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GROWTH FEATURES, YIELD AND BOTANICAL COMPOSITION OF *STYLOSANTHES HAMATA* (CV. VERANO) AS AFFECTED BY PHOSPHORUS SOURCES APPLIED AT VARYING RATES, SOWING METHODS AND STAGE OF GROWTH

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ABSTRACT

The effect of applying phosphorus sources applied at varying rates at different sowing methods and stage of growth at harvest was studied on the agronomic performance of *Stylosanthes hamata* in a split-split plot design. Phosphorus sources at varying rates was assigned to the main plot (8 x 5 m), sowing method to the sub-plot (4 x 5 m) and stage of growth to the sub-sub plot (4 x 2 m) with three replicates. Results revealed that *S. hamata* that was fertilized with poultry manure at 60 kg P ha^{-1} had ($P<0.05$) higher growth parameters at 4 and 8 weeks. There was no significant difference in the growth parameters as affected by sowing method across the stages of growth. Harvesting of *S. hamata* at 12 weeks after sowing (WAS) produced ($P<0.05$) higher dry matter yield than those defoliated at 8 WAS. The proportion of *S. hamata* was ($P<0.05$) was higher in botanical composition than in other legumes and weeds with regard to the factors imposed. It can be concluded that application of poultry manure at 60 Kg P ha^{-1} as a soil amendment has the prospect to enhance the canopy structure of *S. hamata* sward to produce sufficient herbage for ruminant consumption.

Keywords: Agronomy, Manure, Phosphorus, Soil, *Stylosanthes hamata*.

INTRODUCTION

The cheapest source of nutrients are provided by natural pastures, but fail to meet the nutritional needs of livestock throughout the year (Ojo *et al*. 2017). Establishment of legume based pastures "fodder bank" has long been advocated as a plausible way of supplementing feed shortage, and consequently enhance livestock production. This strategy ensures availability of green herbage to grazing animals, particularly during the dry season, in addition to fixation of atmospheric nitrogen in the soil. In fact, not only is soil fertility improved through the use of legumes such as *Stylosanthes*, there are strong evidence of benefits to the soil physical attributes (Tarawali and Mohamed-Saleem, 1995).

Soil fertility is directly proportional to the ability of a soil to sustain plant growth and optimize crop yield (International Atomic Energy Agency, n.d). Given that tropical soils have been implicated for low soil fertility (Olanite *et al*., 2010; Agbede, 2010), mineral fertilizer application could be part of the solution to correct decline in soil fertility (Fofana *et al*., 2004). Sanchez *et al*. (1996) noted that soil fertility depletion in small holder production systems is the major contributor to declining per capita food production. To obtain maximum growth rate and herbage yield from pasture systems, the use of soil amendment to

maintain soil organic matter is inevitable (Ojo *et al*., 2014). Hinsinger (2001) reported that phosphorus in soils occur in organic or inorganic forms, the organic form being the most stable while the inorganic form is less stable.

The optimum rate of phosphorus application is important in improving yields of most plants (Cisar *et al*. 1992), particularly forage legumes. Sanchez *et al*. (1997) stated that intensive and continuous cropping with little or no fertilizer applications culminates in imbalance between nutrients supply and extraction from the soil.

Legumes are phosphorus loving plants and Stylosanthes is an important forage legume that has been widely used for livestock feed (Hanson and Heering, 1994; Nkaa *et al*., 2014). Phosphorus is a macronutrient that is essential for plant growth and the quantity available in the soil is usually inadequate to meet plant requirements (Ojo *et al*., 2015). In Nigeria, legumes suffer from neglect with regard to mineral phosphorus fertilization, and this causes decline in their growth, yield and nitrogen fixation potential as a result of dependence on soil phosphorus and other nutrients naturally available in the soil (Nkaa *et al*., 2014; Singh *et al*., 2011).

Organo-mineral fertilizer is a low input technology that improves the nutrient status of tropical soils for sustainable crop production which combines the properties of both organic and inorganic fertilizers (Ayeni, 2008). However, the use of Aleshinloye organo-mineral for legume pasture fertilization has not been documented in literature. However, there are positive reports of Aleshinloye organo-mineral fertilizer on maize and pepper (Adeoye *et al*., 2008; Fagbola and Ogungbe, 2007; Ojeniyi *et al*., 2009) and *Amaranthus cruentus* (Makinde *et al*., 2010), while numerous studies have reported the use of poultry manure to improve pasture yield (Ojo *et al*., 2015; Shewu, 2014, Sodeinde *et al*., 2009). Therefore, establishment of forage legumes using the appropriate sowing methods, if properly supported with optimum rate of fertilizer application could lead to desirable fertilizer use efficiency to promote growth and sufficient herbage yield for sustainable ruminant animal production. Harvesting of such pastures before senescence sets in is of essence to sustain its productivity and value.

