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Management of Short Fallows Using Two Different Cover Crops

Joy G. Adiele*, Lawrence I. Chukwu, Anthony O. Ano and ThankGod N. Echendu

National Root Crops Research Institute, Umudike. KM 8 Ikot Ekpene Road, PMB 7006 Umuahia Abia Nigeria.

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***Corresponding Author**
Joy G. Adiele
E-mail: *joyadiele@ yahoo.com*
Phone: *234 (0) 803 868 0437*

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ABSTRACT

In Nigeria significant efforts are being made to improve and conserve the soil. In the time past the soil resource base was sustained through long fallows of 10-15 years. Due to population pressure and other conflicting interests on land, fallow period is now between 6 and 12 months. This natural fallow has proved ineffective for the sustenance of soil productivity. The present study compared the soil productivity improvement attribute of three fallow management systems - two leguminous cover crops (*Mucuna pruriens* var. *utilis* and *Pueraria phaseoloides*) seeded on June 2012 and natural fallow dominated by guinea grass (*Panicum maximum*). *Mucuna* treatments significantly provided soil cover until six months, while *Pueraria* provided soil cover for 12 months and reduced weeds compared with *Mucuna* and the control. However, there were no significant differences in soil physicochemical properties before and after round the year fallow. Therefore, both cover crops could be sown to replace the natural fallow. *Mucuna* fallow appears to be an effective system for 6 months fallow while *Pueraria* could provide cover and effectively suppress weeds for 12 months.

1.0. INTRODUCTION

The agricultural system in Nigeria is characterized by low input technologies and soil fertility is restored by fallowing the cropland for a number of years depending on the availability of land. Fallow duration and vegetation type strongly influence soil properties and crop yields. Increasing population densities (especially in SE Nigeria where the staple crops are root and tuber crops) have shortened the fallow periods and threatened the stability of the system (Mendoza-Vega and Messing, 2005). One of the effects is declining soil fertility resulting from frequent use of the land without adequate replenishing of lost nutrients (Hiernaux et al., 2009; Schlecht et al., 2004.). The quality of soil resources is a primary indicator of the sustainable of land management practices. The reduction of fallow duration without increase in fertilizer input has contributed to the impoverishment of soil fertility. Root and tuber crops are 'heavy feeders' and tend to perform poorly under low soil fertility. In view of prevailing short fallow system, the sustainability of root and tuber crops production depends on the optimal use of the available natural resources, including the soil.

It is clear that the different types of plant residues do not contribute to the same extent to humus formation (Alegre et al., 2005). The length of a fallow period and the type of fallow vegetation can affect the rate and extent of soil productivity regeneration (Domergues, 1995). For example, improved tree fallows have great potential for improving soil fertility in areas dominated by soil nutrient deficiency such as nitrogen deficiency (Kwesiga et al., 1999). Soil cover is one of the most vital factors affecting the intensity and frequency of overland flow and soil erosion (Nunes et al., 2011). Cover crops have long been recognized to play an important role in sustainable agriculture due to their functions in preventing soil erosion, improving soil productivity, contributing nutrients to succeeding crops, and suppressing weeds (Adiele and Volk, 2011; Ramos et al., 2010).

Soils under cover crops typically have higher levels of soil organic matter and increased nutrient cycling capacity (DuPont et al., 2009; Ramos et al., 2010). Thus, the introduction of cover crops to replace the natural regrowth of fallow will result in efficient management of the cropping system. Leguminous cover crop fallows can contribute to soil nitrogen (Ikeorgu et al., 2005; Tarawali et al., 1999; Koutika et al., 2001), soil organic matter (Ikeorgu et al., 2006; Tian et al., 1999), and improve crop yield (Ikeorgu et al., 2006; Langyintuo and Dogbe, 2005).

Limited research has been done on the selection of ideal cover crop fallow species that could effectively control erosion, suppress weeds, and provide 6 -12 month soil cover. In order to select an appropriate cover crop that could function effectively in a sandy clay loam soil, it is important to first generate an ideotype. It is important that the cover crop has a positive effect on establishment - provides dense uniform groundcover, control erosion, help suppress weeds, and thrive well in the crop production environment. The extent that the cover crop fallow can become acceptable depends on its ability to protect the soil over a cropping season (365 days).

The objectives of this experiment were to determine the duration and effects of two different leguminous cover crops, *Mucuna pruriens* var. *utilis* and *Pueraria phaseoloides* on a sandy clay loam soil compared to the natural fallow.

