Selection of Drought-Tolerant Pasture Species under Varying Soil and Moisture Conditions in Bauchi State, Nigeria

Amarachi G. Nwokocha [1], Sani Idris [2], Yunusa M. Ishiaku [3]

[1]Department of Agriculture and Industrial Technology, Faculty of Science and Technology, Babcock University, Ilishan Remo, Nigeria.
[2]Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University Zaria, Nigeria.
[3]National Animal Production Research Institute, Ahmadu Bello University Shika Zaria, Nigeria.
*Corresponding Author: sanidris2000@gmail.com

Article history:

Received: 31 January 2023
Accepted: 16 March 2023
Published: 30 June 2023

Keywords: *Pasture species, Soil texture, Water application regime, Drought, Livestock*

Abstract

Livestock production is an agricultural system that serves as humanity's protein and calorie source. Its production is the main economic stay for some people and a complementary source for others. However, land misappropriation and draught constrain the sustainable production of pasture for feeding livestock. Further aggravated by farmer/herder clashes and wetlands extinction. The need for an experiment for the selection of the best pasture species in the Sudan Savannah region that can thrive well under diverse soil textures and moisture status becomes imperative. This trial was conducted in the screen house of Babcock University, objectively to test the performances of *Sorghum almum*, *Andropogon gayanus*, *Brachiaria mulato* and *Centrosema pascuorum* under Sand, Sandy Clay Loam, and Sandy Loam textures and four water regimes: 100%, 75%, 50%, and 25%. Standard agronomic recommendations were practised throughout the experiment. Data collected included plant height, fresh and dry shoot and root weights, number of leaves, and leaf length. Data generated were analyzed using ANOVA. According to the results, Sandy Loam soil (Soil type from Gamawa) was the best for supporting all the pasture species, followed by Sandy Clay Loam (Soil type from Zaki). *S. almum* outperformed other pasture species significantly irrespective of soil textural type and water stress level treatments, followed by *B. mulato*. For water levels; 100% and 75% had the most promising biomass outcome. Based on the results, a 75% water regime which represents 25% deficit of the actual crop water requirement is recommended for the production of the tested pastures in the area.

https://dx.doi.org/10.52951/dasj.23150109

Introduction

Rearing and grazing livestock on grasslands has been a global practice in the history of animal production (FAO, 2009). In Nigeria, the practice of pastoral, semi-nomadic, and controlled livestock management systems are well pronounced (Awoyomi *et al.*, 2022). A year-round supply of herbages of high dry matter and optimal calories has been a major constraint for pasture management (Gill and Tuteja, 2010). Short rainy season and frequent dry spells pose major constraints for pasture production in the Northern part of Nigeria (Idris *et al.*, 2019b). This is a result of low annual precipitation and poor soil properties which dictate the vegetation characteristics of the area (Idris *et al.*, 2019a). Low precipitation facilitates drought and subsequently desertification (Nkechi *et al.*, 2016). Loss of wetlands and floral diversity has been due to low precipitation and rising temperature (Abdulkadir *et al.*, 2017). Applying water through rain or irrigation below the actual crop water requirement could result in water stress (Ibrahim *et al.*, 2020), and this could negatively affect plant growth and development as well as the economic yield, depending on the crop tolerance to water stress and the development stage at which the stress occurs (Culman *et al.,* 2019). Soil water deficit poses threat to crop biomass and pasture species production critically required for the optimum management of livestock, particularly in the Sudan savannah zone of Nigeria (Idris *et al*., 2019b). Numerous negative effects may be manifested through tempered physiological and physical processes which in turn affect crop phenology and quality and quantity of biomass and yield (Zwicke *et al*., 2015). Gill and Tuteja, (2010) reported that water stress conditions resulted in death and plasmolysis of meristematic cells and lipid peroxidation. Wallace *et al*., (2016) complimented that water stress inhibits the reaction of oxygen, thereby hampering photosynthetic functions to cause poor pasture performances. Various physiological mechanisms that enhance crop tolerance to soil water stress had been reported (Khaleghi *et al*., 2019). Per *et al.*, (2017) discovered that, when certain soluble osmolytes within plant tissues accumulate, they enable plant cell membranes to become rigid and resistant to water stress. Studies had shown that positive adjustment of enzyme functionalities within the plant tissues can facilitate their level of water stress tolerance (Nikoleta-Kleio *et al*., 2020). Various methods and tools, including telemetric systems, evaporation pan and Theta Probe are being employed for the determination of crop water requirement and tolerance through precise investigation of soil water content at various depths (De Lara *et al*., 2018). However, most water stress studies considered only environmental and soil moisture characteristics while paying less emphasis on the physiological processes and genetic traits of plants (Sarker *et al*., 2019). Many works on water requirement and deficit irrigation have been conducted on staple crops, however, very few researches captured pasture to identify and select plant species that are tolerant to water deficit conditions for a sustained livestock feed supply. The objective of this research is to identify and select pasture species that are resilient to water stress in the desert encroached area of Bauchi State, Nigeria under Sand, Sandy Clay Loam, and Sandy Loam textures.