Therefore the aim of the present study is to determine the best combination of sowing method, phosphorus fertilization rate and stage of growth at harvest to improve the growth rate, yield and vegetation predominance in *Stylosanthes hamata* cv Verano sward.

MATERIALS AND METHODS

Experimental Field

The field experiment was carried out at Pasture unit of the Directorate of University Farms, while the chemical analyses was carried out at the laboratory of the Department of Pasture and Range Management, both at Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The site lies within latitude 7^{o} 10' N, longitude 3^{o} 2' E and altitude 76 mm. It is located in the derived savannah zone of South-Western Nigeria with a humid climate and mean annual rainfall of about 1037 mm and temperature of about 34.7^{o} C. Relative humidity ranges from 63-96% for the rainy season (late March-October) and 55-82% for the dry season (November-early March) with an annual average of 82% (Fig 1) (Department of Agro-meteorology and water Resources FUNAAB, 2016).

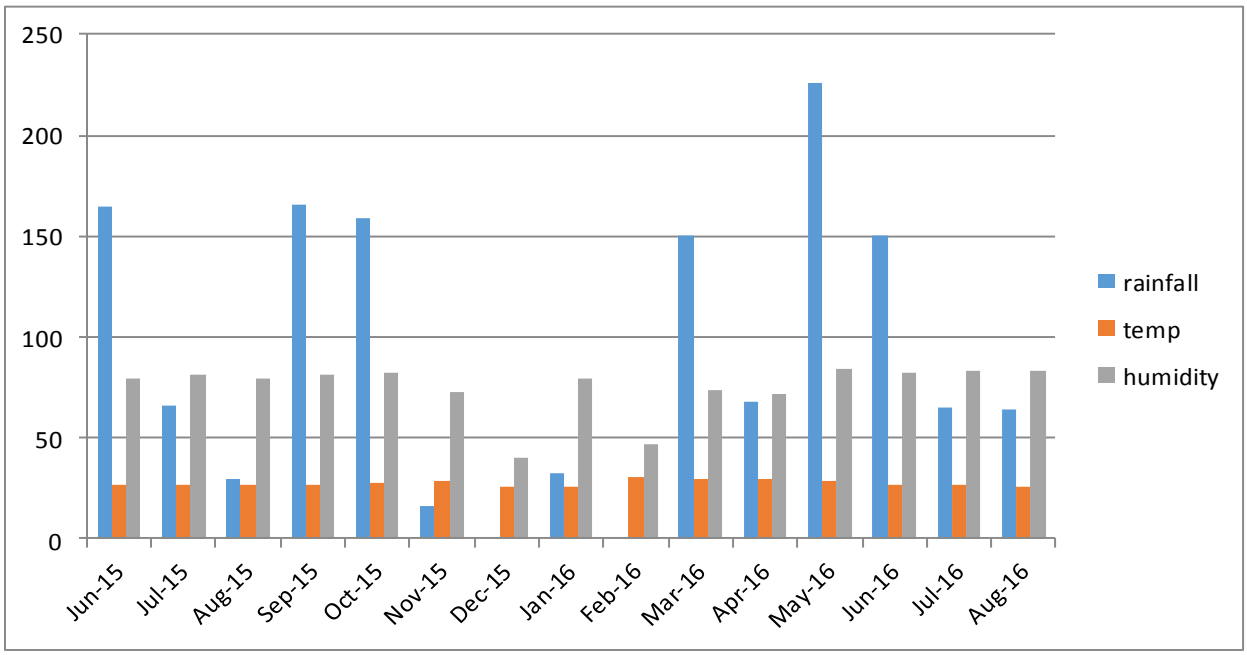


Figure 1: *Rainfall (mm), Temperature (^{o}c) and Humidity (%) in FUNAAB between June (2015) and (2016). Source: Department of Agro-meteorology and water Resources, FUNAAB*

Land Preparation

The land clearing operation was done manually, stumps were removed on the entire field, and the field was allowed to rest for a period of two weeks before making seed beds. The total experimental land measuring 899 m^2 (31 m x 29 m) was mapped out and pegged, so that the main plot measured 9 m x 5 m, 4 m x 5 m for the sub-plot and 4 m x 2 m for the sub-sub-plot. There was a boundary of 1 m between the sub-sub-plots, sub-plots and main plot while that for between blocks was 2 m.