2.0. MATERIALS AND METHODS

2.1. Site description and experimental design

The study was conducted at the the Research Farm of National Root Crops Research Institute Research Farm in Umudike Abia State, Nigeria. (05°29'N, 07°33'E, elevation 122m). The soil was a sandy clay loam (Soil Survey Staff, 1999) from coastal plain sand. The field had previously been planted with sweet potato that had been harvested. Average annual rainfall and maximum temperature of the study area are about 2138.7 mm and 32°C respectively. The trend of mean monthly maximum and minimum temperature and monthly rainfall amount during the period of study are shown in figures 1 and 2 respectively (Meteorology Unit, National Root Crops Research Institute (NRCRI), Umudike).

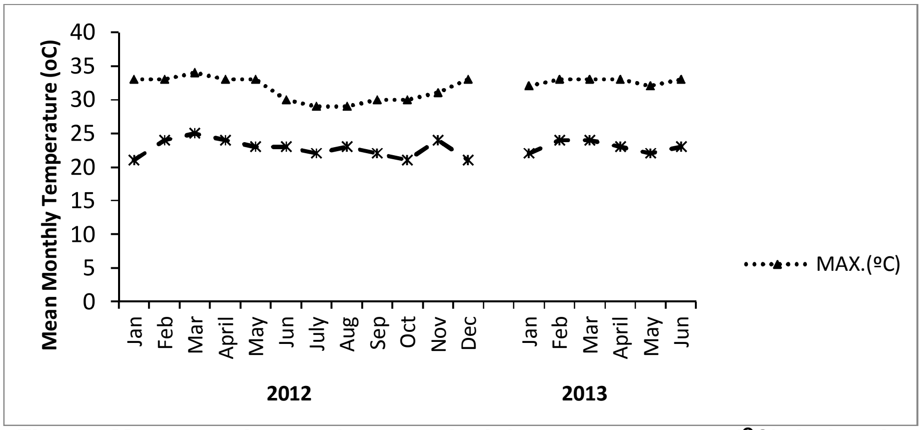

Fig. 1a: Mean monthly maximum and minimum temperature (^{O}C) during the fallow period January 2012 to June 2013

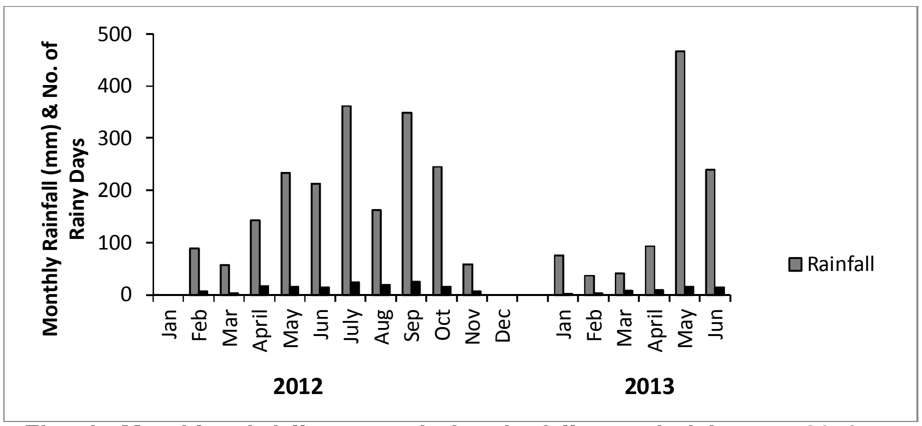

Fig. 1b: Monthly rainfall amount during the fallow period January 2012 to June 2013

The experiment was laid out in randomized complete block design (RCBD) with twelve replications. The treatments were two leguminous cover crops, (*Mucuna pruriens* var. *utilis* and *Pueraria phaseoloides*) seeded during the cropping season and the control (natural regrowth - mainly guinea grass (*Panicum maximum*). The study was initiated in June, when the site was moldboard plowed to a depth of 20 – 25 cm and cross-disked to create a suitable seedbed. The cover crops were broadcast seeded at the recommended seeding rate (*Mucuna @* 70 and *Pueraria @* 10 kg ha^{-1}) on the 6^{th} of June, 2012. The treatment plots were 6.0 m x 4.0 m and the sample area was 5.0 m x 3.0 m in the center of the plot. Pre-fallow soil sample was collected on 5^{th} June, 2012 before establishing the experiment. Cover crop and weed cover were measured a month after seeding and thereafter until June 5, 2013 for cover crop and weed cover.

