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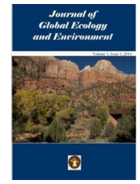

FORAGE BIOMASS YIELD PERFORMANCE OF RHODES GRASS (*Chloris gayana*) ACCESSIONS IN BENISHNGUL-GUMUZ REGION OF WESTERN ETHIOPIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at Kamashi and Assosa forage research stations of Assosa Agricultural Research Center to evaluate the forage yield performance of five chloris gayana accessions under low and mid-altitude agro-ecologies. Kamashi and Assosa were representing low and mid-altitude agro-ecologies respectively. The study was conducted in randomized complete block design with three replications. Plant height at forage harvesting, days to forage harvest, forage dry matter yield, and leaf to stem ratio were significantly ($P < 0.001$) different among the testing agro-ecologies. The highest plant height at forage harvesting and forage dry matter yield was obtained from Kamashi and leaf to stem ratio from Assosa testing environment. Genotype was significantly ($P < 0.001$) affected plant height, days to forage harvest, and leaf to stem ratio. Plant height was significantly ($P < 0.05$) affected by the interaction of genotype and environment. The result of a combined analysis indicated that the days to forage harvest was significantly ($P < 0.001$) affected by genotype. While days to forage harvest was significantly ($P < 0.001$) different among the tested genotypes at both testing environment and *C. gayana* cv., massaba, was early maturing than the others tested *Chloris gyana* accessions at both locations. In conclusion the plant height, dry matter yield, leaf to stem ratio and days to maturity of *C. gayana* is affected by agro-ecology.

Keywords: Agro-ecologies; aoosa; environment; genotype.

1. INTRODUCTION

Feed scarcity in both qualitative and quantitative dimensions is one of the key impediments to livestock production in Ethiopia [1,2]. The quality and quantity of feed resources available to the animals in most parts of the country are mainly affected by the seasonal fluctuation of rainfall [3,4]. Peak crude protein (CP) and metabolizable energy (ME) content of 11.2 percent and 8.2 MJ/kg, respectively, were observed in July and gradually decreased to 3.3 percent and 7.1 MJ/kg in March. In contrast, the content of neutral detergent fiber (NDF) increased from 61% in July to a peak of 80 percent in March.

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This shows that during the long dry season, animals are prone to nutritional deficiency and need to be supplemented [5]. Therefore, reasonable levels of increases in body weight of animals gained during the wet season are lost dramatically during the long dry season. Although, feed supplies are constrained mainly by shrinkage of grazing land, soil fertility, and by the unreliable seasonal rainfall pattern in most areas [6]. The limitation of land for food crop production is also another problem in Ethiopia. Because of this, scarcity of grazing land and livestock feed shortage is critically severe in Ethiopia. Keeping in mind efficient utilization of locally available feed resources, there have to be means of introducing forage production into the existing farming system so that both crop and livestock production can supplement each other. Therefore, to minimize these problems introducing improved forage crops like *C. gayana* in the area is one option.

C. gayana is a species of grass known by the common name Rhodes grass [7]. It is native to Africa but it can be found throughout the tropical and subtropical world as a naturalized species with fine stemmed leafy prostate to erect grass forming up to 1.5m high, palatable for hay not for silage, drought and grazing resistant, salt-tolerant [8]. Rhodes grass was recommended for cultivation in Ethiopia by the Holeta Agricultural Research Center [9] in 1984. Rhodes grass was described by the center as Masaba (name of the variety); Year of release: 1984; rainfall requirement: 600 - 900 mm; altitude range: 1500-2400m above sea level; forage yield: 7-12 ton DM ha^{-1} and seed yield: 70-150 kg ha^{-1} [10]. It is a C4 species widely used as forage in tropical and subtropical areas and known for its ability to withstand dry conditions, soil salinity, and light frost. *C. gayana* grass is proficiently uses solar radiation and soil moisture to rapidly accumulate a relatively high amount of biomass [11]. It is tolerant of moderately saline and alkaline soils and irrigation [12]. Rhodes grass (*C. gayana*) is a widespread popular fodder as pasture or hay because of its luxuriant development and environmental tolerance and excretes salts on the leaf surfaces [13]. It's grown on a wide range of soils from poor sandy soils to heavy alkaline and saline soils [14]. It pasture leys was able to dramatically improve soil organic matter contents in the upper 30cm and water infiltration rates into the soil profile and water holding capacity and its development lower soil temperature during summer [11]. It is a tufted perennial grass that grows to be 1-2 meters tall and spreads by looping runners that form new plants along the stolons. Rhodes grass is a stoloniferous creeping or occasionally tufted perennial grass. Its stem is fine and leafy [15].

With all the above-mentioned advantages, *C. gayana* can be a potential forage and food crop in the Ethiopia that can be easily adopted by farmers. However, there are no recommended accessions of *C. gayana* for the area. Selection based on yield components may help to identify and develop lines having improved and more stable yields [16]. Therefore, the main objective of the study was to study the effects of agro-ecology and accession on forage biomass yield and yield Components of Rhodes Grass (*C. gayana*) to select the best *C. gayana* accessions which produce the highest grass yield under the climatic conditions of the study area.