Materials and Methods

Study area, Soil Sampling and Seed Sourcing

Babcock University is located in Ikenna local government, Ogun State. The area has distinct dry and wet seasons, with an average temperature of *27.1°C; relative humidity of 74.4%; and rainfall amount of 185.4 mm per annum.* Twenty-one soil samples were randomly collected each from; Azare (lat. 11°40’42’’ N, long. 10°11’31’’ E); Zaki (lat. 12°17’57’’ N, long. 10°18’32’’ E), and Gamawa (lat. 12°8’14’’ N, long. 10°32’19’’ E) areas of Bauchi State. The samples were collected during the dry season at a depth of 0 – 20 cm, bulked to form composite samples for each location. Equal weight (5.0 kg) of the soils were accordingly transferred into 4-litre capacity experiment pots bearing a dimension of 5.5 cm height and 18.6 cm diameter equivalent to total area of 0.0865m^2. The pasture seeds were sourced from the National Animal Production Research Institute, Ahmadu Bello University, Shika, Zaria.

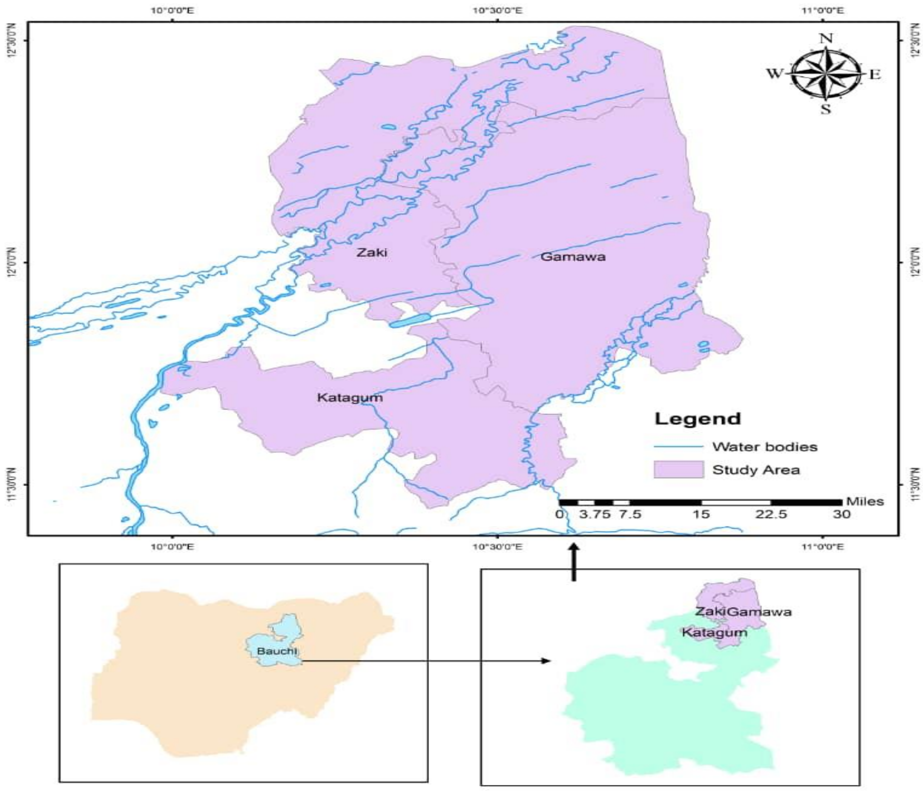

Figure 1. Locations of soil sample collection

Soil physicochemical analyses

Physicochemical properties of the soil determined include; soil particle size, organic carbon, soil pH, available phosphorus, exchangeable bases, exchangeable acidity and total nitrogen according to Okalebo *et al*. (2012).

Table 1. **Characteristics of Soil from the farm field of the Local government areas of Bauchi State namely; Azare Zaki and Gamawa**

Soil Properties	Soil type Gamawa	Soil type Zaki	Soil type Azare
pH (1:2.5 Soil: water)	5.5	6.7	5.9
Total nitrogen (g kg^{-1})	0.8	0.9	0.4
Organic carbon (g kg^{-1})	24.1	69.0	53.1
Available P (mg kg^{-1})	48.4	83.5	81.3
Moisture content (%)	13.4	14.6	15.6
Exchangeable cations Cmol kg^{-1}			
Calcium	15.5	17.5	21.2
Magnesium	1.9	2.7	2.2
Potassium	4.3	6.6	3.3
Sodium	0.9	0.9	8.5
Effective cation exchange capacity	1.8	2.8	2.7
Extractible micronutrients (mg kg^{-1})			
Iron	204.0	243.6	329.8
Manganese	143.5	309.7	287.4
Copper	4.0	3.5	5.1
Zinc	28.6	43.9	32.5
Particle size distribution (g)			
Sand	630	480	920
Silt	200	189	30
Clay	170	331	50
Texture	Sandy Loam	Sandy Clay Loam	Sand

