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GROWTH AND BIOMASS PRODUCTION ASSESSMENT OF SOME HERBACEOUS LEGUMES FOR SOIL CONSERVATION IN NIGERIA

[1]Tanimu, J., [1]Lyocks, S.W.J and [2]Tanimu, Y
[1] Samaru College of Agriculture, Division of Agricultural Colleges,
Ahmadu Bello University, Zaria.
[2] Department of Biological Sciences, Ahmadu Bello University, Zaria.
Corresponding e-mail: *joseph.tanimu@yahoo.com* Tel:+2348037039756

Abstract
This experiment was conducted at the Institute for Agricultural Research Farm, Ahmadu Bello University, Zaria (Latitude 11^{o} 11" N and Longitude 7^{o} 38" E), located in the northern guinea savanna of Nigeria. The objective of the study is to assess the performance of seventeen herbaceous legumes using their rate of growth as a ground cover against erosion, weed suppression and large biomass production for incorporation into the soil to sustain the fertility and conserve the soil and to identify which of them will be fitted for short fallow or medium fallow. The treatments were arranged in a randomized complete block design, with four replications. The results revealed that, *Mucuna pruriens* (white), *Mucuna pruriens* (black) and *Crotalaria ochroleuca* were better significantly ($P < 0.05$) as short fallow (2-3 months) because of their rapid growth to cover the ground and high biomass production (3428.7, 3304.0 and 2822.7 kg ha^{-1} dry matter yield respectively), while *Crotalaria ochroleuca, Laplap purpureus and Cajanus cajan*
Keywords: herbaceous legumes, soil fertility, soil productivity, sustainability, northern Nigeria.

Introduction
Decrease in agricultural productivity and biodiversity in the African continent, particularly its sub-humid zone is being blamed on global environmental changes (Turner *et al*., 1980; Krings, 1990). The sub-humid zone is defined as a region which receives 900-1500 mm average rainfall and has between 180-270 plant growing days per annum (Jahnke, 1982). The region covers 22 % of sub-Saharan Africa about 50 % of Nigerian land mass (Vonkaufman, 1987) and encompasses mainly the northern and southern guinea Savannas (Tiseer *et al*., 2000). It is recognized as having the greatest potential for crop and livestock production (Olufade, 1988). The pressure on the land from both arable and pastoral farming activities causes deforestation at the rate of 35,000 hectares per annum (NEST, 1991). Legume-base farming has been advocated as a means of integrating crop and livestock farming in this zone. The soils are predominantly Alfisols, characterized by low Organic matter, Phosphorus and Nitrogen. They are prone to compaction and accelerated sheet erosion (Adeoye, 1989). They have a rapid decline in soil organic matter (Jenkinson and Ayanaba, 1977), reduction in biotic activities of soil fauna (Lal *et al*., 1980), crusting and compaction (Vander weert, 1974) and overall degradation of soil quality (Nye and Greenland, 1964).

Legumes provide an alternative and inexpensive source of N for soil fertility maintenance and dry or green manure for soil conservation and weed suppression (Muyinda, *et al*., 1988; Kang, 1993; Danso, 1992; COMBS, 1995). Legumes are able to fulfill a large part of their Nitrogen requirements through their capability to fix atmospheric Nitrogen which allows them to grow in Nitrogen-impoverished soils. They also contribute Nitrogen to the soil through their nodulated roots and above ground crop residues after the seed and other components have been harvested. The amount of Nitrogen fixed by the micro organisms varies greatly with the rhizobial strains, legume species and fertility level of the soil among others (Peoples and Crasswell, 1992). However, in arable agriculture, N fixation by legumes is the dominant source of Nitrogen input and could be greater than 80 % of the total soil Nitrogen (Burns and Hardy, 1975). According to Hudgens (2001) legume green manures have proven effective in providing protective ground cover, conserving soil moisture, reducing erosion and lowering labour costs for weeding, they can also contribute nitrogen to succeeding crops, reducing the need for supplemental inorganic fertilizers. However, green manure crop management requires special attention to species compatibility with microclimatic conditions and soil physical, chemical, and biological factors. The amount of nitrogen accumulation in legume biomass is dependent on successful seedling establishment, the length of the legume growth cycle, and the incorporation of legume residues into the soil. The mineralization of legume residues releases nitrogen more gradually over a longer period of time than inorganic fertilizers, reducing nitrate leaching and improving the efficiency of nitrogen uptake by cereal crops. Disadvantages to the integration of legume manures into cereal based cropping include the synchrony of nitrogen availability in relation to cereal crop growth, pest infestation (rats, termites, slugs), and economic considerations related to the opportunity costs of land, labour, and capital inputs.