Cover crop and weed cover were measured using line-transect sampling method with points at 15 cm intervals. Two lines originating from the northeast and northwest corners of the measurement plots were run diagonally to the southwest and southeast corners, respectively. Soil temperature in the top 20 cm was measured at four points within the sample area using a YSI model 43 tele-thermometer.

The cover crop and weed average root length and number were measured on November 20, 2012. Two samples were taken from each plot by carefully uprooting the plants at I m northeast and 1 m southwest in the sample area. The root numbers were counted - four root lengths – two from the left and right side and two from the middle of the plant root bunch were selected and their measurements taken using a ruler.

2.2. Soil sampling and analysis

Post-fallow soil samples were collected from four points within the sample area for each treatment plot. Each sample consisted of a mixture of about 4 subsamples taken in a zigzag fashion within the sample area. A new shovel was used to dig out and discard the soil to a depth of about 20 cm, and then a thin slice of soil 20 cm depth was collected and used as subsamples. After collecting about 4 subsamples in a plastic pail for each treatment, the soil was mixed well and air-dried on a sheet of newspaper in a greenhouse. The soil was crushed in a mortar with pestle and passed through a sieve of 2 and 0.5 mm. Then, 200 gm of the sample from 2 mm sieve, as well as 10 gm of the subsample that was passed through a 0.5 mm sieve were packaged for analysis.

Nitrogen analysis was done using Kjeldahl method. The electronic method of Maclean (1965) was used to determine the pH; available phosphorus was determined by Bray and Kurtz (1945) method. Chromic acid wet oxidation method of Walkley and Black (1934) was used to determine the organic carbon. Particle size distribution was done by the Bouyoucus hydrometer method. Analysis of variance was performed using GenStat mean separation technique. Differences between treatments mentioned were tested at the LSD 5 % significant level. Percent cover was used to estimate the C – Factor in Revised Universal Soil Loss Equation (RUSLE).

3.0. RESULTS

3.1. Cover crop percent cover

The effect of cover crops on percentage of land cover was significant ($p < 0.001$). Area of land covered by *Mucuna* varied from 29.42 to 92.63 % within the growing season of 365 days (Fig. 3.1). At one month after seeding (MAS), *Mucuna* provided 39.30 % cover, it got to its peak 92.63 % at the fourth month and decreased to 29.42 % at the sixth month. The percentage of land covered by the *Mucuna* at 12 MAS was zero. *Pueraria* varied from 14.85 to 96.80 % (Fig. 3.1). It provided 14.85 % cover at one MAS and gradually covered the soil up to 96.80 % at six MAS. At twelfth month, *Pueraria* recorded about 88.48 % land cover.

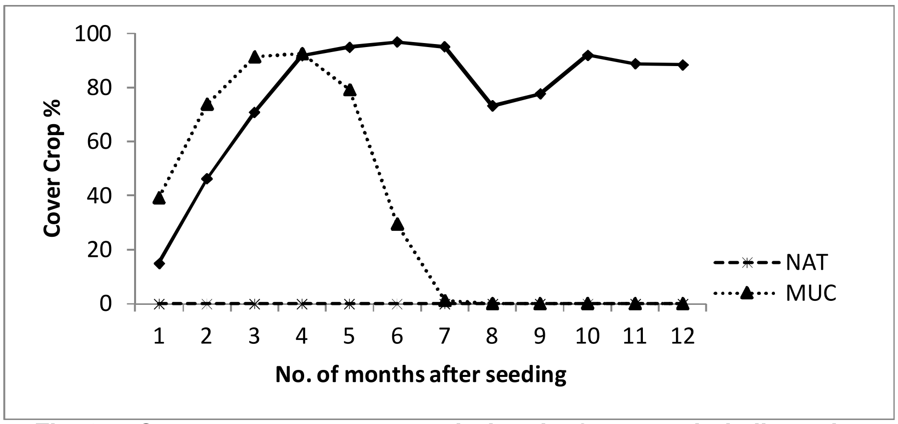

Fig. 3.1: Cover crop percent cover during the fallow period, displaying trend over time. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria*

3.2. Weed cover

The percentage of land covered by weeds overtime was significantly influenced by cover crop species ($p < 0.001$). Percentage of land covered by weeds in all treatments were less than 10 % at start then increased to 28.47 % at 6 MAS in *mucuna* treatments and about 99.58 % at 12 MAS. *Pueraria* recorded about 23.30 % weed cover at 2 MAS, but it later decreased to 0 % at 8 MAS and slowly increased to 11 % at 12 MAS. Control at 2 MAS had more than 50 % weed cover, it increased till it got to its peak 100 % at 5 MAS and maintained this level to the end of the one- year fallow trial (Fig. 3.2).

