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Growth Rate and Biomass Accumulation in Forage Maize (*Zea mays*), Forage Millet (*Echinochloa utilis*), Elephant Grass (*Pennisetum purpureum*) and Gamba Grass (*Andropogon gayanus*)

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Abstract

Background: Understanding the biomass accumulation and growth rate of the forages to feed the animal throughout the year is critical for improved earnings and long-term livestock production. This was found in forage maize (*Zea mays*), forage millet (*Echinochloa utilis*), elephant grass (*Pennisetum purpureum*) and Gamba grass (*Andropogon gayanus*). The experiment was place at Federal University Oye Ekiti in Ekiti State, Nigeria, in latitude N 07° 48.308, longitude E 005° 29.573 and elevation 548.4 meters above sea level, with an annual rainfall of 1778 mm.

Methods: Planting four rows in a complete randomized design (CRD with four replications) was used to test the forage crops. Before planting, the soil in the experimental field had 49.96% organic matter and 33.59% after the crops were harvested. During the growth season, *Pennisetum purpereum* had the maximum plant height and sward height.

Result: The *Zea mays* plant had the maximum leaf breadth (5.44cm at 8 weeks) and the most leaves. *Zea mays* had the largest biomass accumulation (BC) of 113.80% after 8 weeks, followed by *Andropogon gayanus* with 67.15 per cent, *Pennisetum purpureum* with 56.24 per cent and *Echinochloa utilis* with 51.63%. Although there were no significant differences $p \leq 0.05$ in the crude protein levels of the different species, samples from the latest cuts (8th week) had the greatest crude protein content (11.88 % in *Andropogon gayanus*). Crude protein levels were shown to rise in lockstep with grass growth. Although there was no significant difference between the grass species, the crude fibre content of the three grass species was discovered to vary with the growth phase. The greatest fibre content of 13.58% in *Zea mays* was reported during the 6th week, which might be attributable to lignin encrustation in grasses that were harvested late. All of the plant samples of crops showed the same irregular pattern in crude fiber, moisture content and fat content, with no significant variance.

Key words: *Andropogon gayanus, Echinochloa utilis, Pennisetum purpureum, Zea mays.*

Introduction

Grass is a common name for any plant in a large family *Poaceae*. These plants are usually with hollow stems and long narrow, usually green leaves and tiny flowers arranged in spikes (Pardee, 2008). Grasslands currently are producing far less than their production potential.

Hence, it has become imperative to recover their grazing potential (Muhammad *et al.* 2012). One way to monitor and improve on the grazing potential of these grasses is to understand their rate of growth and biomass accumulation. Biomass accumulation simply means the quantity of living matter that can be produced by a specific plant. Growth on the other hand refers to the increase in size or progressive development that is usually irreversible.

Maize (*Zea mays* L.) has the ability of adaptation to different climatic and soil conditions (Ruiz *et al.*, 2008). In industrialized countries its uses are mainly for forage production, raw material for the production of processed foods and recently, for ethanol production (Cox *et al.* 2005). The yield and quality of maize depend on soil fertility (Major *et al.*, 2010), crop management (Irlbeck *et al.* 1993) and genetics (Stuber *et al.* 1987). Forage maize is considered an excellent food for ruminants for its high energy and protein content (Andrieu *et al.* 1993). However, in Mexico, maize silage has a lower energy value for lactation because previous breeding focused on increasing forage yield rather than forage quality for dairy production(Nunez *et al.*, 2003). In La Laguna area, a dairy basin in Mexico, more than 30,000 ha of maize are grown under irrigation and about 1,000 ha under rain fed conditions (SIAP, 2011). The demand for forage maize in dairy farms, located in this area, is high and there is a need to identify hybrids with both good forage quality and high biomass production potential, because the

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forage of maize constitutes 30 to 40% of the daily diet of the dairy cattle (Gonzalez *et al.*, 2005).

