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Effects of Fertilization and Irrigation on Establishment and Growth of Switchgrass (*Panicum virgatum* L.) in Sokoto, Nigeria

A. A. Abdullahi[1], B. L. Aliero[2], A. A. Aliero[2*] and A. A. Zuru[3]

[1]Department of Biology, Shehu Shagari College of Education, Sokoto, Nigeria.
[2]Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto, Nigeria.
[3]Department of Pure and Applied Chemistry, Usmanu Danfodiyo University, Sokoto, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Authors AAA, BLA, AAAliero designed the study, performed the statistical analysis, wrote the protocol, and authors AAA, AAAliero wrote the first draft of the manuscript. Authors BLA and AAZ managed the analyses of the study. Authors AAA, BLA managed the literature searches. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: To determine the effects of fertilization and irrigation on establishment and growth of switchgrass (*Panicum virgatum* L.) in Sokoto, Nigeria and its adaptability.
Study Design: A factorial experiment laid down in split – plot design.
Place and Duration of Study: The study was carried out during 2008/2009 and 2009/2010 dry seasons in upland and lowland areas in Sokoto, Nigeria.
Methodology: The effects of nitrogen fertilizer, manure and irrigation interval on percentage plant establishment, plant height, number of leaves and stem diameter of *P. virgatum* were assessed. Four levels of nitrogen (0, 25, 50 and 75 kg N ha^{-1}), three rates of manure (0, 5 and 10 t ha^{-1}) and three irrigation regimes (w_2, w_4 and w_6).
Results: Results indicate that there is no significant (P = 0.05) increase in percentage plant establishment, plant height, number of leaves and stem diameter by raising nitrogen rate from 50 to 75 kg N ha^{-1}, manure rate from 5 – 10 t ha^{-1} or irrigation intervals from w_2 to w_4 days. The findings of the study revealed that a combination of 50 kg N ha^{-1}, with 5 t ha^{-1} of manure and w_2 irrigation interval enhanced percentage plant establishment, plant height, number of leaves and stem diameter.

**Corresponding author: Email: aaaliero@yahoo.com;*

Conclusion: The combination of treatments 50 kg Nha^{-1}, 5 t ha^{-1} of manure and w_2 irrigation interval were recommended for switchgrass establishment and growth in Sokoto geo-ecological zone of Nigeria.

Keywords: Switchgrass; irrigation; manure; nitrogen; establishment.

1. INTRODUCTION

Switchgrass (*Panicum virgatum* L.*)* belongs to the family Poaceae which was initially known as forage crop in the United State of America (U.S.A.) and Canada since 1980's [1]. Recently, it has been identified as a promising bioenergy feedstock due to its versatile and adaptable nature and can grow, thrive in many weather conditions and soil types. Switchgrass has two distinct ecotypes, the lowland cultivars, which tends to produce more biomass, and the upland cultivars, which are generally more cold tolerant [2].

Seedling establishment is the most critical stage in the development of the crop. Important factors determining establishment success are soil tillage, accurate seed placement, time of seeding and planting depth [3]. Many factors can contribute to stand failure; among them are poor seed quality, dormancy, environmental extremes, poor planting methods, weed competition and seedling morphology [4]. No single method of establishment can be suggested for all situations. The crop can be established both by no-till and conventional tillage, broadcast and sod-seeding [5]. The main fertilizer requirement of Switchgrass is nitrogen. Nitrogen (both organic and inorganic) is important for switchgrass production they supply nutrients, improve soil condition, reduce temperature, and ensures a healthy switchgrass growth, which is manifested in increased vigour, size and green colour of the foliage [6]. Irrigation is a factor of intensified agricultural production it creates favorable conditions for the growth of the crop, flowers as well as seed production. Irrigation increases the acreage, yield and production of switchgrass [7]. Excessive irrigation reduces yield, while inadequate irrigation causes water stress and reduces production [8].

Switchgrass is used primarily for soil conservation [1], forage production [9], game cover [10], as an ornamental grass [11], biomass crop for ethanol, fibre, electricity and heat production [12, 13]. Switchgrass can yield a variety of useful fuels such as synthetic gasoline and diesel fuel, methanol, methane gas, hydrogen as well other chemical byproducts useful for making fertilizers, solvents and plastics [14]. Due to the uncertainty and fluctuations in the prices of fossil fuels, the need to reduce greenhouse gas emission, and growing energy security concerns, renewable and non-polluting sources of energy assume top priority. The potential of switchgrass as a biofuel feedstock in Nigeria has not been explored. There is currently no information on the growth potential of switchgrass and its impact on the natural environment. For example, uncertainty surrounds the effective use of water by the crop and, the lack of information on the basic agronomies dictated that research be under taken to develop a capacity for predicting impacts of large-scale planting of switchgrass in Nigeria.

Growing, developing and utilization of energy crops produced on Nigeria farms as a source of renewable fuels is a concept with great relevance to current ecological and economic issues at both National and Global scales. Growing and developing perennial forage crops such as switchgrass as biofuel could benefit agricultural economy by providing an important new source of income for farmers [7]. In addition, energy production from perennial cropping systems, which are compatible with conventional farming practices, would help reduce degradation of agricultural soils, lower national dependence on fossil fuels, and reduce emissions of green-house gases and toxic pollutants to the atmosphere as well as less displacement of land for food production or loss of biodiversity through habitat destruction. The aim of this research is to evaluate the effects of fertilization and irrigation on the establishment and growth of switchgrass in upland and lowland areas in Sokoto, Nigeria.