Soil Sampling and Analysis

After land preparation and before sowing, soil samples were randomly collected from nine (9) representative spots of the entire experimental field by using diagonal sampling method with the aid of a soil auger at the depth of 0 – 15 cm. The samples were bulked per replicate, mixed thoroughly and sub-samples were taken for analysis to determine the nutrient status of the soil prior to sowing (Table 1).

Manure Collection, Analysis and Application

Poultry manure and Aleshinloye organo-mineral fertilizer were used as sources of phosphorus for Stylosanthes. Aleshinloye organo-mineral fertilizer is a commercial product of Aleshinloye Fertilizer Plant, Ibadan, Oyo State, Nigeria while poultry manure was from egg laying birds that were raised on battery cage system. Sub samples were randomly taken from the poultry manure, thoroughly mixed and air dried for laboratory analysis in order to determine the phosphorus content of the manure. Result showed that it contained calcium (2.35 %), magnesium (0.80 %), potassium (17.53 %), sodium (152.75 ppm), nitrogen (1.56 %) and phosphorus (3.27 %). Aleshinloye organo-mineral contained nitrogen (3 %), phosphorus (2.5 %), and potassium (1.50 %). The soil amendments were applied at 0 (i.e. control), 60 kg P/ha and 80 kg P/ha. The quantity of each manure applied, was calculated based on the phosphorus content of the manures.

Table 1: Chemical Characteristics of the Soil Samples taken at 0-15 cm Depth from the Experimental Site at the onset of the Study

Chemical properties	Values
pH	6.50
Total nitrogen (%)	0.10
Organic carbon (%)	1.55
Available P (mg/kg)	4.11
Acidity (cmol/kg)	0.00
Exchangeable cations (cmol/kg)	14.67
Sodium (Na)	0.08
Potassium (k)	1.75
Calcium (Ca)	11.52
Magnesium (Mg)	1.31
Particle size (%)	
Sand (%)	79
Silt (%)	10
Clay (%)	11
Micro nutrient (mg kg^{-1})	
Zinc (Zn)	77.47
Copper (Cu)	10.51
Manganese (Mn)	43.08
Iron (Fe)	43.08

Sourcing of Seed, Scarification and Sowing

Stylosanthes hamata cv. Verano seeds were sourced from the National Animal Production Research Institute (NAPRI) Shika, Ahmadu Bello University, Zaria. Scarification of the seeds was carried out by placing the seeds in a clothed bag and immersed in hot water (80 ^{0}C) for 3 minutes. The seeds were sown after air drying (Olanite, 1997). Sowing of the seeds was carried out by drilling and broadcasting based on the treatment allotment at a seed rate of 7 kg/ha. Drilling was achieved by sowing the seeds along each row within the plots at a spacing of 50 cm apart, while broadcasting was carried out by mixing the seeds with dried sand and subsequently spread evenly on the plot.

Experimental Design

The study was laid out as a split-split-plot design with an experimental area measuring 899 m^2. The sources of phosphorus at varying rates were assigned to the main plots (8 m x 5 m), sowing methods were assigned to the sub-plots (5 m x 4 m) while age at harvest was allotted to the sub-sub plots (4 m x 2 m).

Data Collection

Measurement of plant height (cm)

Plant height was measured from the base of the plant to the tip of the flag leaf with the aid of a meter rule at 4, 6 and 8 weeks after sowing (WAS).

Estimation of number of leaves per stem

The number of leaves per stem was counted at 4, 6 and 8 weeks of the experiment. Each of the leaflets of the trifoliate leaves was counted as a single leaf.

Estimation of number of stem per plant

The number of stems per plant was counted from the emergence of stems at 4, 6 and 8

weeks of the experiment from randomly selected plants in each plot.

Measurement of stem length (cm)
The length of the longest stem from randomly selected plants was measured and recorded at 4, 6 and 8 weeks of the experiment.