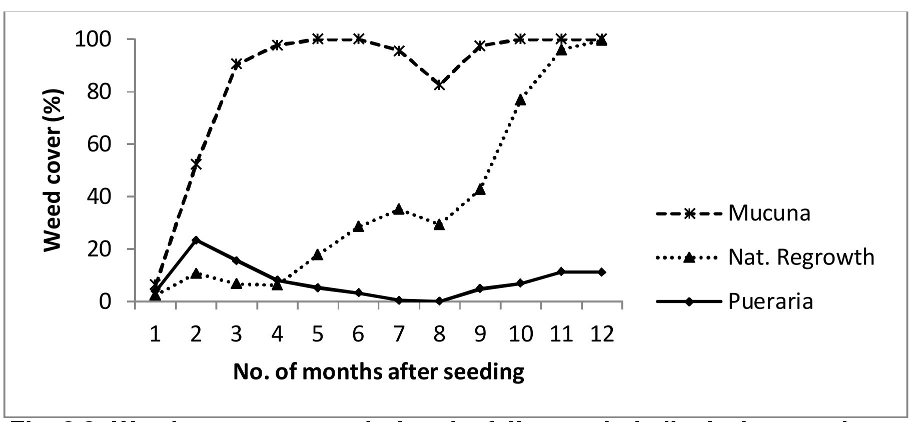

Fig. 3.2: Weed percent cover during the fallow period, displaying trend over time. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria*

3.3. Litter cover

The percent litter cover over time among the treatments was significant ($p < 0.001$). Litter cover in *Mucuna* treatments varied from 22.77 to 63.75 %. *Mucuna* recorded about 39.86 (6 MAS) to 63.75 % (7MAS) cover. It gradually decreased to 4.02 % and 0 % at the eleventh and twelfth MAS. Litter cover in *Pueraria* treatments varied from 4.58 to 26.80 %. It got to its peak at eight MAS and decreased to 0.14 to 0 % at eleventh and twelfth MAS (Fig. 3.3).

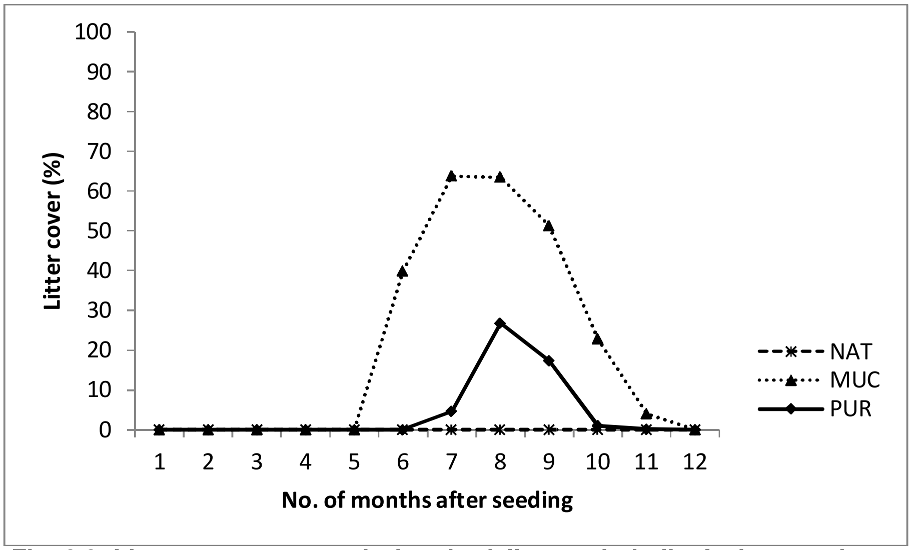

Fig. 3.3: Litter percent cover during the fallow period, displaying trend over time. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria*