2. MATERIALS AND METHODS

Seeds of switchgrass (Alamo) were obtained from United States of America (U.S.A.) through Southern Energy on a Pure Live Seed basis (PLS). The seeds were kept in clean paper envelopes and stored in metal cabinets in the Usmanu Danfodiyo University, Sokoto herbarium in the Department of Biological Sciences.

Field experiments were conducted during the 2008/2009 and 2009/2010 dry seasons at both Bio-energy farm, Sokoto Energy Research Center (SERC) at latitude 13' N and longitude 5' 20 E at 265m above the sea level and University Fadama Teaching and research farm at Kwalkwallawa, Sokoto, at latitude 13.09^0 N and longitude 5.21º E with elevation of 242m [16]. The mean annual rainfall of the year 2008/2009 and 2009/2010 was 552 and 600 mm respectively [17]. Around the study site the temperature averages ranges from 27- 40ºC in April and 18ºC in December - January. The long dry season is characterized by cool, dry and dusty wind that blow from North to East from November to February and hot dry air from March to May [18]. The site falls in the Sudan savanna zone characterized by few scattered trees and numerous shrubs sandwiched by grasses and herbs [19].

The soils of the experimental sites were sandy (lowland) and sandy loam (upland), respectively. Physico-chemical analysis of the soil samples collected at 0 – 15 and 15 – 30 cm soil dept indicated that the soil reaction was slightly acidic with pH values of 5.95, 5.85 and 6.78, 6.29 at both lowland and upland location for the 2008/2009 and 5.84, 5.88 and 6.62, 6.80 at both locations for 209/2010 trails. In both trials bulk density, pH, organic carbon and total nitrogen content were low (Tables 1 and 2). Manure used has the following composition, nitrogen (8.68), phosphorous (10.98), potassium (6600), calcium (0.40), magnesium (1.05) and sodium (8000).

The treatments consist of factorial combinations of three rates of manure (0, 5 and 10 t ha^{-1}), four rates of inorganic nitrogen fertilizer in form of urea (0, 25, 50 and 75 kg Nha^{-1}) and three irrigation intervals (w_2, w_4 and w_6) indicating watering every two, four and six days respectivelydone at field capacity of the soil. The treatments were laid down in a split-plot design and replicated three times. The gross plot size was 4m x 3m (12 m^2) consisting of 36 plots, while, the total area of the experimental sites was 10,000 m^2.

Experimental sites were ploughed, harrowed, levelled and plots demarcated manually. Seed beds of 4m x 3m were prepared. Irrigation channels were laid out to convey water and drain away the excess with one meter leeway between blocks. Seeds were sown on 14^{th} December, 2008/2009 and 2009/2010 respectively. The seeds were sown by direct seeding using a spacing of 1m x 1m at 0.5 – 1.0 cm planting depth as recommended in the Ontario Ministry of Food Agriculture and Rural Affairs guidelines for forage crops [11]. During sowing, five (5) seeds were sown per hole and later thinned to three (3) plants per hole. Nitrogen fertilizer were applied through ring application method in two equal doses according to the treatments, the first dose was applied after the first weeding 2 weeks after planting (WAP), while the second dose was applied by top dressing 6 weeks after planting (WAP). Weeding was carried out manually after every 2 weeks to maintain weed free fields. The incidence of termite was controlled by applying chloropyriphos 20% EC insecticide at the base of the plant at the rate of 1250 ml per 500 liters of water.

Table 1. Physical, chemical and biological properties of experimental soil

Particulars	Lowland		Upland		
	Values	Depth (cm)	Values		Methods
	0-15	15-30	0-15	15-30	
2008/2009					
Sand (%)	46.6	48.6	90.2	92.0	Pipette method
Silt (%)	34.8	38.7	6.7	4.0	
Clay (%)	18.6	12.7	3.1	3.o	
Bulk density, mg m^{-3}	1.71	1.60	0.88	1.17	Core sampler
pH (1:25: soil: Water)	5.95	5.85	6.78	6.29	Glass Electrode pH meter
Organic Carbon (mg/kg)	14.77	14.30	7.59	10.37	Glass Electrode pH meter
Total N, %	0.77	0.60	0.30	0.32	Modified Kjeldahl method
2009/2010					
Sand (%)	53.30	63.10	93.0	92.9	Pipette method
Silt (%)	31.2	21.4	4.0	4.0	
Clay (%)	15.5	15.5	3.0	3.2	
Bulk density, mg m^{-3}	1.62	1.65	0.78	1.15	Core sampler
P^H (1:25: soil: Water)	5.84	5.88	6.62	6.80	Glass Electrode pH meter
Organic Carbon ($mgkg^{-1}$)	14.11	14.08	7.63	9.50	Glass Electrode pH meter
Total N, %	0.73	0.66	0.34	0.36	Modified Kjeldahl

Harvesting was done manually between 15th and 25th April of each season taken at the late boot stage and tied into small bundles..