Determination of botanical composition
Samples were harvested at 8 and 12 weeks after sowing at 8 cm above the ground. The total forage in each harvest was separated into individual plant components (*S. hamata*, other legumes, and weeds) and each component was weighed separately and recorded as a proportion of the total forage harvested.

Determination of Dry Matter yield
Dry matter yield of *S. hamata* was determined by harvesting the plants at 8 and 12 weeks after sowing. Total fresh weight from each plot was weighed. Each of the components per replicate were bulked, thoroughly mixed and fresh sub-samples weighing 500 g, was collected and oven-dried at 65 ^{o}C until constant weight is reached and this was used to estimate dry matter yield.

Statistical Analysis
Data collected were subjected to analysis of variance using the general linear model procedure. The treatment means were separated using Duncan's Multiple Range Test of SAS (2009) package at 5% level of significance.

RESULTS

Average measurements across replicates were used to determine the effect of phosphorus sources applied at varying rates on the growth indices of *S. hamata* at four weeks of age. Poultry manure applied at 60 kg P/ha produced significantly ($P<0.05$) taller plants, higher number of leaves per stem (NL/S) and longer stem length (SL) recording (39.07 cm), (90.11) and (43.23 cm) respectively (Table 2). In contrast, the least value for plant height (PH) was recorded for *S. hamata* fertilized with Aleshinloye organo-mineral at 80 Kg P/ha, and the same soil amendment applied at 60 kg P/ha recorded lower values for NL/S. Higher number of stem per plant (NS/P) (8.50) was observed for the unfertilized legume and the least was recorded for *S. hamata* fertilized with Aleshinloye organo-mineral at 60 kg P/ha. The sowing methods adopted in this study did not significantly ($P>0.05$) influence all the growth indices of the legume.

At six weeks of growth, there was no ($P>0.05$) effect of phosphorus sources applied at varying rate on the agronomic characteristics of *S. hamata* except for the SL which ($P<0.05$) ranged from 39.17 cm for the control plots (i.e. no manure) to 53.25 cm for those fertilized with poultry manure at 60 kg P/ha (Table 3). No significant effect of sowing method on the growth indices of the legume was observed.

Table 2: Effect of Varying Rates of Phosphorus Application and Sowing Methods on the Four (4) Weeks Growth Parameters of *Stylosanthes hamata*

Factors	Plant Height (cm)	Number of Stem /Plant	Number of Leaves /Stem	Stem Length (cm)
Phosphorus				
Aleshinloye 60	23.16[b]	2.53[b]	50.11[b]	25.98[b]
Aleshinloye 80	22.38[b]	4.14[b]	56.75[b]	25.44[b]
Control	28.96[a]	8.50[a]	65.33[b]	36.05[a]
Poultry 60	39.07[a]	7.39[a]	90.11[a]	43.23[a]
Poultry 80	31.42[b]	3.06[b]	57.86[b]	24.51[b]
SEM				
Sowing method	1.35	0.58	7.77	2.06
Broadcasting	37.59	4.81	65.04	31.53
Drilling	40.41	5.43	63.02	34.55
SEM	1.50	0.51	5.33	1.94

[abc]: means on the same column with different superscript are significant ($p<0.05$). SEM: standard error of mean

Table 3: Effect of Varying Rates of Phosphorus Application and Sowing Methods on the Six (6) Weeks Growth Parameters of *Stylosanthes hamata*

Factors	Plant Height (cm)	Number of Stem Plant	Number of Leaves Stem	Stem Length (cm)
Phosphorus				
Aleshinloye 60	25.83	10.50	48.83	39.33[b]
Aleshinloye 80	28.17	10.83	47.17	40.50[b]
Control	28.83	7.83	42.17	39.17[b]
Poultry 60	30.67	8.83	61.50	53.25[a]
Poultry 80	30.00	9.83	41.83	44.33[ab]
SEM	1.64	1.43	6.93	3.12
Sowing method				
Broadcasting	38.73	10.60	43.40	41.73
Drilling	39.47	12.53	49.20	44.90
SEM	1.02	0.89	4.29	2.30

[abc]: means on the same column with different superscript are significant ($p<0.05$). SEM: standard error of mean

Agronomic parameters of *S. hamata* measured at eight weeks of growth differed (P<0.05) as influenced by phosphorus sources applied at varying rate except for NS/P (Table 4). Poultry manure applied at 60 kg P/ha produced the tallest pants (52.14 cm), NL/S (148.22) and SL (59.86 cm), while the control plots (no manure) recorded the least values of 38.74 cm, 85.00 and 46.52 cm respectively. The effect of sowing method was not pronounced on the growth indices of the legume.