To improve the soils for sustainable agriculture, appropriate soil management practice can be adopted. One of such practices involves short fallow techniques using forage legumes. Lal and Okigbo (1990) suggested that properly managed planted fallows and cover crops of mainly leguminous species are more efficient and require less time in restoring soil fertility/productivity than natural fallows. According to Francis *et al*., (1986); Hullugale (1988), Anas and Ghosh (2012) planted fallow of leguminous crops, if properly managed will add substantial amounts of N and other nutrients and organic matter to the soil, recycle nutrient from the subsoil, provide effective cover against erosion, suppress weeds and pests and improve soil physical conditions. Therefore, concerted efforts are being made to identify most suitable species and varieties with desirable agronomic traits including high biomass yield potential to meet up these farmers' desires. The objectives of this study were to assess the growth and biomass production of 17 herbaceous legumes for possible adoption to improve the fertility and productivity of degraded soils in the Northern Guinea Savanna of Nigeria and to identify which of them will be best fitted for short fallow or medium fallow crops in this same zone.

Materials and Methods

Experimental site**:** The experiment was conducted at the Institute for Agricultural Research (IAR) farm, Ahmadu Bello University, Zaria (Latitude 11^{o} 11" N and Longitude 7^{o} 38" E). The long term average rainfall is about 1100 mm. The mean air temperature of the area for the year was 24.26 ^{o}C.

Treatments and experimental Design**:** The treatments consisted of seventeen legume species, laid out in a RCBD, replicated four times. The legumes were grown for 16 weeks before harvesting.

Table 1: Legume species used

S/no.	*Names Legumes*	*S/no.*	*Names Legumes*
1	*Pseudovigna argentea*	10	*Crotalaria ochrolueca*
2	*Centrosema pascuorum*	11	*Macroptilum atropurpureum*
3	*Chamaecrista rotundifolia*	12	*Stylosanthes hamata*
4	*Clitoria ternatae*	13	*Cajanus cajan*
5	*Stylosanthes guidnensis*	14	*Centrosema brasilianum*
6	*Pueroria phaseoloides*	15	*Lablab purpureus*
7	*Psophocarpue palustria*	16	*Mucuna pruriens* var. IRZ (white)
8	*Crotalaria verrucosa*	17	*Mucuna pruriens* var. utilis (black)
9	*Aeschynomene histrix*		

Soil sampling and analysis**:** Soil samples of the experimental site were collected at the commencement of the experiment at 0- 20 cm depth, bulked, air dried and sieved through a 2 mm sieve. Sub samples were taken and analyzed for particle size distribution (Klute, 1986), soil pH was determine in water with a pH glass electrode using a soil: solution ratio of 1:2.5, soil organic carbon (Nelson and Sommers, 1982), exchangeable bases (Juo, 1979), total nitrogen by the Kjeldahl procedure (Bremner, 1982) and available P was extracted using Bray I method.

***Land preparation, planting and weeding*:** The site was cleared, harrowed and leveled to avoid depressions that could encourage water logging in the field. Seventeen legume species Table 1 were planted on flat plots of 120 m^2 . Phosphorus as single super phosphate at the rate of 50 kg P_2O_5 ha^{-1} was broadcasted and incorporated before sowing. The small seeded legumes were drilled, while the large seeded ones were planted at 25 cm intra-row. The rows were spaced at 75 cm. Plots were maintained weed free manually.

***Germination count and growth/canopy height*:** The germination percentage was determined at 4 weeks after sowing (WAS). The readings of growth/canopy height were done at two weeks interval. Measurements started at 6 WAS and continued to 16 WAS.

***Biomass production determination*:** The dry matter was determined at 6, 8, 12 and 16 WAS, using a one square meter point quadrat. The quadrat was randomly placed in each plot and all the biomass that falls within the quadrat was carefully removed and oven dried to constant weight and the dry matter recorded.

***Data analysis*:** The data collected from germination, growth/canopy height and dry matter weight were subjected to analysis of variance (ANOVA). Where the differences from the means were significant, Duncan Multiple Range Test (DMRT) was used to separate the means.

Results and Discussion

Some Physico-chemical properties of the soil determined before the commencement of the study are presented in Table 2. The results showed that, the textural class was sandy loam. The soil pH in water was slightly acidic (5.26). The soil organic carbon (5.88 g kg^{-1}) and total nitrogen (0.53 g kg^{-1}) were both low. These are characteristics of the Nigerian Savanna soils which has been attributed largely to the rapid mineralization rate of organic matter under high temperature and rainfall conditions that exist in the tropics. The available P was 5.00 mg kg^{-1}. The exchangeable cations, Ca^{2+} (1.98 c mol), Mg^{2+} (0.68 c mol), K^+ (0.14 c mol) and Na^+ (0.19 c mol), all were classified as medium according to modified FAO suitability classification system, which makes the soil to be moderate in fertility status (Young, 1976).

