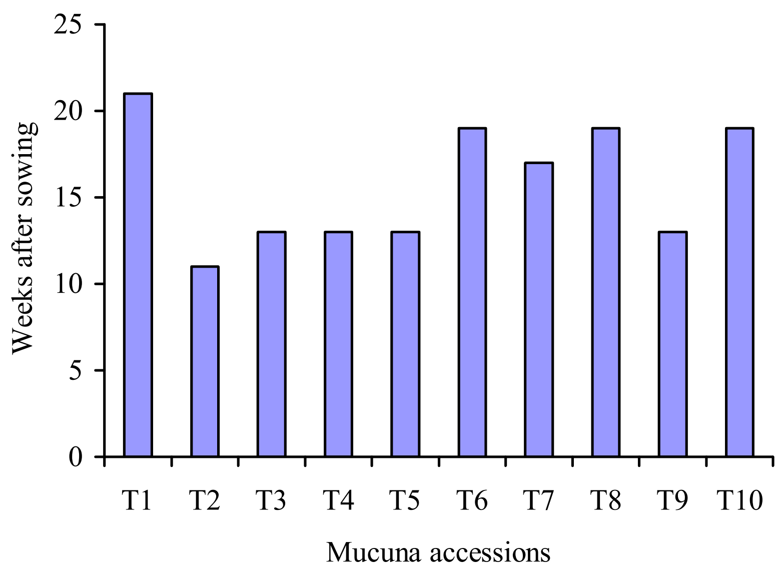

Figure 2: Canopy duration of *Mucuna* accessions (T1= *Mucuna cochinchinensis*, T2 = *M. georgia*, T3 = *M. ghana*, T4 = *M. jaspaeda*, T5 = *M. pruriens* IRZ, *M. pruriens* IRZ, T6 = *M. pruriens* (var. utilis), T7 = *M. rajada*, T8 = *M. veracruz* (black seeded), *M. veracruz* (black seeded), T9 = *M. veracruz* (mottled seed), T10 = *M. veracruz* (white seed) grown in Makurdi, Nigeria during the 2005 cropping season.

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Table 5: Cost-benefit analysis comparing effects of *Mucuna* and inorganic fertilizers on maize grain yield and gross revenue (₦) [1].

Treatment	Grain Yield (t/ha)	[2]Crop value (₦/ha)	Cost of labour for seedbed preparation + weeding (₦/ha)	[3]Cost of *Mucuna* (₦/ha)	[4]Cost of Fertilizer (₦/ha)	Total Cost (₦/ha)	Net benefit (₦/ha)	Margin over No *Mucuna* + No Fertilizer (₦/ha)	% Increase	B:C ratio
M. cochinchinensis	3.2	160,000	15,000	8,000	-	23,000	137,000	127,000	1,270	6.96
M. georgia	1.9	95,000	15,000	8,000	-	23,000	72,000	62,000	620	4.13
M. ghana	2.7	135,000	15,000	8,000	-	23,000	112,000	102,000	1,020	5.87
M. jaspaeda	2.8	140,000	15,000	8,000	-	23,000	117,000	107,000	1,070	6.09
M. pruriens IRZ	3.1	155,000	15,000	8,000	-	23,000	132,000	122,000	1,220	6.74
M. p. var. *utilis* (control)	2.8	130,000	15,000	8,000	-	23,000	107,000	97,000	970	5.65
M. rajada	2.0	100,000	15,000	8,000	-	23,000	77,000	67,000	670	4.35
M. veracruz (black)	3.1	155,000	15,000	8,000	-	23,000	132,000	122,000	1,220	6.74
M. veracruz (mottle)	2.6	130,000	15,000	8,000	-	23,000	107,000	97,000	970	5.65
M. veracruz (white)	2.4	120,000	15,000	8,000	-	23,000	97,000	87,000	870	5.22
No *Mucuna* + Fertilizer	2.6	130,000	15,000	-	30,000	45,000	107,000	97,000	970	5.67
No *Mucuna* + No fertilizer	0.5	25,000	15,000	-	-	15,000	10,000	-	-	1.67