Forage millet (*Echinochloa utilis),* is a tropical annual Pearl millet, allogamous (cross-pollinated) diploid cereal, belonging to the *Poaceae* family, subfamily *Panicoideae*, tribe *Paniceae*, sub tribe *Panicinae*, section *Penicillaria* and genus *Pennisetum*. The entire plant is fed to animals as hay or silage while the seeds are for human and animal consumption. It is a bunch grass growing 4-8 ft. tall, on smooth ½–1 inch diameter stems, with upright side shoots (tillers). Compared to sorghum, it will produce more tillers and has a woodier stem (Kajuna *et al.* 2001). The inflorescence (4–20 in) is a terminal spike, resembling that of cattail. Seeds are cylindrical, typically white, or yellow, but there are varieties with colors ranging from brown to purple. Leaf blades are long and pointed. Gamba grass has a broad natural distribution in Africa. The native range of Gamba grass extends across the tropical and subtropical savannah of Africa, from Senegal on the west coast to Sudan in the east, south to Mozambique, Botswana and South Africa (Csurhes and Hannan-Jones, 2016). Like savannahs elsewhere, extended dry seasons are a feature of much of this region (Csurhes and Hannan-Jones, 2016). Elephant grass originated from sub-Saharan tropical Africa (Clayton *et al.* 2013). It has been introduced as forage into most tropical and subtropical regions worldwide. It was introduced into the USA in 1913, in the 1950s into Central and South America and the West Indies and in the 1960s into Australia. It is commonly naturalized and sometimes becomes invasive. Elephant grass in mainly found from 10 °N to 20 °S. It is often regarded as a weed in crops, along roadsides, waterways, wetlands, floodplain, swamps, forest edges, disturbed areas and wastelands (Setterfield *et al.* 2014).

The overall objectives are to develop a model that can correctly predict: The growth rate of four grasses (Forage Maize, Forage Millet, Gamba grass and Elephant grass); and Biomass accumulation of the four grass species. The specific objectives is to: Obtain the varietal differences in each grass growth rates; Determine the nutrient content of the soil before planting and after harvesting; Determine the nutrient content of the grass at different stages of growth; understand the effect of cutting on the nutrient composition of the various grass species; and to recommend the best grass species for grazing based on growth rate, biomass accumulation and nutrient composition at the end of the experiment.

MATERIALS AND METHODS

Site location

The experiment was conducted at a location, which was situated at latitude - N 07° 48.308, longitude - E 005° 29.573 and 548.4 m above sea level with an annual rainfall of 1778 mm (Garmin 72H, GPS Model). This research work was conducted between the months of July-August 2017 (rainy season).

Soil description

The soil of experimental area was an upland loam soil (Not given the %age of sand, silt and clay etc.). Soil samples were analysed in May 2017, pH was 5.60, high in organic matter (39.83%), N (2.36%), P (117.09 ppm), Zn (72.63 ppm) and Cu (17.35 ppm). (Give NP K kg/ha)

Treatments and cultural practices as fertilizer, irrigation or rainfall, spacing.The treatments were evaluated by growing 4 rows using completely randomized design (CRD) with 4 replications.

Statistical analysis

The data was analysed using the PROC GLM of SAS (2008) with cut time, grass specie, as fixed effects. The Tukey's honestly significant difference test at 5% probability level was used to separate the differences between treatment means.

Analytical methods

Here is give all the methods and procedures of analysis:

Analyses for proximate composition was done at IITA Ibadan, Nigeria using the procedures of A.O.A.C. (2010), Crude protein (CP) was determined using the Kjeldahl method. Moisture content was determined using Oven drying method, Crude Ash was determined using furnace method. Crude fibre was determined using the Soxhlet method. The soil used was analyzed to determine all major nutrients and many of the micronutrients present in the soil before planting and after harvesting was done.