Three (6) plants were randomly tagged from the inner rows of each plot and were used for recording the growth parameters unless indicated otherwise. Percentage Plant Establishment was obtained by counting all plants from the net plots at seven (7) days after germination and converted to percentage. Plant height was recorded second week after sowing (WAS). The height was measured from ground level to the tip of the tallest leaf of the three tagged plants using meter rule and repeated after every two (2) weeks for the rest of the period of the experiment. The numbers of leaves per plant from the three tagged plants were counted from the second (2nd) week after emergence (WAE) and then every 2 weeks for the rest period of the experiment. Stem diameter was measured at 2 to12 weeks after planting at (2) week's interval with the aid of a Vernier caliper 2 cm above ground level of the three tagged plants and the stem diameter average obtained. Data collected were subjected to statistical analysis using statistical package for social sciences (SPSS) version 16. Factorial analysis was carried out and significant mean were separated using Duncan's New Multiple Range Test (DNMRT) P = 0.05.

3. RESULTS AND DISCUSSION

3.1 Switchgrass Establishment

Nitrogen application significantly (P = <0.05) influenced switchgrass establishment and nitogen treated plots had the highest plant establishment in both lowland and upland areas in the two seasons (Table 2). However, there was no significant difference between plots treated with 50 and 75 kg/ha^{-1} nitrogen. Application of farmyard manure resulted in a significant increase in plant establishment in the upland area only. During the 2008/2009 season there was significant increase (P= <0.05) in the establishment of plots treated with farmyard manure at the rate of 5 and 10 t ha^{-1}. In 2009/2010 growing season, a significant effect in plant establishment was observed between plots treated with manure and the control. In 2008/2009 and 2009/2010 growing seasons and in both locations irrigation intervals had a significant (P = <0.05) effect on the establishment of switchgrass. Results indicate that irrigation intervals had greater influence on the plant establishment. Out of the three irrigation intervals used, W_6 recorded the least while, W_2 had the highest percentage plant establishment though not (P= <0.05) significantly different from W_4 irrigation interval (Table 2). Interaction effect between nitrogen, manure and irrigation regime on percentage plant establishment was insignificant.. The higher plant establishment observed for all the levels of nitrogen used indicates stimulating influence of the element in seed germination and establishment [19]. Availability of adequate nitrogen element ensures rapid protein synthesis and subsequent cell division leading to rapid tissue formation and enlargement. Akoun [20] reported that manure increases the nutrient status of a soil, which leads to increase in plant activity. Significant effect of varying irrigation regimes on plant establishment observed in this study could be because the seedlings had to develop deep fibrous root system that enable them to absorb water to a greater depth.

3.2 Plant Height

The application of nitrogen had a significant (P= <0.05) effect on the plant height and increasing the level of nitrogen resulted in the increase in plant height. At 2 WAP in both seasons and locations, control plots recorded the shortest plants, though not significantly different from those treated with 25 kg Nha^{-1}. Application of 75 kg Nha^{-1} recorded the tallest plant though not significantly different from plants treated with 50 kg Nha^{-1}. Similarly, at 4 to 12 WAP in both locations and seasons there were no significant difference in plant height between plants treated with varied level of nitrogen. However, there were significant difference (P = <0.05) between plants treated with the three levels of nitrogen and control (Tables 3 and 4).

Table 2. Effect of nitrogen, manure and irrigation on the establishment of Switchgrass

Treatment	2008/2009		2009/2010	
	Lowland	Upland	Lowland	Upland
Nitrogen (kg ha^{-1})				
0	64.11b	63.30b	65.78b	64.67
25	65.44ab	64.74ab	66.63ab	64.85
50	66.78a	65.07a	67.63a	65.41
75	66.04a	65.52a	67.93a	65.74
SEM±	0.85	0.82	0.88	0.85
Significance	*	*	*	Ns
Manure (t ha^{-1})				
0	64.83	63.72^{b}	66.25	64.31^{b}
5	65.75	65.00^{ab}	67.14	65.81^{a}
10	66.19	65.25^{a}	67.58	66.14^{a}
SEM±	0.75	0.71	0.77	0.72
Significance	ns	*	ns	*
Irrigation intervals				
W_2	66.50^{a}	64.08	68.36^{a}	67.19^{a}
W_4	65.89^{a}	65.42	67.61^{a}	64.92^{a}
W_6	64.39^{b}	64.47	65.00^{b}	64.14^{b}
SEM±	0.74	0.72	0.70	0.67
Significance	*	ns	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. SEM± = standard error of means*

Table 3. Effect of nitrogen, manure and irrigation on the plant height of Switchgrass at Lowland in 2008/2009