Plant height, NS/P, and SL of *S. hamata* were significantly affected by the interaction of the three factors tested in this study (p<0.001), as well as NL/S (P=0.003) (Table 5).

Table 4: Effect of Varying Rates of Phosphorus Application and Sowing Methods on the Eight (8) weeks Growth Parameters of *Stylosanthes hamata*

Factors	Plant Height (cm)	Number of Stem Plant	Number of Leaves Stem	Stem Length (cm)
Phosphorus				
Aleshinloye 60	46.32^{ab}	10.06	100.22^{ab}	51.96^{ab}
Aleshinloye 80	44.76^{bc}	13.28	113.50^{ab}	50.87^{ab}
Control	38.74^{c}	11.17	85.50^{b}	46.52^{b}
Poultry 60	52.14^{a}	11.33	148.22^{a}	59.86^{a}
Poultry 80	42.84^{bc}	11.11	115.72^{ab}	49.02^{b}
SEM	1.11	1.53	15.49	3.06
Sowing Method				
Broadcasting	44.68	6.40	118.64	51.38
Drilling	45.24	6.38	106.62	51.91
SEM	1.49	0.67	10.26	2.01

^{abc}: means on the same column with different superscript are significant (p<0.05). SEM: standard error of mean

Table 5: Interaction effect of Varying Rates of Phosphorus Application, Sowing Methods, and Age at Harvest on the Growth Parameters of *Stylosanthes hamata*

Factors	Growth parameters			
Phosphorus × Sowing method ×Age	PH	NS/P	NL/S	SL
P values	<0.001	<0.001	0.003	<0.001
F Values	17.33	3.523	2.32	8.85

P<0.05 are significant. PH: Plant Height, NS/P: Number of Stem/Plant, NL/S: Number of leaves/Stem, SL: Stem Length.

Table 6: Effect of Varying Rates of Phosphorus Application, Sowing Methods, and Age at Harvest on the Dry Matter Yield (DMY) of *Stylosanthes hamata*

Phosphorus sources	**Aleshinloye** 60	**Aleshinloye** 80	**Poultry** 60	**Poultry** 80	**Control**	**SEM**
	13.87	10.66	14.13	11.26	8.88	1.80
Sowing method	**Broadcast**		**Drilling**			
	10.14		13.38			1.19
Age at harvest	8WAS		12 WAS			
	7.00[b]		16.52[a]			0.82
Interaction						
	WAS × Phosphorus		WAS × Sowing		Phosphorus × Sowing	
P values	0.504		0.708		0.934	
	Phosphorus × sowing × WAS					
P values	<0.001					

[abc]: means on the same row with different superscript are significant (p<0.05). SEM: standard error of mean. DM: Dry matter, WAS: weeks after sowing

The effect of age at harvest was teased out on the botanical composition of the legume sward (Fig. 2). *S. hamata* was significantly higher than other legumes and weeds in the sward at eight and twelve weeks of harvest. The legume was also higher than other botanical components in the sward as affected by varying application rates of phosphorus sources (Fig. 3). The least proportion was recorded for other legume component across the treatments except for the plots fertilized with Aleshinloye organo-mineral at 60 Kg P/ha and 80 Kg P/ha. Sward components was influenced by sowing methods with *S. hamata* recording higher proportion than other components (Fig. 4). However, the legume component was slightly higher in the plots where *S. hamata* seeds were broadcasted compared to drilling. The dry matter yield (DMY) of *S. hamata* was (P<0.0.5) higher at 12 weeks (16.52 t ha^{-1}) than 8 weeks (7.00 t ha^{-1}) after planting (Table 6). There was no effect of phosphorus sources applied at varying rates and sowing method on the DMY of the legume.