***Germination percentage and plant/canopy height*:** The results of germination percentage and growth/canopy height of the herbaceous legumes are presented in Table 3. There was a significant ($P < 0.05$) difference on the germination percentage of the various legumes. *Mucuna pruriens* (white) gave the highest germination percentage, while the *Macroptilum atropurpureum* gave the lowest value. The large seeded legumes generally gave better germination than the small seeded legumes.

Table 2: Some physical and chemical properties of the soil

Particle size analysis		Chemical properties	
Sand (g kg^{-1})	650	pH (water)	5.26
Silt(g kg^{-1})	200	Organic Carbon (g kg^{-1})	5.88
Clay (g kg^{-1})	150	Total nitrogen (g kg^{-1})	0.53
Textural class	Sandy loam	Available P (Bray 1) (mg kg^{-1})	5.00
		Ca (c mol^+ kg^{-1})	1.98
		Mg (c mol^+ kg^{-1})	0.68
		K (c mol^+ kg^{-1})	0.14
		Na (c mol^+ kg^{-1})	0.19

Table 3: Germination and growth/canopy height of herbaceous legumes

Legume species	***Growth performance of legumes (Plant height)***				
	Germination (%)	4**WAS** (cm)	8**WAS** (cm)	12**WAS** (cm)	16**WAS** (cm)
Pseudovigna argentea	48.75f	2.33ij	11.78e-h	18.13fgh	23.22ghi
Centrosema pascuorum	75.00cd	8.10fg	23.88def	42.73de	48.78cde
Chamaecrista rotundifolia	76.25bcd	8.18fg	14.68e-h	13.95h	19.25hi
Clitoria ternatae	83.75abc	9.75ef	30.35cd	45.80d	51.73cde
Stylosanthes guidnensis	71.25cd	2.75ij	21.83d-g	38.95def	56.40cd
Pueroria phaseoloides	55.00ef	0.50j	6.30h	22.53e-h	34.28fg
Psophocarpue palustria	48.75f	3.58hij	10.25fgh	13.25h	14.33i
Crotalaria verrucosa	70.00cd	5.53ghi	17.53d-h	36.60d-g	51.03cde
Aeschynomene histrix	73.75cd	6.00f-i	26.05de	42.03de	62.33c
Crotalaria ochroleuca	85.00abc	20.30cd	84.55a	185.25a	182.78a
Macroptilum atropurpureum	41.25f	4.15g-j	8.33gh	16.28gh	30.38fgh
Stylosanthes hamata	76.25bcd	6.95fgh	23.48def	37.68d-g	42.95def
Cajanus cajan	80.00a-d	30.08a	72.15a	145.20b	191.68a
Centrosema brasilianum	80.00a-d	12.65e	21.63d-g	24.68e-h	40.08ef
Lablab purpureus	65.00de	18.18d	24.33def	43.63d	91.03b
Mucuna pruriens var. IRZ (white)	91.25ab	26.08b	40.03cb	73.48c	56.83cd
Mucuna pruriens var. utilis (black)	95.00a	22.65bc	48.53b	69.87c	57.90c
SE ±	4.889	1.295	4.473	6.734	4.482

Means followed by the same letter(s) within a column are significantly not different from each other at 5 % level of significance.

On the growth/canopy height from 4 WAS to 16 WAS, there were also significant ($P < 0.05$) difference among the legumes. At 4 WAS, *Cajanus cajan* gave taller plants than all the other legumes, while the least was *Pueroria phaseoloides*; it was closely followed by *M. pruriens* (white), *M. pruriens* (black) and *Crotalaria ochroleuca*. At 8 WAS (2 months), *C. ochroleuca* and *C. cajan* gave significantly ($P < 0.05$) taller plants than all other legumes, while *P. phaseoloides* were still the shortest plants among the legumes. The growth/canopy height at 12 WAS (3 months) showed that *C. ochroleuca* and *C. cajan* still gave the tallest plants. When the experiment was terminated at 16 WAS (4 months) both *C. cajan* and *C. ochroleuca* gave taller plants, that were significantly ($P < 0.05$) higher than all other legumes. However, it was noted that *M. pruriens* (white) and *M. pruriens* (black) and other creeping legumes had better ground cover than the *C. ochroleuca* and *C. cajan*, which was good for effective control of soil erosion and weeds. Mureithi *et al*., (2003); Jatango (2003) reported significant ground/plot cover of nine month growth of herbaceous legumes as follows: *Stylosanthes hamata* > *Stylosanthes guidnensis* > *Chamaecrista rotundifolia* > *Clitoria ternatae* > *Centrosema pascuorum* > *Aeschynomene histrix* > *M. cochinchinensis* > *Lablab purpureus* in northern Ghana. According to Jatango (2003) plant height, Mureithi *et al*., (2000a) spread and ground cover were some of the criteria considered for the selection of fallow legume species. *M. cochinchinensis*, *L. purpureus* and *Clitoria ternatae* had the widest spread. These legumes spread laterally as a result of their morphology (being creepers by nature) and particularly being planted as mono crops (Jatango, 2003).