Agronomic Management and Experimental Design

The experiment was arranged in a Completely Randomized Design (CRD) with four pasture species, three soil textures and four water stress levels as the superimposed treatments. Each treatment combination was replicated three times. The pasture seeds were sown by broadcasting using standard rates. The rates were 80; 10, 35, and 30 kg/ha downscaled as 0.692 g/pot, 0.0865 g/pot, 0.303 g/pot, and 0.258 g/pot for *A. gayanus*, *S. almum*, *B. mulato* and *C. pascuorum* respectively. After germination, all the pots were watered adequately for one week before subjecting them to four varied water stress levels. The water stress levels; were 100%, 75%, 50% and 25% actual crop evapotranspiration (ETa) which is given in equation 1. Available soil moisture status was determined in-situ using ThetaProbe – HH2 moisture meter, Delta – T Device model for computing irrigation supply schedule:

ETa = ETref × Kc ------- equation 1

Where:

ETa = actual crop evapotranspiration
ETref. = reference crop evapotranspiration
Kc = crop coefficient value

Compound fertilizer (NPK 15:15:15) was basally applied at a standard rate of 150 kg/ha (1.29g/pot equivalent) to each of the experimental pots except for *C. pascuorum* which is a legume and was fertilized with 100 kg/ha downscaled as 0.86g/pot equivalence. Data collection was achieved for plant height, leaf length and the number of leaves at the end of each week from week 1 to week 5 using the meter rule and manual counting respectively. Fresh shoot and root weights were recorded using an electronic weighing scale during the fourth and fifth week after planting. Dry shoot and root weights were calculated after oven drying at a temperature of 65° to a constant weight.

Statistical analyses

Data collected were subjected to Analysis of Variance using Statistical Analysis Systems (SAS). Means with statistical differences were separated using Duncan Multiple Range Test at $P \leq 0.05$ significance level.

Results and discussion

Table 2 shows the effect of soil texture, pasture species and water stress level on plant height (PLH). Mean values of PLH across the five weeks for soil textural type factor ranged from 32.02 to 61.46 cm. The lowest was recorded in the first week and the highest in the fifth week. The PLH for pasture species ranged from 23.25 to 70.03 cm. Concerning the water stress level, it ranged from 31.53 to 71.23 cm for all the weeks. The first order interaction i.e., soil texture (ST) × pasture species (PS) and ST × water stress (WS), PLH was significant in the second, third, and fifth week. For soil type, there was no significant difference in PLH in the first and fourth week. However, in the second week, the PLH under Sandy Clay Loam was significantly higher compared to that under Sand and Sandy loam soil types. Sandy Clay Loam and Sandy loam soil types were not significantly different from each other. Nevertheless, PLH in Sandy loam showed a highly significant difference compared to Sand and Sandy Clay Loam soil textures which were also not significantly different from each other in the fifth week. For the effect of pasture species on PLH, *Sorghum almum* (*S. almum*) recorded significantly higher values across the weeks than other species. Contrarily, *Centrosema pascuorum* (C. *pascuorum)* performed significantly lower for PLH parameter across the weeks. For the water stress factor, 100% (WS4) which was the control caused significantly higher PLH across all the weeks compared to the other levels. Also, the water stress level at 25% (WS3) led to a significant increase in PLH compared to other deficit levels for all the weeks. This study revealed that PLH was higher under SCL compared to other soil textures which could be due to the high level of nitrogen observed in the SCL, which is in affirmation with Malik *et al*. (2014), who reported nitrogen's positive effect on rice PLH. It was also observed that *S. almum and Brachiaria mulato* (*B. mulato*) maintained a higher PLH across the weeks despite water stress levels. This corroborated the finding of Schneider *et al.,* (2018) who observed an increase in the activity of pasture plants under water stress, due to their ability to maintain normal metabolic processes.

Table 2. Effect of soil texture, Pasture species and water stress levels on plant height (cm)

Soil Texture (ST)		**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Azare (S)		33.02	41.13b	43.79b	54.04a	54.52b
Gamawa (SL)		32.48	39.10c	45.38a	53.96a	61.46a
Zaki (SCL)		32.65	43.52a	45.85a	52.19b	55.21b
SE		0.855	0.511	0.333	0.276	1.33
P. Species (PS)						
A. gayanus		30.53c	38.33c	44.22c	52.94c	55.08c
B. mulato		33.64b	42.39b	45.58b	56.25b	63.25b
C pascuorum		23.25d	29.58d	32.81d	38.78d	39.89d
S. almum		43.44a	54.69a	57.42a	66.42a	70.03a
SE		1.410	1.988	0.999	1.111	2.588
Water Stress (WS)						
WS1		30.53c	34.78d	31.36d	37.39d	39.19d
WS2		31.53bc	39.44c	41.67c	50.47c	53.06c
WS3		32.94b	42.86b	50.86b	59.42b	64.72b
WS4		35.86a	47.92a	56.14a	67 .11a	71.28a
SE		1.000	1.743	1.555	1.555	1.222
Interactions						
ST × PS		ns	*	*	ns	*
ST × WS		ns	*	*	ns	*
PS × WS		*	*	*	*	*
ST × PS × WS		*	*	*	ns	*

WS1 = 75% water stress, WS2 = 50% water stress, WS3 = 25% water stress, WS4 = No water stress, SE = standard error. * = significance at 5% LOS. Different letters indicate significant differences among treatment means with the same column at $P < 0.05$ probability level, ns = no significant difference at $P < 0.05$ probability level.