Model functions

Model for biomass accumulation

The equation for bio-mass accumulation (BMA) was derived using the following parameters:

GS: Grass species
CT: Cutting time
SL: Sward length
LW: leaf width
AVGnL: Average number of leaves
OM's: Soil organic matter

$$BMA = OM's + GS + E_t$$

Where

E_t = Error due to time and can be minimized by taking note of the CT. CT is Indepent while PH, SL, LW and AVGnL are all dependent on CT.

$E_t = CT + \varepsilon_t$

ε_t is uncontrollable and it is the error due to chance.

$CT = PH + SL + LW + AVGnL + \alpha$

Where α is a constant or intercept.

For Gs1

$CT = -5.026 - 0.061PH + 0.97SL + 0.157LW + 0.644AVGnL$

ε_t (Error of estimate for Gs1) = 0.270

For Gs2

$CT = -2.7 + 0.07PH + 0.062SL + 0.694LW + 0.304AVGnL$

ε_t (Error of estimate for Gs2) = 0.326

For Gs3

$CT = -4.556 + 0.069PH + 0.003SL + 0.258LW + 0.005AVGnL$

ε_t (Error of estimate for Gs3) = 0.406

For Gs4

$CT = -2.63 + 0.21PH + 0.056SL + 0.294LW + 0.384AVGnL$

ε_t (Error of estimate for Gs4) = 0.193

Model functions

Model functions forgrass growth rate

$$\%G_{gri} = 2BM_{si}\% - \%S_{pgi} + \%M_{pi} + U_{fei} + F_i - N_{gi} \pm E_T$$

Where

G_{gr} = Grass growth rate.

$\%S_{pg}$ = Viability of species seeds is expressed in terms of percentage.

$\%M_p$ = Management practices is expressed in percentage.

U_{fe} = Unforeseen interference exigencies is expressed in terms of percentage.

$BM_{si}\%$ = Soil organic matter content in percentage.

i = Expressed in function of days.

The grass growth model will be expressed in percentage.

RESULTS AND DISCUSSION

Physic-chemical properties description

Soil before planting

Table 1 and 2 provides an overview of the physicochemical characteristics of the soil at the time of planting. The surface horizon of the soil (0-20 cm) comprises 89 percent sand, 4 percent silt and 7 percent clay, which indicates that the texture of the soil is loam according to the standard soil classification soil (USDA, 2014). It was also determined that the particle size, which indicated that the fine earth fractions were dominated mainly by sand followed by clay and silt in the soil; the soil has a high amount of sand and a very low amount of clay and silt, which presumes that the low level of silt may be due to low content of these properties in their parent materials; the particle size was also determined, which indicated that the fine earth fractions were dominated mainly by sand in the soil.

Soil after harvest

Table 3 and 4 presents the physicochemical characteristics of the soil as of the time of harvest. The loam texture of the soil is indicated by the fact that the soil at a depth of 0-20 centimeters comprises 73 per cent sand, 11 per cent silt and 16 percent clay. This is in accordance with the standard soil categorization (USDA, 2014). The changes in the soil texture, particularly in relation to the decrease in sand particles, might be owing to the plants' use of sand in the form of silica as a defence mechanism against plant-eating predators. This is particularly relevant to the reduction in sand particles. After the harvest, there was a decrease in the amount of organic matter that was present in the soil; this might be explained by the fact that it was consumed in the process of the grasses' conversion of photosynthesis into biomass.

Table 1: Soil physical properties before planting of grass species.

Physical properties	Concentration (%)
Sand	89
Silt	4
Clay	7
Total organic carbon	28.71
% Organic matter	50.00

Table 2: Soil chemical properties before planting of grass species.

Chemical properties	Concentration (Convert in to kg/ha)
N%	2.96
K (cmol/kg)	0.30
Na (cmol/kg)	0.08
Ca (cmol/kg)	2.46
Mg (cmol/kg)	0.80
ECEC	3.67
pH	6.6
Fe (PPM)	178.91
Cu (PPM)	26.01
Cl (PPM)	0.13
Zn (PPM)	89.82
Mn (PPM)	126.35

Table 3: Soil Physical Properties after Harvesting of grass species.