Treatment	Plant height (cm)					
	2 WAP	WAP	6WAP	WAP	10WAP	12 WAP
Nitrogen (kg ha^{-1})						
0	5.37^{b}	30.09^{b}	51.13^{b}	69.80^{b}	113.81^{b}	134.01^{b}
25	5.44^{b}	30.43^{a}	51.54^{a}	71.90^{a}	114.53^{a}	135.18^{a}
50	5.57^{a}	30.59^{a}	51.64^{a}	72.17^{a}	114.71^{a}	135.38^{a}
75	5.58^{a}	30.61^{a}	51.69^{a}	72.22^{a}	114.78^{a}	135.44^{a}
SEM±	0.06	0.21	0.14	0.94	0.25	0.22
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	5.41^{b}	30.43	51.41	70.80	113.34^{b}	134.95^{b}
5	5.51^{ab}	30.48	51.55	71.58	114.47^{a}	135.03^{a}
10	5.55^{a}	30.52	51.54	71.69	114.56^{a}	135.03^{a}
SEM±	0.05	0.18	0.13	0.86	0.23	0.24
Significance	*	Ns	ns	ns	*	*
Irrigation intervals (days)						
W_2	5.60^{a}	30.90^{a}	51.75^{a}	72.01	115.28^{a}	135.29^{a}
W_4	5.52^{a}	30.49^{b}	51.50^{a}	71.76	114.51^{b}	135.00^{ab}
W_6	5.35^{b}	30.04^{c}	51.25^{b}	70.30	113.59^{c}	134.72^{a}
SEM±	0.05	0.16	0.13	0.84	0.17	0.23
Significance	*	*	*	ns	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means*

Application of manure was significant (*P* =≤ 0.05) on plant height. The higher the amount of manure applied, the taller the plants. However, plots treated with 10 t ha^{-1} of manure gave the tallest plants at 2 WAP during both 2008/2009 and 2009/2010 growing seasons and control plots had the shortest plants in both seasons and locations.

Effect of irrigation on plant height at lowland area during 2008/2009 and 2009/2010 seasons is presented in Tables 2 and 3. Results indicate that varying irrigation intervals had greatly affected the plant height. At all the stages, w_6 irrigation interval recorded the shortest plants, while w_2 irrigation intervals recorded the tallest plants though not significantly different (*P*=≤0.05) from plots with w_4 irrigation interval at 8 and 12 WAP, but significantly different at w_2, w_4, w_6 irrigation intervals at 10 WAP. Similarly, for plants at the upland location and in both seasons, results revealed that at all the growth stages, w_6 irrigation intervals had the shortest plants while, w_2 and w_4 day irrigation intervals recorded the tallest plants (Tables 5 and 6). The interaction effect was significant (P =≤ 0.05) at 8 WAP in 2008/2009 at lowland, but was insignificant in 2009/2010 at both locations (Tables 3 - 6). The significant effect of nitrogen on plant height indicates that it is an important element in the growth and development of switchgrass. Nitrogen stimulates growth and enhances the production of the rich green colour characteristic of a healthy plant. The result obtained in this study on the effect of manure on plant height showed that the nutrients contained in the manure might facilitate the plant growth. On the effect of irrigation interval on plant height could be due to the high level of capillarity water and water use efficiency of the crop.

Table 4. Effect of nitrogen, manure and irrigation on plant height of Switchgrass at Lowland in 2009/2010

Treatment	**Plant height (cm)**					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	5.44^{b}	30.07^{b}	51.24^{b}	70.50^{b}	113.87^{b}	134.86^{c}
25	5.53^{b}	30.50^{a}	51.56^{a}	71.96^{a}	114.59^{a}	135.58^{b}
50	5.63^{a}	30.70^{a}	51.72^{a}	72.24^{a}	114.78^{a}	135.78^{ab}
75	5.65^{a}	30.69^{a}	51.74^{a}	72.29^{a}	114.84^{a}	135.84^{a}
SEM±	0.05	0.16	0.14	0.16	0.24	0.12
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	5.48^{b}	30.41	51.48	71.64	113.38^{b}	134.44^{b}
5	5.58^{a}	30.52	51.58	71.75	114.54^{a}	135.53^{a}
10	5.62^{a}	30.53	51.64	71.84	114.64^{a}	135.58^{a}
SEM±	0.05	0.15	0.13	0.22	0.22	0.14
Significance	*	ns	ns	ns	*	*
Irrigation intervals (days)						
W_2	5.68^{a}	30.83^{a}	51.85^{a}	72.07^{a}	115.34^{a}	135.80^{a}
W_4	5.58^{b}	30.55^{b}	51.58^{b}	71.82^{a}	114.54^{b}	135.56^{a}
W_6	5.42^{c}	30.08^{c}	51.27^{c}	71.35^{b}	113.67^{c}	135.18^{b}
SEM±	0.04	0.13	0.11	0.21	0.15	0.13
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means*

3.3 Number of Leaves

The application of nitrogen had significant (*P* =≤ 0.05) effect on number of leaves per plant. At lowland location, Tables 7 and 8 showed that nitrogen application in both seasons significantly (*P* =≤0.05) affected the number of leaves per plant. In 2008/2009 growing season, at 2 WAP the lowest number of leaves (2.22) was recorded on plots without application of nitrogen and the highest (3.48) was obtained on plots treated with 75 kg Nha^{-1} though not significantly different from those treated with 50 kg Nha^{-1}. At 12 WAP, plots treated with 75 kg Nha^{-1} recorded the highest leaf number. In 2009/2010 growing season and at 6 WAP there was no significant difference in leaf number between plots treated with 25, 50 and 75kg Nha^{-1}. The control plots had the least number of leaves. At 2, 4, 8, 10 and 12 WAP, increasing nitrogen rate from 25 to 50 and 75 kg Nha^{-1} did not bring about significant changes in the number of leaves per plant. In 2008/2009 growing season, Table 9 shows that at 2 WAP in the upland area, the lowest number of leaves (1.63) was recorded in control plot and the highest (2.89) was obtained in plot treated with 75 kg Nha^{-1} though not significantly different from plots treated with 50 and 25 kg Nha^{-1}.