Table 3 shows the effect of soil textural type, pasture species and water stress level on the number of leaves (NL). For ST treatment, the NL increased from the first week (max 4.77) to the second week (max. 5.48) and shoot up in the third week (max. 6.21) before it progressively declined in the fourth week (max. 5.65). This means that it followed a sinusoidal pattern from the first week to the fifth week. This trend was not different for PS and WS factors. The highest NL for WS treatment was observed under 0% water stress level (WS4) having obtained 5.20 leaf count in week 1 and 7.53

in week 3. Contrarily 75% (WS1) obtained 3.94 in week 1 and 4.75 in week 3. All interactions showed a significant difference except in ST x WS week 1; PS x WS week 2 and 5 and ST x PS x WS week 5. From the results, there wasn't any significant difference observed in NL from week 1 to 4 based on ST variation. However, NL was observed to be significantly lower in SCL compared to SL in week 5. The number of leaves was significantly higher in *C. pascuorum* across the weeks studied compared to other pastures. The water stress level at 0% influenced higher NL across all the weeks compared to other stress levels. It was deduced that a 25% deficit also significantly influenced NL compared to other water stress levels. A significant reduction in the NL at 25% water stress observed may not be unconnected with the water stress adoption mechanism by the pastures. Lambers *et al.* (2008) stated that plants respond to water deficit through various mechanisms including shading of leaves, early maturing, and development of fewer leaves. The outcome is in harmony with Pandit *et al.* (2016), who reported low NL due to water deficiency.

Table 3. Effect of soil texture, pasture species and water stress levels on the number of leaves (No./plant) at various weeks after planting (WAP)

Soil texture (ST)	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
Azare (S)	4.77	5.44	6.21	5.65	4.85ab
Gamawa (SL)	4.58	5.48	6.17	5.56	5.10a
Zaki (SCL)	4.67	5.33	5.98	5.42	4.71b
SE	1.44	0.999	1.000	1.166	1.388
Pasture Species (PS)					
A. gayanus	4.14c	4.97c	5.89c	5.56b	4.53b
B. mulato	3.44d	3.97d	5.39d	5.31b	4.39b
C. pascuorum	6.28a	7.36a	7.08a	6.03a	6.33a
S. almum	4.83b	5.36b	6.25b	5.28b	4.31b
SE	0.888	1.222	0.795	0.758	1.000
Water Stress (WS)					
WS1	3.94b	4.87b	4.75d	4.11c	3.81c
WS2	4.44b	5.19b	5.81c	5.25bc	4.28c
WS3	4.81ab	5.84ab	6.53b	5.83ab	5.28b
WS4	5.20a	6.17a	7.53a	6.97a	6.91a
SE	0.555	0.644	0.224	0.477	0.666
Interaction					
ST × PS	*	*	*	*	*
ST × WS	ns	*	*	*	*
PS × WS	*	ns	*	*	ns
ST × PS×WS	*	*	*	*	ns

WS1 = 75% water stress, WS2 = 50% water stress, WS3 = 25% water stress, WS4 = No water stress, * = significance at 5% LOS, SE = Standard error. [3]Different letters indicate significant differences among treatment means with the same column at P < 0.05 probability level, ns = no significant difference at P < 0.05 probability level.

Table 4 shows the effect of soil textural type, pasture species and different water stress levels on leaf length (LL), fresh shoot weight (FSW) and fresh root weight (FRW**).** The LL depicted an abrupt trend from week 4 to week 5 across the various treatments.

For soil textures, LL in week 5, (34.92 – 35.63 cm) was numerically but inconsistently higher than in week 4 (32.11 – 36.13 cm). For PS factor however, the difference was obvious as *B. mulato* had 40.97 and 48.28 cm LL in fourth and fifth week respectively. In a sharp contrast *C. pascuorum* had 9.92 and 8.67 in week 4 and 5 respectively. In the same table, it can clearly be observed that the fresh shoot weight (FSW) and fresh root weight (FRW) in week 4 were higher than the dry shoot and dry root weights. This is expected due to water content contribution to their gross fresh weights. In week 4, the FSW and FRW ranged from 0.60 to 2.03 g/plant. In weeks 4, LL had values not significantly different from each other in Sand and SL soil types except for SCL. Higher values of FSW were observed in SL and SCL and are significantly higher than that of Sand textural class in week 4. Also, SCL influenced high FRW in week 4 compared to other soil types. In terms of dry biomass, SCL and SL influenced higher dry shoot weight compared to Sand in week 4 (Table 5). Dry shoot weights (DSW) and dry root weight (DRW) were consistently higher under SCL soil. This may be due to the high level of total nitrogen (N), available phosphorus (Av. P) and exchangeable Potassium (K) of this location which could have positively impacted on the DSW and DRW. This is in agreement with previous results, which reported that N, Av. P, and K significantly influence shoot and root development (Lasheen *et al*., 2021, Tshewang *et al.,* 2020 and Song *et al*., 2010).