2. MATERIALS AND METHODS

2.1 Study Area

The trial was conducted under field conditions at Assosa and Kamash forage research stations of Assosa Agricultural Research Center during the main cropping seasons of 2016/17 to 2018/19 (for three consecutive years) under rain fed conditions. The test locations represent the high and mid-altitude areas ranging in altitude from 1000 to 1550 m.a.s.l. The farming system of the study areas is Agro pastoral. Descriptions of the test environments are indicated in Table 1.

2.2 Experimental Treatments and Design

The five accessions of five *C. gayana* (*C. gayana* 6627, 7384, 6336, Massaba and 6633) for this research experiment were collected from ILRI and Holleta Agricultural Research Center. The accessions were planted in a 3 m x 4 m plot using a randomized complete block design (RCBD) with three replications at the beginning of the main rainy season. There was one year of establishment, followed by several years where the grass was harvested. The seed was sown 30 cm spacing between plants by drilling at 3 cm depth. The total experimental area was 13 m × 26 m (338 m2) with an individual plot size of 12 m2 and spacing between plots and replications of 1.5 and 2 m, respectively at each testing environment. The treatments were sown according to their recommended seeding rates: 2-15 kg ha-1.

2.3 Data Collection

Data were collected on days to forage harvest, plant height at harvesting (PHH), leaf to stem ratio, and forage dry matter (DM) yield. PHH and number of branches per plant (NBPP) were taken on six plants randomly selected from each plot. PHH was measured using steel tape from the ground level to the highest leaf. For the determination of biomass yield, accessions were harvested at the forage harvesting

Table 1. Descriptions of the test environments for geographical position

Parameters	Study sites	
	Kamashi	Assosa
Latitude	09. °30′N	10°30’N
Longitude	35°45′E	034°20’E
Altitude(m.a.s.l)	1000	1550
Annual rainfall (mm)	1150	1316
Daily minimum Temperature (^{0}C)	25	16.75
Daily maximum Temperature (^{0}C)	30	27.9

stage (50% blooming stage) inlaid quadrant which has a 1m2 area. The weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 500 g sample was taken from each plot to the laboratory. The sample taken from each plot was weighed to know their sample fresh weight and oven-dried for 72 hours at a temperature of 65 0C to determine dry matter yield.

2.4 Statistical Analysis

Analysis of variance (ANOVA) procedures of SAS general linear model (GLM) was used to compare treatment means (SAS, 2002). LSD test at 5% significance will be used for comparison of means. The data was analyzed using the following model:

$Y_{ijk} = \mu + T_i + Bk_{(j)} + e_{ijk}$

Where, Y_{ijk} = measured response of treatment i in block k of location j,
μ = grand mean,
T_i = effect of treatment i,
$Bk_{(j)}$ = effect of block k j, and
e_{ijk} = random error effect of treatment i in block k of location j.

3. RESULTS AND DISCUSSION

3.1 Effects of Environment and Genotype and their Interaction Agronomic Traits

A combined analysis of variance for measured agronomic traits of *C. gayana* accessions tested over environments is presented in Table 2. Plant height at forage harvest (PHH), forage dry matter yield, leaf to stem ratio, and days to forage harvest were significantly ($P < 0.001$) different among testing environments. The higher values for the measured agronomic traits were obtained from Kamash, except the leaf to stem ratio was obtained from the Assosa testing environment. Genotype difference was significantly ($P < 0.001$ for PHH; $P < 0.01$ for LSR; $P < 0.001$ for DFH) influence plant height at forage harvest (PHH), leaf to stem ratio (LSR) and days to forage harvest (DFH). Testing environment by genotype interaction effects revealed non-significant ($P > 0.05$) difference for the measured agronomic traits, except significant ($P < 0.05$) difference for plant height at forage harvesting.

The measured agronomic traits performance of the tested *C. gayana* accessions was stable across the environment and this might be due to the interaction effect of genotype and environment was non-significantly influence measured agronomic traits, except plant height at forage harvesting. In agreement with this study [17] was reported that the major difference in genotype stability is due to the crossover interaction effect of genotype and environment. According to [18], the interaction is a result of changes in a cultivar's relative performance across environments due to differential responses of the genotypes to various edaphic, climatic, and biotic factors. When genotypes perform consistently across locations, breeders can effectively evaluate germplasm with a minimum cost in a few locations for the ultimate use of the resulting varieties across wider geographic areas [19]. However, with high genotype by location interaction effects, genotypes selected for superior performance under one set of environmental conditions may perform poorly under different environmental conditions [20]. [17] reported that the development of cultivars or varieties, which can be adapted to a wide range of diversified environments, is the ultimate goal of plant breeders in a crop improvement program. Therefore, the result obtained in this study in line with the report of the above authors [17, 19].