Table 5. Effect of nitrogen, manure and irrigation on plant height of Switchgrass at Upland in 2008/2009

Treatment	Plant height (cm)					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	5.30^{b}	30.01^{b}	51.07^{b}	70.37^{b}	113.73^{b}	133.94^{b}
25	5.36^{b}	30.35^{a}	51.39^{a}	71.80^{a}	114.42^{a}	134.99^{a}
50	5.49^{a}	30.49^{a}	51.56^{a}	71.75^{a}	114.41^{a}	135.01^{a}
75	5.53^{a}	30.50^{a}	51.59^{a}	71.80^{a}	114.46^{a}	135.05^{a}
SEM±	0.05	0.14	0.16	0.15	0.18	0.19
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	5.33^{b}	30.23	51.30	71.34	114.12	134.70
5	5.43^{a}	30.35	51.40	71.43	114.29	134.78
10	5.49^{a}	30.43	51.50	71.52	114.36	134.76
SEM±	0.05	0.13	0.14	0.19	0.17	0.20
Significance	*	Ns	Ns	ns	ns	ns
Irrigation intervals						
W_2	5.53^{a}	30.61^{a}	51.61^{a}	71.76^{a}	114.91^{a}	135.06^{a}
W_4	5.45^{a}	30.43^{a}	51.49^{a}	71.47^{a}	114.22^{b}	134.74^{ab}
W_6	5.28^{b}	29.98^{b}	51.10^{b}	71.06^{b}	113.64^{c}	134.44^{c}
SEM±	0.04	0.11	0.14	0.18	0.12	0.19
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means*

At 4 to 12 WAP in 2008/2009 and 2009/2010 growing seasons, there were no significant differences in leaf number between plants given 50 kg Nha^{-1} and those that received 75 kg Nha^{-1}. The control treatment had the least number of leaves. On the effect of manure, the results revealed that the higher the amount of manure applied the higher the number of leaves per plant.

Table 6. Effect of nitrogen, manure and irrigation on the plant height of Switchgrass at upland in 2009/2010

Treatment	Plant height (cm)					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	5.37^{b}	30.12^{c}	51.14^{b}	70.43^{b}	113.80^{b}	134.09^{b}
25	5.42^{b}	30.41^{b}	51.49^{a}	71.82^{a}	114.56^{a}	135.05^{a}
50	5.54^{a}	30.70^{ab}	51.63^{a}	72.04^{a}	114.86^{a}	135.17^{a}
75	5.60^{a}	30.59^{a}	51.66^{a}	71.86^{a}	114.52^{a}	135.12^{a}
SEM±	0.05	0.12	0.14	0.13	0.16	0.18
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	5.39^{b}	30.33^{b}	51.38	71.46	114.35	134.87
5	5.50^{a}	30.45^{ab}	51.50	71.56	114.43	134.85
10	5.55^{a}	30.59^{a}	51.56	71.60	114.53	134.85
SEM±	0.04	0.11	0.13	0.19	0.17	0.19
Significance	*	*	ns	ns	ns	ns
Irrigation intervals (days)						
w_2	5.60^{a}	30.69^{a}	51.73^{a}	71.83^{a}	115.01^{a}	135.23^{a}
w_4	5.52^{b}	30.53^{a}	51.52^{a}	71.53^{ab}	114.38^{b}	134.84^{b}
w_6	5.33^{c}	30.15^{b}	51.18^{b}	71.25^{b}	113.93^{c}	134.51^{b}
SEM±	0.04	0.10	0.12	0.18	0.13	0.17
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means*

At lowland locations in 2008/2009, there were significant differences in the number of leaves on plots that received 5 and 10 tha^{-1} manure at 2 WAP (2.94) and (3.42). The least number of leaves were recorded with the control (2.31) treatment. At 4 -12 WAP there were no significant differences in the number of leaves recorded on plants treated with 5 or 10 t ha^{-1} manure and least number of leaves were recorded with the control treatments. Irrigation intervals at 2 to 12 WAP significantly (P = ≤ 0.05) affected number of leaves per plant for both locations and growing seasons (Tables 7 - 10).

At the lowland location in 2008/2009 and 2009/2010 growing season and at all stages, 2 days irrigation interval recorded higher number of leaves, followed by w_4 and w_6 (Tables 7 and 8). In the 2008/2009 growing season, number of leaves did not differ significantly with irrigation frequency in the upland location (Table 9) and a similar trend was observed in 2009/2010 growing season at all stages (Table 10). Similarly, there were no significant interaction between nitrogen and manure, nitrogen and irrigation, manure and irrigation and nitrogen, manure and irrigation on the number of leaves per plant in both seasons and locations. When the number of leaves per plant in plots treated with different nitrogen levels, were compared at various stages of growth and growing seasons, the result revealed that switchgrass responds positively to increased nitrogen supply. This is a clear indication that high levels of nitrogen fertilizer stimulate the growth of new leaves both in terms of number, size and weight of leaves. The positive effect of manure on the number of leaves per plant could be due to the contribution of manure in improving the fertility status of the soil.