The *pasture Sorghum almum (SA)* showed significantly higher LL at week 4 compared to other pasture species. However, at week 5 higher mean values were observed in *S. almum* and *B. mulato*. Fresh shoot weight was statistically higher in *S. almum* compared to other pasture species at weeks 4. At week 5, *B. mulato* showed significantly higher FSW compared to other pastures, however, *S. almum* still maintained a higher value with respect to FSW. The parameter of FRW in week 4 was observed to be significantly higher in *S. almum* compared to the others. The *S. almum* also had a higher value of FRW compared to other pasture species in week 5. Water stress level at 25% significantly influenced LL, FSW and FRW compared to other water stress levels except for the control (WS4).

Table 4. Effect of soil texture, pasture species and water stress level on leaf of length, fresh shoot weight, and fresh root weight at various weeks after planting (WAP)

	Leaf length/plant (cm)		**Fresh shoot weight (g/plant)**		**Fresh root weight (g/plant)**	
Soil texture (ST)	**WK4**	**WK5**	**WK4**	**WK5**	**WK4**	**WK5**
Azare (S)	36.13a	35.63b	1.06b	0.85b	0.77a	0.44a
Gamawa (SL)	34.96a	39.94a	1.55a	1.02a	0.86a	0.49a
Zaki (SCL)	32.11b	34.92b	1.43a	0.78b	1.03a	0.44a
SE	0.866	1.122	0.099	0.0781	0.551	0.111
Pasture Species (PS)						
A. gayanus	39.36b	40.81b	1.17b	0.51c	0.79b	0.31c
B. mulato	40.97b	48.28a	1.32b	1.71a	0.71b	0.51b
C. pascuorum	9.92c	8.67c	0.86c	0.88bc	0.60b	0.45ab
S. almum	47.42a	49.56a	2.03a	0.96b	1.45a	0.56a
SE	1.888	1.678	0.0144	0.008	0.008	0.007
Water Stress (WS)						

WS1	24.11d	25.69d	0.45d	0.32d	0.33c	0.19c
WS2	31.92c	35.03c	0.95c	0.61c	0.64bc	0.32bc
WS3	38.08b	41.36b	1.71b	1.16b	1.12ab	0.57ab
WS4	43.56a	45.22a	2.26a	1.45a	1.45a	0.75a
SE	2.000	1.883	0.0044	0.00055	0.0045	0.0023
Interaction						
ST × PS	*	*	*	*	ns	*
ST × WS	*	ns	Ns	ns	*	ns
PS × WS	*	*	*	*	*	ns
ST × PS × WS	ns	ns	*	*	ns	*

WS1 = 75% water stress, WS2 = 50% water stress, WS3 = 25% water stress, WS4 = No water stress, * = significance at 5% LOS, ns = no significant difference, SE = Standard error. Different letters indicate significant differences among treatment means within the same column at P < 0.05 probability level.

Table 5. Effect of soil texture, pasture species and different water stress levels on, dry shoot weight and dry root weight at WAP

Soil texture (ST)	Dry shoot weight(g/plt) WK4	Dry root weight(g/plt) WK4
Azare	0.18b	0.12b
Gamawa	0.22a	0.14b
Zaki	0.22a	0.23a
SE	0.00033	0.00033
Pasture Species (PS)		
A. gayanus	0.17b	0.16b
B. mulato	0.21b	0.15b
C. pascuorum	0.11c	0.08c
S. almum	0.32a	0.27a
SE	0.0002	0.0011
Water Stress (WS)		
WS1	0.08d	0.07c
WS2	0.16c	0.11b
WS3	0.26b	0.20a
WS4	0.32a	0.29a
SE	0.00011	0.0044
Interaction		
ST x PS	ns	*
ST x WS	*	*
PS x WS	*	Ns
ST x PS x WS	*	*

WS1 = 75% water stress, WS2 = 50% water stress, WS3 = 25% water stress, WS4 = No water stress, * = significance at 5% LOS, ns = no significant difference SE = Standard error. Different letters indicate significant differences among treatment means within the same column at P < 0.05 probability level. at P < 0.05 probability level.