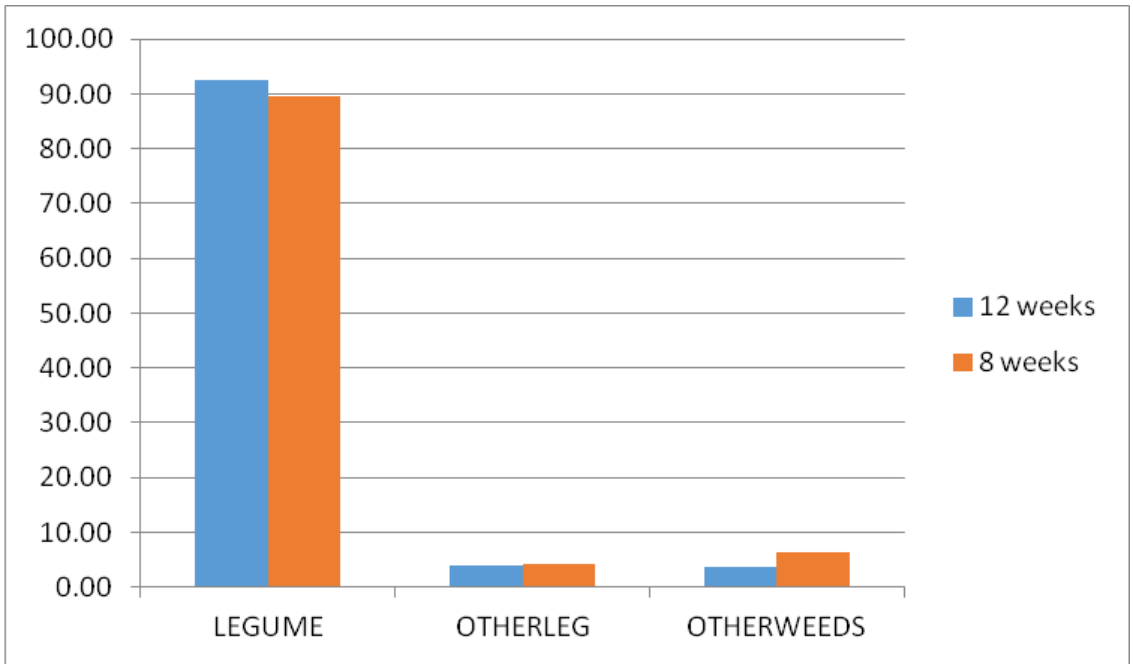


Figure 2: *Botanical composition (%) of Stylosanthes hamata harvested at 8 and 12 weeks after sowing*

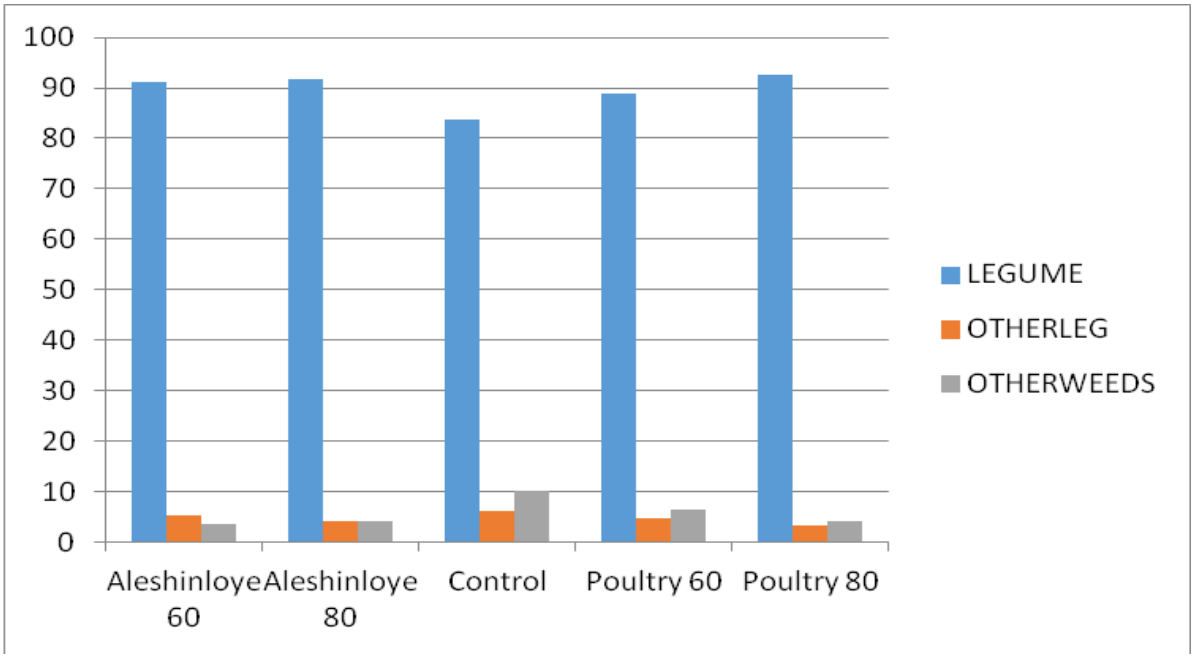


Figure 3**:** *Botanical composition (%) of Stylosanthes hamata as affected by phosphorus sources at varying rates*