Table 7. Effect of nitrogen, farmyard manure and irrigation on the number of leaves per plant of Switchgrass at lowland location in 2008/2009

Treatment	Number of leaves					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	2.22^{c}	2.78^{c}	4.11^{c}	5.19^{c}	6.41^{c}	6.15^{d}
25	2.63^{b}	4.19^{b}	5.22^{b}	5.78^{b}	7.52^{b}	8.07^{c}
50	3.22^{a}	4.56^{a}	5.56^{b}	6.22^{a}	7.78^{b}	8.52^{b}
75	3.48^{a}	4.78^{a}	6.11^{a}	6.59^{a}	8.22^{a}	8.89^{a}
SEM±	0.19	0.17	0.19	0.19	0.20	0.18
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	2.31^{c}	3.56^{b}	4.69^{b}	5.42^{b}	6.89^{b}	7.36^{b}
5	2.94^{b}	4.19^{a}	5.36^{a}	6.08^{a}	7.61^{a}	8.06^{a}
10	3.42^{a}	4.47^{a}	5.69^{a}	6.33^{a}	7.94^{a}	8.31^{a}
SEM±	0.17	0.22	0.22	0.19	0.21	0.28
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
w_2	3.17^{a}	4.33^{a}	5.56^{a}	6.33^{a}	7.86^{a}	8.22^{a}
w_4	2.94^{a}	4.14^{a}	5.31^{a}	5.97^{b}	7.56^{b}	8.00^{a}
w_6	2.56^{b}	3.75^{b}	4.89^{b}	5.53^{b}	7.03^{b}	7.50^{b}
SEM±	0.19	0.23	0.23	0.19	0.22	0.29
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P = 0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means.*

Table 8. Effect of nitrogen, manure and irrigation regime on the number of leaves per plant of Switchgrass at lowland location in 2009/2010

Treatment	Number of leaves					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	2.78^{c}	3.48^{c}	4.78^{b}	5.96^{c}	6.96^{c}	7.48^{c}
25	3.56^{b}	4.96^{b}	5.85^{a}	6.56^{b}	8.07^{b}	8.85^{b}
50	3.89^{ab}	5.11^{ab}	6.00^{a}	6.85^{ab}	8.30^{ab}	9.15^{ab}
75	4.11^{a}	5.41^{a}	6.22^{a}	7.19^{a}	8.67^{a}	9.44^{a}
SEM±	0.20	0.20	0.20	0.20	0.21	0.19
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	3.00^{c}	4.14^{c}	5.19^{c}	6.03^{c}	7.36^{c}	8.22^{b}
5	3.58^{b}	4.75^{b}	5.67^{b}	6.67^{b}	8.03^{b}	8.81^{b}
10	4.17^{a}	5.33^{a}	6.28^{a}	7.22^{a}	8.61^{a}	9.17^{a}
SEM±	0.17	0.22	0.19	0.17	0.20	0.22
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
W_2	3.89^{a}	5.08^{a}	6.03^{a}	6.97^{a}	8.33^{a}	9.03^{a}
W_4	3.72^{a}	4.86^{a}	5.83^{a}	6.75^{a}	8.14^{a}	8.83^{a}
W_6	3.14^{b}	4.28^{b}	5.28^{b}	6.19^{b}	7.53^{b}	8.33^{b}
SEM±	0.19	0.24	0.20	0.19	0.22	0.23
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means.*

Manure increases the supply of both macro and micronutrients as well as enhances the physico-chemical properties of the soil. This led to high vegetative growth and hence higher number of leaves compared to the number of leaves recorded on plants on the control plot.

Table 9. Effect of nitrogen, manure and irrigation regime on the number of leaves per plant of Switchgrass at upland location in 2008/2009

Treatment	Number of leaves					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	1.63^{c}	2.22^{c}	3.44^{c}	4.52^{c}	5.67^{c}	5.52^{c}
25	2.19^{b}	3.52^{b}	4.48^{b}	5.15^{b}	6.93^{b}	7.48^{b}
50	2.56^{ab}	3.93^{a}	5.56^{a}	5.93^{a}	7.15^{ab}	7.89^{a}
75	2.89^{a}	4.22^{a}	5.59^{a}	6.15^{a}	7.44^{a}	8.19^{a}
SEM±	0.19	0.18	0.17	0.19	0.21	0.19
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	1.72^{c}	2.92^{b}	4.28^{b}	4.86^{b}	6.22^{b}	6.69^{b}
5	2.33^{b}	3.56^{a}	4.86^{a}	5.53^{a}	6.89^{a}	7.39^{a}
10	2.89^{a}	3.94^{a}	5.17^{a}	5.92^{a}	7.28^{a}	7.72^{a}
SEM±	0.16	0.22	0.24	0.20	0.22	0.28
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
w_2	2.64^{a}	3.81^{a}	5.06^{a}	5.83^{a}	7.19^{a}	7.64^{a}
w_4	2.31^{ab}	3.47^{ab}	4.83^{ab}	5.47^{a}	6.89^{a}	7.33^{ab}
w_6	2.00^{b}	3.14^{b}	4.42^{b}	5.00^{b}	6.31^{b}	6.83^{b}
SEM±	0.19	0.23	0.25	0.21	0.22	0.29
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means.*

The highest number of leaves per plant recorded on plots with W2 irrigation intervals could be attributed to the fact that frequent irrigation could provide the crop with adequate moisture in the surface layer, resulting in better crop nourishment and consequently higher number of leaves and prolonging irrigation intervals decrease plant yield per hectare.