Physical properties	Concentration (%)
Sand	73
Silt	11
Clay	16
Total organic carbon	19.30
% Organic matter	33.59

Table 4: Soil chemical properties after harvesting of grass species.

Chemical properties	Concentration
N%	1.99
K (cmol/kg)	0.37
Na (cmol/kg)	0.10
Ca (cmol/kg)	4.01
Mg (cmol/kg)	1.00
ECEC	5.51
pH	5.5
Fe (PPM)	93.22
Cu (PPM)	16.83
Cl (PPM)	0.10
Zn (PPM)	71.73
Mn (PPM)	106.23

Growth attributes

Plant height

In Table 5, the results show that Elephant grass had the highest plant height, which was statistically significant $p \leq 0.05$ from the other three grasses at all the stages of growth, followed by forage maize, which was more than forage millet. However, the forage millet recorded higher than Gamba grass but statistically non- significant at two, four, six and eight weeks. The growth of the species could be attributed to their adaptability to the environment and their ability to effectively grow under harsh climatic conditions. Elephant grass was regarded as one of the highest yielding tropical grasses and according to FAO in 2015 the forage is very popular throughout the tropics, notably in cut-and-carry systems. The plant height for the various grass species is affected by stand density, species, composition and sward height while the growth rate is controlled genetically as well as by environmental factors such as weather, soil and management factors.

Sward height

The same trend was observed in sward heights. The differences in the sward height can easily be explained by the same causes of difference in the plant height such as genetic causes, soil organic components, fertilizer application *etc.* This is due to the sward height is directly linked to the plant's total height. All ingestive behaviour variables except bite area *i.e.* bite weight, rate, depth, and volume were significantly related to sward height irrespective of forage species and sward height always had a greater effect than bulk density.

Realini *et al.* 1999, suggested that maintaining a sward height of 10 cm offers advantages in terms of individual animal output and output per hectare compared with grazing at 5 cm and that compensatory growth does not seem to be an important phenomenon in heavy finishing steers.

Average number of leaves

There was a large amount of variation in the number of leaves, with Zea mays having the greatest typical number of leaves produced per week (Table 5). The average number of leaves on each plant is significant because it has a direct impact on the total quantity of dry matter that is made available for eating by the animal from each plant. This is because animals primarily consume the leaves of forage plants. The amount of photosynthesis that can take place on a plant is closely related to its size, thus the number of leaves is another factor that must be considered. Differences in the number of leaves that are seen during growth can be attributed to a variety of factors, including the types of nutrients that are available to each plant, differences between species, the genetic make-up of individual plants and the amount of sunlight that is received by the plants as well as its quality.

Forage quality

Crude protein (CP)

The crude protein content of the four grass species did not differ statistically. However, the crude protein content was observed to increase nearly linearly as the grasses grew. Samples from the last cuttings (8th week) had the highest crude protein content (11.88% in *Andropogon gayanus*). The increase in the crude protein with time could be attributed to the high level of nitrogen in the soil. For instance, nitrogen

Table 5: Growth attributes of *Zea mays*, *Echinochloa utilis*, *Pennisetum pupureum* and *Andropogon gayanus*.