3.4. Mean soil temperature

At 0090 Greenwich Meridian Time (GMT), soil temperature over the time among the fallow treatments was significant ($p < 0.001$) at day 192, 226, 254, 289, and 318 (8 MAS). Soil temperature varied from 25.37 to 28.46 °C. Soi sampling date (Fig. 3.4a).) *Mucuna* treatments recorded the average lowest soil temperature compared with *Pueraria* or control until 4 MAS. At 1600 GMT, soil temperature over time among the fallow treatments was also significant ($p < 0.001$) at day 192, 226, 254, and 318. *Mucuna* treatments also recorded the average lowest soil temperature at 28.845 °C, the control had the highest at 30.317 °C followed by the *Pueraria* treatments at 29.650 °C across the sampled dates (Fig. 3.4b).

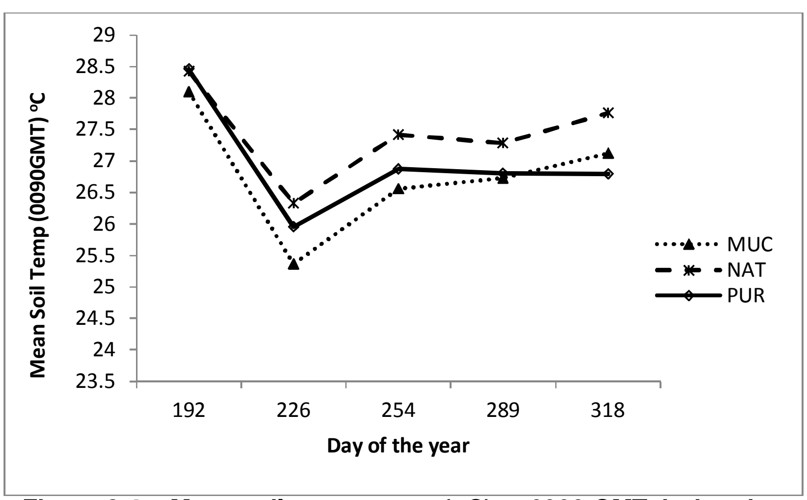

Figure 3.4a: Mean soil temperature (oC) at 0900 GMT during the fallow period, displaying trend over time. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria*

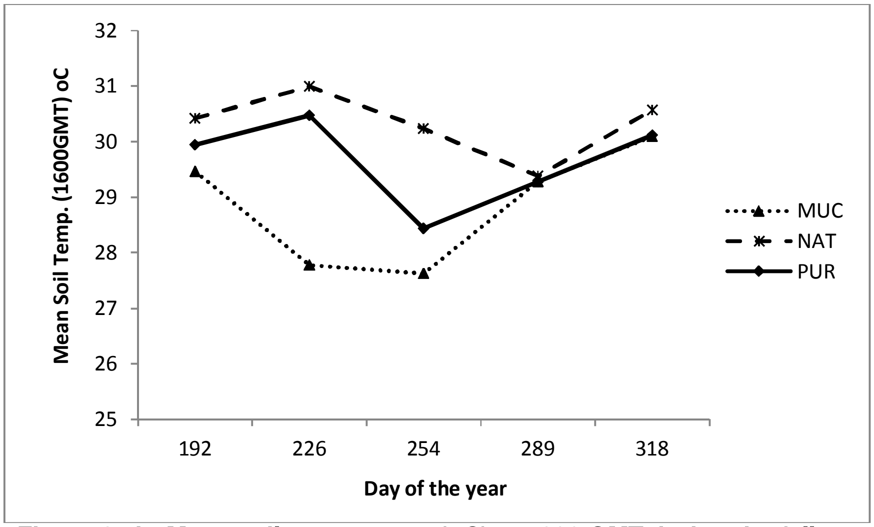

Figure 3.4b: Mean soil temperature (oC) at 1600 GMT during the fallow period, displaying trend over time. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria*

3.5. Mean root number and length of *mucuna, pueraria*, and guinea grass

The mean root number and length among the fallow treatment species differed significantly ($p < 0.001$) at day 325 (5 MAS). The mean root numbers varied from 15 to 203. *Mucuna* and *Pueraria* treatments recorded 15 and 21 mean number of roots (NOR) respectively, while the control (guinea grass) had about 203 NOR (Fig. 3.5a). The root lengths also differed significantly among the different fallow species. *Mucuna* and *Pueraria* cover crops recorded about 95.0 and 96.8 cm respectively, while the control had about 23.9 cm at the sampled date (Fig. 3.5b).