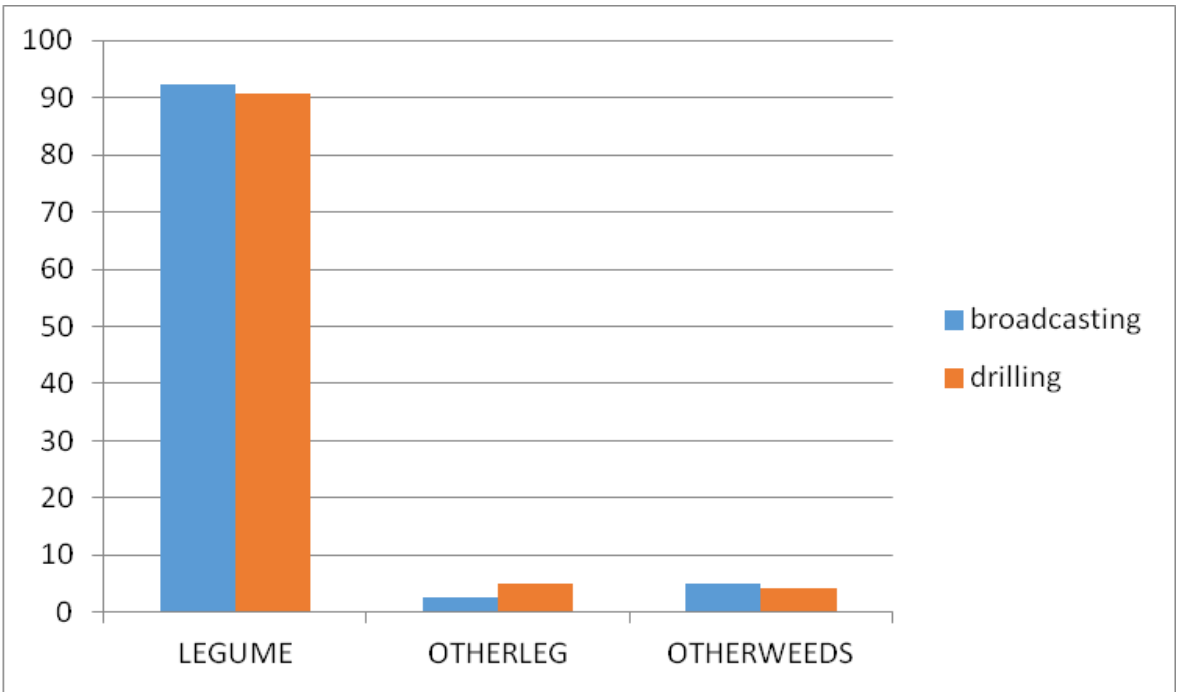


Figure 4*: *Botanical composition (%) of Stylosanthes hamata as affected by sowing methods

DISCUSSION

The height of a crop at harvest is dependent on variable factors which indicates specie inherent potential to thrive with regard to the environmental factors to which the crop is subjected (Shewu, 2014). The values recorded for plant height across the stages of growth only differs at four and eight weeks after planting as affected by phosphorus sources applied at varying rates. In this study, *S. hamata* fertilized with poultry manure at 60 Kg P/ha was the tallest and the values recorded compares well with the mean of 49.72 cm reported by Bhatt *et al*. (2010) when *S. hamata* Taub. was grown in an open field. This clearly suggests that fertilizing *S. hamata* with poultry manure at 60 Kg P/ha is capable of providing the legume with the nutrients required to grow well, thereby increasing its ability to utilize sunlight to photosynthesize and produce more feed for animals. Elsewhere, Khalid *et al*. (2003) reported that phosphorus fertilizer application gradually increased plant height, number of leaves per plant, and leaf area per plant. Specifically, our result for plant height is in agreement with the range of 21.31 – 53.13 cm reported by de Leeuw *et al*. (1992) when *S. hamata* cv Verano was established on manually-hoed land. However, Moles *et al*. (2009) and Falster and Westoby (2003) noted that plant investment in height improves access to light and serves as an ecological strategy for crops.