As shown in Table 6 *A. gayanus* interacting with 0% water stress level gave higher mean values for PLH at week 2 and 3 and significantly higher values in weeks 4 and 5. The same interaction also influenced high value of NL at week 1 and a significantly higher NL in week 3 and 4. The *A. gayanus* interacting with 25% deficit influenced higher values for PLH in week 2, 3 and 4. *Centrosema pascuorum* (*C. pascuorum*) interacting with a 25% deficit gave higher values of PLH than the other excluding the control in week 3. However, PLH observed in *S. almum* pasture showed higher yield compared to others across the weeks and NL was also positively influenced relative to others.

Table 6. Effect of pasture species and water stress level interactions on plant heights and Number of leaves, at various weeks after planting (WAP)

P. Species	Water Stress level	Plant height (cm)				Number of leaves/plant		
		WK2	WK3	WK4	WK5	WK1	WK3	WK4
A. gayanus	WS1	33.33fg	31.78h	35.11i	35.22g	3.44f	4.22i	4.00h
	WS2	36.78ef	41.56e	52.67fg	50.00f	4.11e	5.67fgh	5.22efg
	WS3	40.89de	50.56d	59.44de	64.11e	4.33de	6.33def	6.00cd
	WS4	42.33cd	53.00cd	64.56cd	71.00cd	4.67de	7.33bc	7.00ab
B. mulato	WS1	46.11c	36.44fg	43.89h	45.00f	4.33de	4.33i	3.33i
	WS2	51.89b	52.22cd	58.78de	65.33de	4.67de	5.78fgh	5.11efg
	WS3	54.89b	65.67b	72.67b	78.56b	4.78d	6.89cd	5.67def
	WS4	65.89a	75.33a	90.33a	91.22a	5.56c	8.00ab	7.00ab
C.pascuorum	WS1	37.33ef	33.56g	44.00h	48.78f	2.67g	4.56i	4.11h
	WS2	42.44cd	42.33e	53.89ef	60.89e	3.33f	5.22h	4.89g
	WS3	43.78cd	50.22d	61.11cd	70.56cd	3.56f	5.56gh	5.67def
	WS4	46.00c	56.22c	66.00c	72.78c	4.22de	6.22defg	6.56bc
S. almum	WS1	22.33i	23.67i	26.56j	27.78h	5.33c	5.89efgh	5.00fg
	WS2	26.67h	30.56h	36.56i	36.00g	5.67c	6.56cde	5.78de
	WS3	31.89g	37.00fg	44.44h	45.67f	6.56b	7.33bc	6.00cd
	WS4	37.44ef	40.00ef	47.56gh	50.11f	7.56a	8.56a	7.33a
SE		2.177	2.555	1.997	2.000	2.323	1.765	2.222

WS1 = 75% water stress, WS2 = 50% water stress, WS3 = 25% water stress, WS4 = No water stress, SE = Standard error. Different letters indicate significant differences among treatment means within the same column at $P < 0.05$ probability level.

Table 7 shows the interaction between pasture species and water stress level on the length of leaves (LL), fresh shoot weight (FSW), fresh root weight (FRW), and dry shoot weight (DSW) in week 4 and 5. Except for the control (0% water stress level), a 25% deficit influenced positive yield. However, *B. mulato* versus 25% deficit facilitated significantly higher values of LL index at week 4 and 5, and significantly increased FSW and FRW in week 4 compared to other water stress levels. A similar trend was observed when other pasture species interacted with water stress level at 25%. Nevertheless, *B. mulato* yield was the most positively influenced compared to other pastures. In general, at 25% water stress, all parameters evaluated were not severely affected compared to the severity observed at 75% deficit. This result confirmed previous work which discovered that moderate water deficit stress does not severely affect plants' performance. DaCosta and Huang (2007), and Santos *et al.,* (2009) opined that pasture plants naturally adjust to damages caused by moderate water stress easily, while severe conditions affect them adversely.

Table 7. Effect of pasture species and water stress level interactions on length of leaves, fresh shoot weight, fresh root weight and dry shoot weight at various WAP

P. Species	Water stress level	WK 4	WK5	WK 4	WK 5	WK 4	WK 4
A. gayanus	WS1	26.22h	26.22g	0.38f	0.17f	0.24f	0.06fg
	WS2	40.11ef	39.67e	0.68ef	0.38ef	0.52def	0.13def
	WS3	42.56cde	47.33cd	1.77de	0.75bcd	0.84cde	0.22cd
	WS4	48.56b	50.00bcd	1.85bcd	0.84a	1.57b	0.28c
B. mulato	WS1	31.89g	34.00f	0.51 de	0.26bcdef	0.53def	0.11efg
	WS2	42.11def	46.33d	1.55bcd	0.78bcde	1.09c	0.26c
	WS3	51.11b	55.22b	2.17b	1.04bc	1.88ab	0.39b
	WS4	64.56a	62.67a	3.88a	1.75a	2.28a	0.53a
C pascuorum	WS1	32.22g	37.78ef	0.68f	0.38efg	0.37ef	0.13def
	WS2	36.44fg	47.22cd	1.10ef	0.67cdef	0.55def	0.21cde
	WS3	47.00bcd	52.67bc	1.82 b	1.93bcde	1.04c	0.28c
	WS4	48.22bc	55.44b	1.68bc	1.69bcdef	0.87cd	0.22cd
S. almum	WS1	6.11j	4.78j	0.23bcd	0.45a	0.16f	0.02g
	WS2	9.00ij	6.89ij	0.48bcd	0.61def	0.39ef	0.05fg
	WS3	11.67ij	10.22hi	1.08bcd	0.94def	0.74cde	0.14def
	WS4	12.89i	12.78h	1.64ef	1.52a	1.10c	0.23cd
SE		3.111	2.000	0.001	0.0012	0.00099	0.0031