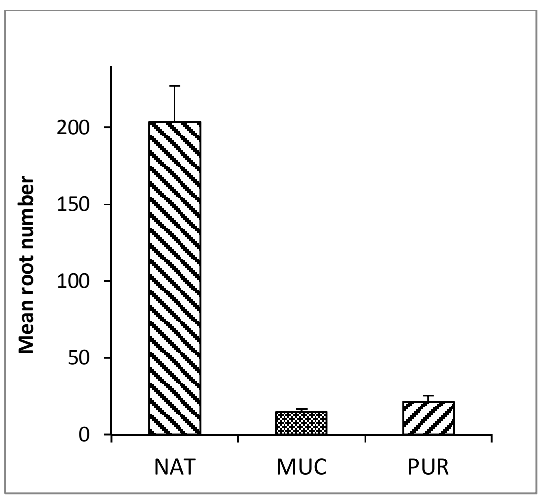

Fig. 3.5a: Mean root length of *mucuna*, *pueraria*, and guinea grass. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria* at 5 MAS

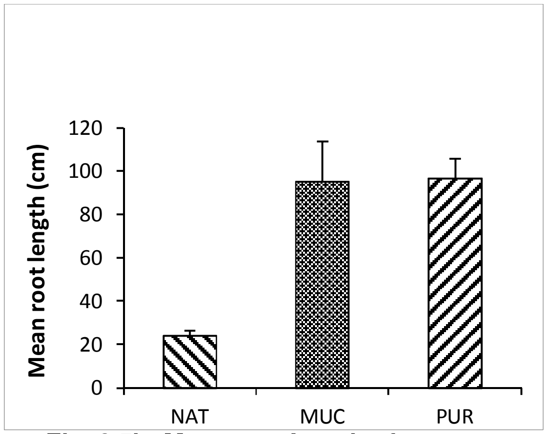

Fig. 3.5b: Mean root length of *mucuna*, *pueraria*, and guinea grass. NAT – indicates natural regrowth, MUC – *Mucuna*, and PUR – *Pueraria* at 5 MAS

3.6. Soil texture, pH, and nutrient concentrations

There were no significant differences in soil properties before and after the fallow treatments. However, soil texture varied between 61.3 to 61.97 % sand, 14.38 to 17.13 % silt, and 21.57 to 23.82 % clay among the treatments (Table 1.0). Soil pH in *Pueraria* treatments with a value of 4.8 was significantly lower than 5.1 obtained from soils in both Mucuna treatments and the control. There was no significant difference in organic matter (OM), nitrogen, phosphorus, calcium, and magnesium content of the soil in pre-fallow and fallow treatments (Table 1). However, percent OM and nitrogen were slightly higher in *Pueraria* treatments compared to pre-fallow, *Mucuna*, and the control (Table 1.0).

Table 1.0: Soil properties before and after one-year leguminous cover crop fallow

	Sand (%)	Silt (%)	Clay (%)	pH H_2O	P (Mg/kg)	N (%)	OC (%)	OM (%)	Ca (cmol/ kg)	Mg (cmol/kg)
Mucuna	61.63	14.38	23.82	5.092	23.13	0.0779	1.635	2.82	2.233	0.767
Pueraria	61.97	17.13	23.4	4.883	22.17	0.093	1.682	2.899	2.467	1.033
Natural Regrowth	61.3	14.63	21.57	5.142	22.19	0.051	1.54	2.657	2.433	1.033
PRE Fallow `	60.47	16.8	22.73	5.000	20.43	0.0779	1.614	2.784	2.133	1.2
SED	1.421	1.569	1.719	0.0853	1.865	0.0152	0.1333	0.2299	0.1985	0.2621
LSD (0.05)	2.892	3.191	3.497	0.1736	3.795	0.03092	0.2713	0.4677	0.4038	0.5333

SED, standard error of difference of treatment means; LSD, least significant difference at 95% confidence level.