The observed difference in the number of stem/plant (NS/P) of *S. hamata* occurred only at four weeks of growth, where the unfertilized legume had higher stem numbers than for other treatments. This infers that amending the soil with either poultry manure or Aleshinloye organo-mineral at the adopted rates could not have increased the number of branches of the legume at that stage of growth. Higher values recorded for number of leaves/stem (NL/S) and

stem length (SL) in the plots fertilized with poultry manure at 60 Kg P/ha across the stages of growth corroborates the report by Falster and Westoby (2003) that plant height is directly proportional to traits such as leaf mass fraction, leaf area ratio, leaf mass per area and canopy area. Given that leaves are arranged alternately along the stem length of legumes (Barnhart, 2018), higher stem length (SL) recorded for the treatment that received poultry manure at 60 Kg P/ha than others implied better mineralization of the manure, which consequently produced more leaves that would be relished by ruminants during grazing.

Generally, result from this study shows a pattern of growth rate which depict slow mineralization rate for legume that was fertilized with Aleshinloye organo-mineral at 60 Kg P/ha and 80 Kg P/ha at four weeks of age. Meanwhile, there was a transition at eight weeks of age where the growth rate of these treatments improved, though slightly lower than the rate observed for the plots fertilized with poultry manure at 60 Kg P/ha. This indicates a progressive increase in the rate of nutrient release by Aleshinloye organo-mineral, with possibility that the threshold of application rate as adopted in this study is yet to be reached. Across the treatments, no effect of sowing method was observed on the agronomic characteristics of the legume. Despite the decline in available moisture during the period of study, the legumes thrived well and survived the dry season with the manure type used irrespective of the sowing method employed.

Among the botanical components, *S. hamata* cv Verano out-competed other companion species and weeds with regard to the treatments imposed. This observation therefore corroborates the findings by Santos *et al*. (2016) that higher soil cover and vegetation predominance were recorded for forage peanut, siratro and lablab when planted in a coffee plantation. This results further strengthen the report by Muraina (2015) that *S. hamata* is a good competitive legume. While it is desirable in agronomic systems to achieve the highest possible yield, it is also important that sown pasture species smothers weed to achieve the desired yield as indicated in the result of our study.

The agronomy of pasture crops varies due to many factors such as the soil quality, plant density, fertilizer dose, growing season and stage of maturity. Following nitrogen, phosphorus is the second most deficient nutrient in plants (Munir *et al*. 2004), and its optimum rate of application has been reported to improve yield of crops (Cisar *et al*. 1992). The DMY of the legume in this study at both harvesting times surpassed the yield of 1-2.2 t DM/ha to 2.2-7.0 t DM/ha reported by Mani *et al*. (1992) for fodder banks and natural pasture. The disparity in the previous and present findings might be attributed to manure application rates and climatic differences as the studies were carried out in different parts of Nigeria. Admittedly, high yield of *S. hamata* recorded at 12 WAS are consequences of additional branches, leaf formation and stem development (Akinola *et al*. 1971; Robertson *et al*. 1976) in addition to their deep tap root system (Amodu, 2002). Elsewhere, *S. hamata* has been reported to improve bulk density, infiltration rate and water holding capacity of the soil (de Leeuw *et al*. 1992).

In this study, there was no difference in the DMY of *S. hamata* under the influence of sowing method and this contradicts the report by Onifade and Akinola (1986) and Onifade and Akinola (1990) that broadcasting stylo seed produced higher DMY in northern part of Nigeria. The difference in the result obtained could be premised on variation in climatic condition, manure application and age at harvest.

CONCLUSION

The application of poultry manure at 60 Kg P ha $^{-1}$ was a better option for increasing the growth rate and proportion of *S. hamata* in the

sward. However, the use of this manure will further enhance soil cover and vegetation predominance of the legume. Dry matter yield of *S. hamata* was not affected by the factors imposed except for age at harvest indicating higher yield at 12 WAS than 8 WAS. It can be concluded that application of poultry manure at 60 Kg P ha^{-1} as soil amendment have prospect to enhance the canopy structure of *S. hamata* sward to produce sufficient herbage for ruminant consumption.

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