3.4 Stem Diameter

Nitrogen application significantly (*P*=≤0.05) influenced stem diameter of switchgrass. At lowland location in both 2008/2009 and 2009/2010 growing seasons, the widest stem diameter was obtained in plots treated with 50 and 75 kg Nha^{-1} and the control experiment had the lowest stem diameter. At upland location, in both seasons at 2,4,10 and 12 WAP, there were significant (*P*=≤0.05) differences in stem diameter among plants treated with 50 and 75 kg N ha^{-1} but there was no significant difference in stem diameter among plants treated with 25 kg N ha^{-1} and control experiment. Tables 11 to 14 showed that manure application significantly (*P*=≤ 0.05) influenced stem diameter.

Table 10. Effect of nitrogen, manure and irrigation regime on the number of leaves per plant of Switchgrass at upland location in 2009/2010

Treatment	Number of leaves					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	2.26^c	2.85^c	4.00^c	5.11^c	6.19^c	6.07^c
25	2.74^b	4.07^b	5.15^b	5.78^b	7.52^b	8.07^b
50	3.22^a	4.63^a	6.22^a	6.59^a	7.78^{ab}	8.56^a
75	3.52^a	4.85^a	6.30^a	6.78^a	8.11^a	8.85^a
SEM±	0.21	0.20	0.20	0.22	0.22	0.20
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	2.33^c	3.53^b	4.89^b	5.44^b	6.78^b	7.36^b
5	2.97^b	4.19^a	5.53^a	6.19^a	7.50^a	8.06^a
10	3.50^a	4.58^a	5.83^a	6.56^a	7.92^a	8.25^a
SEM±	0.18	0.23	0.27	0.23	0.24	0.30
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
W_2	3.31^a	4.44^a	5.75^a	6.50^a	7.83^a	8.28^a
W_4	2.94^{ab}	4.11^{ab}	5.47^{ab}	6.11^a	7.50^a	7.94^{ab}
W_6	2.56^b	3.75^b	5.03^b	5.58^b	6.86^b	7.44^b
SEM±	0.20	0.25	0.27	0.23	0.24	0.30
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P = 0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means.*

Table 11. Effect of nitrogen, manure and irrigation on the stem diameter of Switchgrass at Lowland location in 2008/2009

Treatment	Stem diameter (cm)					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	0.56^b	0.83^d	1.15^d	1.44^c	1.72^b	1.91^c
25	0.59^b	0.91^c	1.20^c	1.49^b	1.76^b	2.00^b
50	0.68^a	0.98^a	1.30^a	1.56^a	1.83^a	2.06^a
75	0.72^a	1.01^a	1.34^a	1.60^a	1.87^a	2.09^a
SEM±	0.02	0.02	0.02	0.02	0.02	0.02
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	0.56^c	0.86^c	1.17^c	1.45^c	1.72^c	1.95^c
5	0.65^b	0.94^b	1.24^b	1.53^b	1.81^b	2.02^b
10	0.70^a	0.99^a	1.33^a	1.58^a	1.86^a	2.08^a
SEM±	0.02	0.02	0.02	0.02	0.02	0.02
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
W_2	0.68^a	0.97^a	1.28^a	1.56^a	1.84^a	2.06^a
W_4	0.64^a	0.93^a	1.25^{ab}	1.53^{ab}	1.80^{ab}	2.02^a
W_6	0.59^b	0.88^b	1.21^b	1.49^b	1.76^b	1.95^b
SEM±	0.02	0.02	0.03	0.02	0.02	0.02
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means.*

Table 12. Effect of nitrogen, manure and irrigation on the stem diameter of Switchgrass at Lowland location in 2009/2010

Treatment	Stem diameter (cm)					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	0.62^{b}	0.89^{c}	1.21	1.51^{c}	1.78^{d}	1.99^{c}
25	0.66^{b}	0.98^{b}	1.26	1.55^{c}	1.83^{c}	2.07^{b}
50	0.74^{a}	1.02^{a}	1.36	1.91^{a}	2.10^{a}	2.14^{a}
75	0.78^{a}	1.05^{a}	1.40	1.94^{a}	2.12^{a}	2.14^{a}
SEM±	0.02	0.02	0.02	0.02	0.02	0.02
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	0.62^{c}	0.92^{c}	1.23^{c}	1.58^{c}	1.84^{c}	2.01^{c}
5	0.71^{b}	0.99^{b}	1.31^{b}	1.67^{b}	1.93^{b}	2.08^{b}
10	0.76^{a}	1.04^{a}	1.38^{a}	1.72^{a}	1.98^{a}	2.16^{a}
SEM±	0.02	0.02	0.02	0.04	0.03	0.02
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
W_2	0.74^{a}	1.02^{a}	1.35^{a}	1.70^{a}	1.96^{a}	2.16^{a}
W_4	0.71^{a}	0.99^{a}	1.31^{ab}	1.66^{ab}	1.93^{ab}	2.12^{a}
W_6	0.65^{b}	0.94^{b}	1.27^{b}	1.61^{b}	1.87^{b}	2.05^{b}
SEM±	0.02	0.02	0.03	0.04	0.04	0.03
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means*