4.0. DISCUSSION

In this study, *Mucuna* provided on an average about 68 % soil cover and suppressed weeds by 12 % for the first six months. But at 12 MAS, average *Mucuna* cover was 33.92 % and weed increased to 37.65 %. Also, *Mucuna* provided about 48 % leaf litter from 6 to 10 MAS. At 6 MAS, average *Pueraria* cover was about 69 % and it reduced weeds to 10 %, *Pueraria* maintained adequate soil cover at 78 % on an average and suppressed weeds effectively by 8 % during the one- year fallow. Adequate soil cover enhances weed suppression and reduces the germination and establishment of new weeds, including the relative competitive ability of established weed seedlings (Den Hollander, 2007; Teasdale, 1998). This would be expected since most weed species require light to activate a phytochrome-mediated germination process (Teasdale, 1998). Teasdale and Daughtry (1993) showed that chlorophyll in living vegetation intercepted red light and reduced the red to far-red ratio sufficiently to convert phytochrome to an inactive form. In this study, *Mucuna* had an initial fast establishment and provided soil cover for 6 months, but was completely overtaken by weeds later. *Pueraria*, though it had an initial slow establishment, adequately provided soil cover and suppressed weeds during the one- year fallow period.

Cover crops percent cover is an important factor in determining the susceptibility of a field to erosion. Soil erosion reduces the long-term productivity of soils. Soil cover is expressed quantitatively as sub-factor in the C - Factor of the revised universal soil loss equation (RUSLE) and greatly impacts estimates of soil loss. C – Factor values represent conditions that can be managed most easily to reduce erosion. Values of C may vary from near zero for a much protected soil to about 1.5 for a finely ridged exposed soil (Lane et al., 1997; Kort et al., 1998; USDA-ARS, 2003). In this study, Mucuna treatments provided approximately about 68 % soil cover which equals 0.024 C – sub factor at first six months. *Pueraria* at 6 MAS provided about 69 % soil cover which also equals 0.024 C – sub factor. During the one- year fallow, *Pueraria* maintained an average of 78 % soil cover which equals 0.012 C – sub factor (ESL-USLE, 2013; USDA-ARS, 2003). Therefore, not only did Mucuna and Pueraria suppress weeds effectively, but also reduced soil loss by providing adequate groundcover.

Soil temperature influences decomposition of organic matter and microbial activities in the soil. Mucuna maintained the lowest soil temperature at 0900GMT and 1600GMT. This may be dependent upon the extent and thickness of cover it provided during the sampled period. Adequate cover during fallow could also result to reduced soil temperatures. Consequently, less soil water will be lost through evaporation, thereby increasing water availability to the microbial community. At 5 MAS, Mucuna provided more soil temperature stability than Pueraria and the control. In the tropics, greater temperature stability increases microbial biomass carbon (Six et al., 2002).

Rooting system was an important characteristic for selection of leguminous covers. Their root zone bacteria can improve nitrogen-fixation, enhance the availability of minerals, alter susceptibility to environmental stress, and stimulate the production of plant growth hormones (Sturz and Christie, 2003). Living leguminous cover crops maintain a rhizosphere, an area of concentrated microbial activity close to the root. The rhizosphere is the most active part of the soil because it is where the peak of nutrient and water cycling occurs (USDA-NRSC, 2012). *Mucuna* and *Pueraria* provide living roots that would attract and feed microbes that provide soil nutrients. Therefore, cover crops could provide the easiest source of food for soil microbes and enhance soil management. Growing cover crop fallow to replace weeds especially guinea grass in a natural regrowth fallow could feed the foundation species of the soil food web as much as possible in readiness for other food crops.

In addition, *Mucuna* and *Pueraria* had fewer roots compared to the guinea grass that had numerous fibrous roots, there could be ease and reduced cost of labor during field preparation especially where manual labor is used.

Though changes in the soil nutrient content before and after the one- year fallow period were not significant, incorporation of the cover crops litter during field preparation will improve the soil condition. This is as a result of decomposition and mineralization of the organic matter during the growing season (Koutika et al., 2001).

5.0 CONCLUSION

This study examined the effect of leguminous cover crop managed fallow on soil resource. Results from the study indicate that living cover crops that match the ideotype can be sown to replace the natural regrowth that comprises weeds especially the guinea grass (soil nutrient miners). It also demonstrates the need for proper fallow management in the era of shortened fallow duration. *Mucuna* and *Pueraria* cover crops could be sown to replace the natural fallow. *Mucuna* fallow appears to be an effective system for 6-month fallow while *Pueraria* could provide cover and effectively suppress weeds for 12-months. Further study is required to determine additional cover crop species that possess the characteristics specified by this study. The studies should consider earlier seeding, extended soil temperature sampling throughout the fallow period - using equipment that can penetrate the soil during dry season.

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