WS1 = 75% water stress, WS2 = 50% water stress, WS3 = 25% water stress, WS4 = No water stress. Different letters indicate significant differences among treatment means with the same column at P < 0.05 probability level, SE = Standard error

Conclusion

Based on the results and discussion presented, this study inferred that *Sorghum almum* (*S. almum*) was the best-performing pasture species with respect to plant height, dry shoot and dry root weights. The number of leaves was highest in *Centrosema pascuorum*. Zero and 25% water stress levels on dry root weight in the week 4 had similar performance. Sandy loam had outperformed other soil textural types. Therefore, Sandy Loam soil is best for producing the test pasture species. Alternatively, Sandy Clay Loam can be suitably used since it has optimally supported good performance. Inference can be drawn that adding full water requirement, that is 0% to 25% water stress levels gave the best output, thus recommended for massive propagation of pasture species in the study areas.

Conflict of Interest

Regarding the publication of this manuscript, the authors declare that, there is no conflict of interest whatsoever.

Acknowledgements

The authors wish to convey thanks to the Babcock University for providing the needed space to conduct the research. Similar thanks go to the National Animal Production Research Institute for proving the researchers with good quality pasture seeds.

References

Abdulkadir, A., Lawal, A. M., and Muhammad, T.I. (2017). Climate change and its implications on human existence in Nigeria: a review. *Bayero Journal of Pure and Applied Sciences*, *10*(2), 152-158. https://doi.org/10.4314/bajopas.v10i2.26

Awoyomi, O. J., Olasoju, M. I., Kehinde, O. O., Adebowale, O. O., Awoyomi, F. S. O., Agbajelola, V. I., and Ogugua, A. J. (2022). Impact of COVID-19 on livestock production and marketing in Nigeria. *Nigerian Journal of Animal Production*, *49*(3), 215–232. https://doi.org/10.51791/njap.v49i3.3552

Culman, M., De Farias C.M, and Bayona C. (2019). Using agrometeorological data to assist irrigation management in oil palm crops: A decision support method and results from crop model simulation. *Agric Water Management*, *213*, 1047–1062. https://doi.org/10.1016/j.agwat.2018.09.052

DaCosta, M. and Huang. B. (2007). Changes in antioxidant enzyme activities and lipid peroxidation for bentgrass species in responses to drought stress. *Journal of American Society for Horticultural Science*, *132*(3), 319- 326. https://doi.org/10.21273/JASHS.132.3.319

De Lara, A., Khosla, R., and Longchamps, L. (2018). Characterizing spatial variability in soil water content for precision irrigation management. *Agronomy 8*(5), 1–8. https://doi.org/10.3390/agronomy8050059

FAO. (2009). *The State of Food and Agriculture. Livestock in the Balance*. Food and Agriculture Organisation of the United Nations, Rome: http://www.fao.org/docrep/012/i0680e/i0680e00.htm

Gill, S. S., and Tuteja, N. (2010). Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. *Plant Physiological Biochemistry*, *48*(12), 909–930. https://doi.org/10.1016/j.plaphy.2010.08.016

Ibrahim T., Idris S., Yahaya S.M., Adamu M., Abubakar, F., and Abu S.T. (2020). Determination of Water and Nitrogen Use Efficiency and Crop Coefficient of Wheat (Triticum aestivum L.) as Influenced by Irrigation ® Regimes and AQUASORB Rates in Sudan Savanna Nigeria. *Nigerian Journal of Soil and Environmental Research 19*, 1 – 13.

Idris, S., Lawal, H. M., Maiyaki, M. M., Mahmud, A. T. and Adamu, M. (2019a). Influence of various land use systems on selected soil productivity parameters of wetland soils. *Fudma Journal of Sciences 3* (2), 295 – 301.

Idris, S. Lawal, H.M., Adamu, M., and Haruna, M. A. (2019b). Comparative Assessment of Wetland and 'Tudu' Soil and Groundwater Quality for Forage Crop Production in Sudan Savannah Zone, Nigeria, Proceedings at the 3rd Biennial Conference of The Society for Grassland and Development in Nigeria Held At The National Animal Production Research Institute, A.B.U – Shika, Zaria. 3rd – 6th Nov. 2019.