At lowland location in both seasons widest stem diameter were obtained in plots treated with 10 and 5 t ha^{-1} of manure are significantly different (*P*= ≤0.05). The smallest stem diameter was recorded in the control plots. Similarly, at upland locations and in both seasons widest stem diameter were obtained in plots treated with 10 tha^{-1} manure though not significantly different from plots treated with 5 tha^{-1} manure. The smallest stem diameter was obtained in the control plots (Tables 13 and 14). At lowland location in both growing seasons irrigation interval had a significant (*P*= ≤0.05) effect on stem diameter during the period under observation. At upland location in both seasons the results indicated that at various weeks after planting there were significant differences in stem diameter except for plants irrigated at W_2 and W_4. However, for 4, 6,8,10 and 12 WAP, there were significant differences in stem diameter across the varying irrigation intervals (Tables 13 - 14).

Table 13. Effect of nitrogen, manure and irrigation on tem diameter of Switchgrass at upland location in 2008/2009

Treatment	Stem diameter (cm)					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	0.48^b	0.77^b	1.05^d	1.34^c	1.61^b	1.84^b
25	0.51^b	0.76^b	1.10^c	1.41^b	1.62^b	1.85^b
50	0.60^a	0.85^a	1.20^b	1.46^a	1.76^a	1.94^a
75	0.64^a	0.89^a	1.26^a	1.50^a	1.80^a	1.97^a
SEM±	0.03	0.02	0.02	0.03	0.03	0.03
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	0.48^b	0.76^b	1.10^b	1.37^b	1.64^b	1.84^b
5	0.57^a	0.83^a	1.16^a	1.44^a	1.71^a	1.91^a
10	0.61^a	0.86^a	1.20^a	1.48^a	1.75^a	1.95^a
SEM±	0.02	0.02	0.03	0.02	0.03	0.02
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
W_2	0.60^a	0.88^a	1.21^a	1.49^a	1.76^a	1.97^a
W_4	0.56^a	0.82^b	1.16^b	1.43^b	1.70^b	1.90^b
W_6	0.50^b	0.75^c	1.09^c	1.36^c	1.64^c	1.83^c
SEM±	0.03	0.02	0.02	0.02	0.03	0.02
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means*

Table 14. Effect of nitrogen, manure and irrigation regime on the stem diameter of Switchgrass at upland location in 2009/2010

Treatment	Stem diameter (cm)					
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Nitrogen (kg ha^{-1})						
0	0.54^b	0.82^b	1.11^d	1.41^c	1.69^b	1.92^b
25	0.57^b	0.83^b	1.17^c	1.48^b	1.90^c	1.94^b
50	0.66^a	0.92^a	1.27^a	1.54^a	1.84^a	2.00^a
75	0.70^a	0.95^a	1.30^a	1.57^a	1.88^a	2.04^a
SEM±	0.02	0.03	0.02	0.03	0.03	0.03
Significance	*	*	*	*	*	*
Manure (t ha^{-1})						
0	0.55^c	0.82^b	1.16^b	1.43^b	1.76^b	1.92^b
5	0.64^a	0.89^a	1.22^a	1.51^a	1.83^a	1.98^a
10	0.68^a	0.93^a	1.27^a	1.55^a	1.87^a	2.02^a
SEM±	0.02	0.02	0.03	0.02	0.03	0.03
Significance	*	*	*	*	*	*
Irrigation intervals (days)						
W_2	0.66^a	0.94^a	1.27^a	1.56^a	1.88^a	2.04^a
W_4	0.62^a	0.89^b	1.22^b	1.50^b	1.83^{ab}	1.98^b
W_6	0.57^b	0.81^c	1.15^c	1.43^c	1.75^b	1.90^c
SEM±	0.02	0.02	0.03	0.02	0.03	0.02
Significance	*	*	*	*	*	*

*Means in a column with different superscripts are significantly different (P=0.05), * = significant at 5% levels, ns = not significant. WAP = weeks after planting. SEM± = standard error of means.*

The smallest stem diameter produced by the control indicates that nitrogen has a profound effect in increasing the stem diameter of switchgrass probably due to its effect on enhancing plant vegetative growth. Nitrogen was reported to influence stem diameter of switchgrass [5]. The enhanced stem diameter observed due to the application of manure might be due to the improvement of soil nutritional content and structure which improve plant growth and development [21]. The observed differences in stem diameter due to irrigation could be related to water use efficiency of the crop. The development of deep rooted system promotes vegetative growth of the plants which resulted in enhanced the stem diameter [22].

4. CONCLUSION

From the results obtained in this study, combination of 50 N kg/ha^{-1}, 5 t ha^{-1} manure and W_2 irrigation intervals proved to be optimum for plant establishment, plant height, number of leaves per plant and stem diameter for the growth of switchgrass in Sokoto, geoecological condition of Nigeria. Therefore, these conditions could be useful for increased switchgrass production in the study area. Increasing the nitrogen, manure rates and irrigation intervals above the levels used led only to a marginal increase in the parameters evaluated. Based on the findings of this study, switchgrass could be cultivated under irrigation both in lowland and upland conditions in Sokoto with manure and nitrogen fertilizer supplementation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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