***Biomass production* (*Dry matter yield*):** The results of the legumes biomass production is shown in Table 4. There were significant differences among the treatments from 6 WAS to 16 WAS when the experiment was terminated. The results showed that at 6 WAS *M. pruriens* (white) gave a significantly ($P < 0.05$) higher dry matter yield than all other legumes and it was closely followed by *M. pruriens* (black) and *C. ochroleuca*. At 8 WAS (2 months) and 12 WAS (3 months) *M. pruriens* (white) and *M. pruriens* (black) gave higher values than all other treatments followed by *C. ochroleuca*; were not different from each other statistically. At 16 WAS, the dry matter yield of *C. ochroleuca* was the highest, followed by *L. purpureus* and *C. cajan* after which *M. pruriens*

Table 4. Herbaceous legumes biomass production (dry matter yield).

Legume species	6*WAS* (kg ha^{-1})	8*WAS* (kg ha^{-1})	12**WAS** (kg ha^{-1})	**16WAS** (kg ha^{-1})
Pseudovigna argentea	59.3f	231.3d	761.3c	719.3f
Centrosema pascuorum	444.7cd	442.0cd	972.7c	1483.3ef
Chamaecrista rotundifolia	150.0ef	369.3d	726.0c	1660.0ef
Clitoria ternatae	47.3f	214.7d	720.7c	1019.3f
Stylosanthes guidnensis	45.3f	158.0d	805.3c	2400.0cde
Pueroria phaseoloides	33.3f	94.7d	543.3c	1274.0ef
Psophocarpue palustria	76.0f	191.3d	589.3c	803.3f
Crotalaria verrucosa	68.7f	290.1d	741.3c	1374.7ef
Aeschynomene histrix	42.0f	202.0d	911.3c	1912.0def
Crotalaria ochrolueca	596.0c	958.0b	2822.7b	5896.7a
Macroptilum atro-purpureum	58.7f	353.3d	510.7c	1140.7ef
Stylosanthes hamata	51.3f	211.3d	745.3c	1903.3def
Cajanus cajan	121.3ef	827.3cb	954.7c	4666.7b
Centrosema brasilianum	144.7ef	269.3d	713.3c	985.3f
Lablab purpureus	338.7de	802.7cb	886.7c	4818.7ab
Mucuna pruriens var. IRZ (white)	905.3b	1606.7a	3428.7a	3362.7c
Mucuna pruriens var. utilis (black)	1147.3a	1456.0a	3304.0ab	3032.7cd
SE ±	**76.32**	**138.28**	**180.62**	**388.43**

Means followed by the same letter(s) within a column are significantly not different from each other at 5 % level of significance.

(white) and *M. pruriens* (black) followed. Mureithi (2003) reported a similar result where *M. pruriens* (Velvet bean) *L. purpureus*, *C. ochroleuca* (Sunhemp) and *Canavalia ensiformis* (Jack bean) were identified as outstanding based mainly on high biomass accumulation.

The results showed that if herbaceous legumes are to be planted for short fallow (2-3 months) *M. pruriens* (white), *M. pruriens* (black) and *C. ochroleuca* will be better in terms of large biomass production. However, if the planted fallow will be for a longer period of time up to 4 months, *C. ochroleuca*, *L. purpureus*, and *C. cajan* will be better. According to Mureithi *et al*., (2003) one of the criteria for the selection of herbaceous legumes for soil fertility improvement included biomass production. Earlier, Mureithi *et al*. (2000a) had reported the assessment of farmers perception for the selection of green manure legumes, as a key to adoption of the legumes to include, high biomass production among other characteristics to have plenty available for incorporation into the soil. Dyck (1997) reported that based on legume phenology and cumulative dry matter production, the legumes are classified into two groups: Short fallow crops with fast emergence and substantial biomass production within 2-3 months of growth and long duration legumes with slow establishment, 6-12 months or longer to yield substantial biomass.

Conclusion and Recommendation

This work has identified *M. pruriens* (white), *M. pruriens* (black) and *C. ochroleuca* as short fallow (2-3 months) legumes that farmers can use for their rapid ground cover for effective control of soil erosion and weeds. For high biomass production (2822.7 – 3428.7 kg ha^{-1} dry matter yield at 3 months after sowing) for incorporation into the soil to improve the soil organic carbon, soil fertility and productivity. For medium fallow (4-5 months) *C. ochroleuca*, *L. purpureus*, and *C. cajan* is recommended to the farmer, for slow establishment and to yield substantial biomass (4666.7 – 5896.7 kg ha^{-1} dry matter yield at 4 months after sowing) at the long run to sustain soil fertility and productivity and also to conserve the soil.

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