Khaleghi, A., Naderi, R., Brunetti, C., Maserti, B. E., Salami, S. A., and Babalar, M. (2019). Morphological, physiochemical and antioxidant responses of Maclurapomifera to drought stress. *Sci. Rep.* 9(1), 19250. https://doi.org/10.1038/s41598-019-55889-y

Lambers, H., Chapin, F. S., and Pons, L.T., (2008). *Plant physiological ecology* (2nd ed.). Springer Science + Business Media, LLC, 233 Spring Street, New York, NY 10013, USA. 79 – 150. https://doil 10.1007/978-0-387-78341-3

Lasheen, F. F., Negm, A. H., Hassan, S. E., Azab, E., Gobouri, A. A. and Hewidy, M. (2021). Nitrogen, Phosphorous, and Potassium Application Rate on the Young Seedling Growth of Salvadora persica *Agriculture*, *11*(4), 291. https://doi.org/10.3390/agriculture11040291

Malik, T.H., S.B. Lal, N.R.Wani, D. Amin, R.A.Wani. (2014). Effect of different levels of nitrogen on growth and yield attributes of different varieties of basmati rice (Oryzasativa L.). *International Journal of Scientific and Technological Research*, 3(3), 444-448

Nikoleta-Kleio, D., Theodoros, D., and Roussos, P. A. (2020). Antioxidant defense system in young olive plants against drought stress and mitigation of adverse effects through external application of alleviating products. *Sci. Hortic Amsterdam* 259, 11. https://doi.org/10.1016/j.scienta.2019.108812

Nkechi, O. Alphonsus, A., and Ekenedilichukwu, E. (2016). Mitigating climate change in Nigeria: African traditional religious values in focus. *Mediterranean Journal of Social Sciences, 7*(6), 299-308.

Okalebo, R., Gathua, W.K., and Woomer, P.L. (2012). *Laboratory methods of Soil and Plant Analysis: A Working Manual* (2nd Ed.). TSBF-CIAT and SACRED Africa, Kenya, 29 – 62.

Pandit, M. Chakraborty, M., Haider, Z. A., Pande, A., Sah, P., and Sourav, K. (2016). Genetic diversity assay of maize (*Zea mays* L.) inbreeds based on morphometric traits and SSR markers. *African Journal of Agricultural Research.* 11(24):2118–2128.

Per, T. S., Khan, N. A., Reddy, P. S., Masood, A., Hasanuzzaman, M., and Khan, M. I. R., (2017). Approaches in modulating proline metabolism in plants for salt and drought stress tolerance: Phytohormones, mineral nutrients and transgenics. *Plant Physiological Biochemistry*, *115*, 126–140. https://doi.org/10.1016/j.plaphy.2017.03.018

Sarker, K. K., Hossain, A., Timsina, J., Biswas, S. K., Kundu, B. C., and Barman, A. (2019). Yield and quality of potato tuber and its water productivity are influenced by alternate furrow irrigation in a raised bed system. *Agricultural Water Management*, 224,105-750.

Santos, M.G., Ribeiro, R.V., Machado, E.C., and Pimentel, C. (2009). Photosynthetic parameters and leaf water potential of five common bean genotypes under mild water deficit. *Biology Plant* 53(2), 229 – 236. https://doi.org/10.1007/s10535-009-0044-9

Schneider, J.R., Caverzan, A., and Chavarria, G. (2018). Water deficit stress, ROS involvement, and plant performance. *Archive of Agronomy and Soil Science*. *65*, (8), 1160 – 1181. https://doi.org/10.1080/03650340.2018.1556789

Song, C.J., Ma, K.M., Qu, L.Y., Liu, Y., Xu, X.L, and Fu, B.J. (2010). Interactive effects of water, nitrogen and phosphorus on the growth, biomass partitioning and water-use efficiency of *Bauhinia faberi* seedlings. *Journal of Arid Environments. 74*(9),1003 –1012.

Tshewang, S., Rengel, Z., Siddique, K. H. M. and Solaiman, Z. M. (2020). Nitrogen and Potassium Fertilisation Influences Growth, Rhizosphere Carboxylate Exudation and Mycorrhizal Colonisation in Temperate Perennial Pasture Grasses, *Agronomy*, *10*(12), 1012 - 1878. https://doi.org/10.3390/agronomy10121878

Wallace, J. G., Zhang, X. C., Beyene, Y., Semagn, K., Olsen, M., and Prasanna, B. M., (2016). Genome-wide Association for Plant Height and Flowering Time across 15 Tropical Maize Populations under Managed Drought Stress and Well-Watered Conditions in Sub-Saharan Africa. *Crop Science*, 56(6), 2365–2378. https://doi.org/10.2135/cropsci2015.10.0632

Zwicke, M., Picon-Cochard, C., Morvan-Bertrand, A., Prud'homme, M. P., and Volaire, F. (2015). What functional strategies drive drought survival and recovery of perennial species from upland grassland? *Ann. Bot. 116*(6), 1001–1015. https://doi.org/10.1093/aob/mcv037