Parameters	Plant height (cm)				Sward height (cm)				Leave width				Average number of leaves			
Cutting times (Weeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
Zea mays	59.79^{b}	88.51^{b}	124.80^{b}	145.37^{a}	43.78^{b}	64.21^{b}	76.42^{b}	89.85^{b}	2.52^{a}	3.72^{a}	4.66^{a}	5.44^{a}	5.13^{a}	5.60^{a}	7.87^{a}	8.67^{a}
Echinochloa utilis	51.01^{c}	73.54^{c}	108.33^{c}	126.64^{b}	37.83^{c}	57.00^{c}	65.73^{c}	75.93^{c}	0.67^{b}	1.51^{d}	2.76^{d}	3.56^{c}	4.94^{a}	5.00^{a}	7.03^{b}	7.81^{b}
Pennisetum purpureum	84.34^{a}	109.89^{a}	136.83^{a}	155.69^{a}	55.76^{a}	84.17^{a}	103.51^{a}	117.43^{a}	2.08^{a}	2.88^{b}	4.28^{b}	4.51^{b}	4.13^{b}	4.26^{b}	5.15^{d}	5.88^{c}
Andropogon gayanus	45.60^{c}	75.638^{c}	94.35^{d}	111.37^{c}	30.91^{d}	50.96^{c}	64.24^{c}	80.26^{c}	1.24^{b}	1.90^{c}	3.19^{c}	4.61^{b}	3.88^{b}	4.46^{b}	5.61^{c}	6.08^{c}
SEM	1.02	1.22	0.76	1.55	0.47	1.13	0.52	0.81	0.11	0.04	0.04	0.06	0.11	0.04	0.04	0.06

Means on the same column with different superscripts (a, b, c, d) differ significantly ($p<0.05$). SEM (Standard Error of Mean).

is required for protein synthesis, formation of chlorophyll and nucleic acids.

Crude ash

The crude ash content did not vary among the grass species statistically. Although, the highest crude ash content of 5.80% was recorded at the 6th week *in Andropogon gayanus*. Ash content represents all the important nutritional ingredients especially minerals, both micro and macronutrients, which are very important for the normal physiological functions of the animal's body. The irregular patterns of the crude ash as seen in the results can be attributed to the fact that the grasses absorbed some silicon from the sand soil. This was reported by Alice Klein (2017), reported that the absorption of sand from the soil could be seen as an evolutionary defence mechanism against plant consuming predators. This could easily explain the marked reduction in the levels of sand present in the soil at the end of the experiment. The high ash composition of the forage species observed during the rainy season in the present study may be due to high concentration of such minerals, which is precursor to the proximate formation in the rainy season than in dry season. Minerals activate enzymes and are essential co-factors of metabolic reactions. They also function as carrier of protein according to George *et al.* (2005).

Crude fibre

The crude fibre content of the grasses showed an irregular pattern of rise and fall during the experiment in which the patterns were similar in the moisture content although, the crude fibre content across the grass species did not differ statistically during the growing season. However, the fibre content of the three grasses increased due to the encrustation of lignin in them as the grasses matured. High cutting frequency reduces growth and development, whereas long intervals between harvests lead to accumulation of fibre and reduction in quality (Tessema *et al.* 2010).

The highest crude fibre level 13.58% was recorded at the 6th week in *Zea mays* although, it was dropped a little in the values and this could be attributed to the changes in season during the period of the experiment (August break), which could have resulted in differences in available water levels in the soil in those periods. Khairani *et al.* (2013) also demonstrated the effects of cutting interval on yield and quality vary in the different grass species.

Fat promotes the absorption of fat soluble vitamins hence, it is very important in diets. Fat content in *Zea mays*, *Echinochloa utilis*, *Pennisetum purpureum* and *Andropogon gayanus* did not differ statistically. The implication of this result is that an analysis into the relative content of fat soluble vitamins in the four species of grasses would most probably yield had no statistical difference. This could be attributed to similarities in the genetic makeup of the plants or the uniformity of the soil used for the experiment.

Moisture content

Inside Table 6, the moisture content did not vary between the grass species statistically. However, the highest moisture

Table 6: Proximate composition of *Zea mays*, *Echinochloa utilis*, *Pennisetum pupureum* and *Andropogon gayanus*.