[1]₦120.00 = US$ 1.00
[2]Crop value based on prevailing local market price of maize grains @ ₦50.0/kg
[3]Cost of *Mucuna* = cost of seeds (30 kg/ha) @ ₦ 100.0 + cost of planting and thinning
[4]Cost of fertilizer = cost of 500 kg NPK 20:10:10/ha @N50.0 + cost of application

DISCUSSION

The high germinability of *M. cochinchinensis* may be related to its large seed size (Qi *et al*., 1999), which has been shown to improve germination percentages in *Mucuna* (Barbedo *et al*., 1988). In an earlier study in the forest zone of Nigeria, *M. cochinchinensis*, *M .jaspaeda*, *M. veracruz* (mottled seeds) and *M. veracruz* (white seed) had the highest leaf area index (LAI), while *M. veracruz* (black seed) had the lowest (Chikoye & Ekeleme, 2001). In this study, however, *M. veracruz* (black seed) was among the accessions with the highest LAI. This study also confirmed the superiority of *M. cochinchinensis* in DM production reported previously by Carsky *et al*., (1998), Akobundu *et al* (2000), and Chikoye and Ekeleme (2001). Based on growth characteristics (germinability, nodulation, LAI, DM, canopy cover and persistence) the best three accessions were *M. cochinchinensis*, *M. veracruz* (black seed), and *M. veracruz* (white seed).

Table 6: Effects of *Mucuna* accessions on Striga weeds in *Mucuna*-maize rotation in 2006 at the Experimental Station of the University of Agriculture, Makurdi, Nigeria.

	***Striga* stand count (No/m²)**			
Treatment	**6WAP**	**12WAP**	**At Harvest**	**Weed fresh weight (g/m²)**
M. cochinchinensis	2b	4b	4b	133c
M. georgia	3b	4b	5b	138c
M. ghana	2b	4b	5b	140c
M. jaspaeda	3b	5b	5b	132c
M. pruriens IRZ	3b	4b	4b	138c
M. p. var *utilis*(control),	3b	5b	5b	142c
M. rajada	3b	4b	5b	133c
M. veracruz (black),	2b	4b	4b	142c
M. veracruz (mottle),	2b	4b	4b	135c
M. veracruz (white),	2b	5b	5b	140c
No *Mucuna* + *fertilizer*	3b	5b	5b	275b
No *Mucuna* + no fertilizer	5a	7a	10a	550a

Means with same letter within a column do not differ significantly at 5% level of probability (DNMRT); WAP = Weeks after planting

Maize grown in rotation with some *Mucuna* accessions produced more grains than plots treated with inorganic fertilizer with no *Mucuna*. The benefits of using *Mucuna* (e.g. higher crop yields and greater soil fertility) have been reported for yam and soybean (Chikoye *et al*., 2005).

Soils planted with *Mucuna* had improved physico-chemical properties. Greater biological activity (e.g. earthworm abundance and microbial biomass) occur in organically managed soils than in conventionally managed soils (Mader *et al.,* 2002). Biological activities in the soil impact positively on the physical and chemical properties of the soil such as plant mineral nutrition and soil aggregate stability. In this study, organic matter, total N, available P and the CEC were higher in soils planted with *Mucuna.* Nutrients in organic systems are less dissolved in the soil solution, and microbial transformation process may have contributed to the plants' P supply (Mader *et al*., 2002). With the improved soil aggregate stability and nutrients, especially available P, maize grain yields were high in the *Mucuna* plots.

The significant reduction in *Striga* density in plots with *Mucuna* indicates that *Mucuna* has the ability to suppress *Striga* in the same manner as high rates of inorganic fertilizer. These findings corroborate (Pesch & Pieterse, 1982; Olaniyan *et al.,* 1991). Consequently, *Mucuna*, which fixes nitrogen, inhibits germination of *Striga* seeds, and produces large quantities of residual biomass is recommended as a low–input technology for soil improvement and weed suppression.

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