Parameters	Crude protein (CP)				Ash				Moisture content				Crude fat				Crude fibre			
Cutting times (Weeks)	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
Zea mays	3.31	7.31	8.81	11.19	4.38	4.86	5.87	4.97	7.88	8.75	10.56	8.95	1.51	1.68	2.02	1.71	10.13	11.25	13.58	11.51
Echinochloa utilis	3.56	6.69	8.75	10.75	4.77	4.46	5.83	4.80	8.58	8.02	10.49	8.63	1.64	1.54	2.01	1.65	11.03	10.32	13.49	11.10
Pennisetum pupureum	3.81	6.94	8.63	10.38	5.12	4.62	5.77	4.60	9.22	8.31	10.44	8.28	1.77	1.59	1.99	1.58	11.86	10.68	13.35	10.64
Andropogon gayanus	3.69	7.31	8.69	11.88	4.93	4.86	5.80	5.27	8.88	8.74	10.38	9.48	1.70	1.67	2.00	1.82	11.42	11.25	13.42	12.19
SEM	0.02	0.02	0.02	0.06	0.09	0.08	0.08	0.17	0.25	0.14	0.15	0.30	0.05	0.03	0.09	0.06	0.38	0.18	0.19	0.39

Means on the same column with different superscripts (a, b, c, d) differ significantly ($p<0.05$). SEM- Standard error of mean.

Table 7: Biomass accumulation and growth rate of *Zea mays, Echinochloa utilis, Pennisetum pupureum* and *Andropogon gayanus*

	Biweekly biomass accumulation(%)				Biweekly growth rate(%)			
Grass species	2 weeks	4 weeks	6 weeks	8 weeks	2 weeks	4 weeks	6 weeks	8 weeks
Zea mays	72.35	90.91	102.15	113.80	41.65	41.01	40.77	40.39
Echinochloa utilis	41.10	44.47	48.93	51.63	41.61	41.11	40.78	40.46
Pennisetum purpureum	40.22	42.31	44.86	56.24	81.57	81.07	80.80	80.52
Andropogon gayanus	48.31	56.16	61.71	67.15	71.59	71.01	70.79	70.28

content 10.56 % was observed at the 6th week in *Zea mays* as it further decreased in the 8th week (Table 6). Grass with lowest moisture content could store for a longer time without spoilage. Also the moisture content affects the amount of dry matter available to the animals for consumption. With higher levels of moisture, there would be lesser levels of dry matter, which would imply that the requirement of animals for forage increased but may not meet their nutrient and fiber requirement level.

Onyeonagu and Eze (2012) reported that considerable differences in proximate composition can be observed in grasses harvested under different seasonal variations. Relative composition of forages is a function of various factors that interact with one another to produce varied results. They also reported high proximate composition of the grass species observed may be due to the high concentration of such mineral. These are precursors to the proximate formation.

Biomass accumulation and growth rate

In comparison to *Zea mays*, which accumulated biomass at a rate of 113.80 percent after 8 weeks, the data showed (Table 7) that Echinochloa utilis only accumulated biomass at a rate of 51.63 percent. At the 2 weeks growth stage, Pennisetum purpureum likewise had the greatest growth rate, which was 81.57 per cent, followed by Andropogon gayanus, which had a growth rate of 71.59 percent. The amount of biomass that was produced rose proportionally with the number of weeks, whereas the growth rate decreased proportionally. This suggests that quick-growing grasses, once planted, had a reduction in growth proportionate to their age as they became older

CONCLUSION

During the course of the experiment, it was discovered that *Pennisetum purpureum* was the kind of grass that grew the quickest; nevertheless, in comparison to *Zea mays*, it had a much lower biomass accumulation yield (51.63 per cent) (113.80 per cent). In addition, it had the greatest growth rate, which came in at 80 per cent. The model that was developed for this research can provide precise projections about the growth rates of all four types of grass as well as the accumulation of biomass. Due to the fact that the conclusions of this research were only based on a single season in the tropics, it is recommended that the same research experiment be carried out in a range of locations and seasons in order to validate the findings.

Conflict of interest: None.

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