3.2 Days to Forage Harvest

The mean days to forage harvest for the five tested *C. gayana* accessions in two agro-ecologies of the Benishangul-Gumuz region are presented in Table 3. The result of the combined analysis showed that days to forage harvest was significantly ($P < 0.001$) influenced by genotype. *C. gayana* cv. Masaba was the early maturing genotype among the tested genotypes in both the tested locations. The early maturing characteristic of forage genotypes is an important agronomic trait to increase the frequency of

Table 2. Combined analysis of variance for measured agronomic traits of five Rhodes grass (*C. gayana*) accessions

SN	Traits	Mean square		G X E	Mean	CV
		Genotype	Environment			
1	Plant height (cm)	***	***	*	116.75	12.37
2	Forage DM yield (t/ha)	ns	***	ns	5.23	51.35
3	Leaf to stem ratio	**	***	ns	0.76	23.50
4	Days to forage harvest	***	***	ns	94.87	3.06

*ns= non-significant, * = P < 0.05, **=P < 0.01, ***=P < 0.001*

Table 3. Mean days to forage harvest of five Rhodes grass (*C. gayana*) accessions

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Kamashi	
1	*C. gayana* 6627	91.00[a]	105[a]	98.00[a]
2	*C. gayana* 7384	91.00[a]	105[a]	98.00[a]
3	*C. gayana* 6336	91.00[a]	105[a]	98.00[a]
4	*C. gayana*6633	91.00[a]	105a	98.00[a]
5	*C. gayana*Massaba	76.67[b]	88[b]	82.33[b]
	Mean	88.13[b]	101.6[a]	94.87
	CV	4.71	20.10	7.98
	P-value	0.0000	0.0000	0.0000

Table 4. Mean leaf to stem ratio of five Rhodes grass (*C. gayana*) accessions

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Kamashi	
1	*C. gayana* 6627	0.98	0.61[a]	0.79
2	*C. gayana* 7384	0.84	0.38[b]	0.61
3	*C. gayana* 6336	1.01	0.65[a]	0.83
4	*C. gayana* 6633	0.89	0.71[a]	0.80
5	*C. gayana* Massaba	0.87	0.68[a]	0.77
	Mean	0.92[a]	0.60[b]	0.76
	CV	17.38	32.50	32.17
	P-value	0.1451	0.0086	0.0786

forage harvesting per year. A difference in maturity period is an important agronomic trait to select companion crops in mixed fodder systems for maximum production [20]. [21] also reported that days to maturity had an advantage of selecting companion crops that best synchronize to the days to maturity for better compatibility and forage yield. Late maturing varieties stay green for a longer period so farmers get green feed for their livestock for a longer period. On the other hand, early maturing varieties could be raised in short rains to feed the livestock during the critical period of feed shortage. Days to forage harvest were significantly (P < 0.001) late at Kamash testing environment than Assosa and this might be due to the Assosa soil is more acidic than Kamash soil, while the Kamash soil is more fertile than Assosa soil. Also, the result of this study revealed the days to forage harvest was earlier at Assosa red soil than Kamash black soil. In agreement with this study [22] reported the days to forage harvest for Vetch forage earlier at Holota red Nitosol than Ginchi black clay Verisol.

3.3 Leaf to Stem Ratio

The leaf to stem ratio at forage harvesting of tested *C. gayana* accessions indicated in Table 4. The result of this study revealed that the leaf to stem ratio was non-significant (P > 0.05) among the tested accessions at both locations. Testing environment differences were significantly (P < 0.001) affect the leaf to stem ratio. The higher leaf to ratio was obtained from Assosa and this might be due to days to forage harvest was later at Kamash, this leads as a function of the longer periods of physiological growth with reduced defoliation frequency stimulating stem growth at the expense of leaf production. In agreement with this study, [23] reported that a decrease in leaf to stem ratio with longer cutting intervals is a function of the longer periods of physiological growth with reduced defoliation frequency stimulating stem growth at the expense of leaf production. The leaf to stem ratio has significant implications on the nutritive quality of the grass as leaves contain higher levels of nutrients and less fiber than stems. The result indicated that the leaf to stem ratio is an important factor affecting diet selection, quality, and intake of forage [24]. The leaf to stem ratio is associated with the high nutritive value of the forage because the leaf is generally of higher nutritive value [25] and the performance of animals is closely related to the amount of leaf in the diet. Therefore, according to the report of these authors, the *C. gayana* grown at Assosa is more nutritious than *C. gayana* grown at Kamash due to the leaf to stem ratio was higher at Assosa than Kamash. Leaf to stem ratio was significantly ($P < 0.01$) different among genotype at Kamash and the least leaf to stem ratio was recorded for *C. gayana* 7384 accession.

3.4 Plant Height at Forage Harvesting

The mean days to forage harvest for the five tested *C. gayana* accessions under the two agro-ecological zones of the Benishangul-Gumuz region are presented in Table 5.Mean plant height of *C. gayana* accessions were non-significant ($P > 0.05$) among genotype tested at Assosa. The combined analysis also did not show significant variation in plant height among the tested genotypes. However, plant height at forage harvesting was significantly ($P < 0.001$) affected by genotype at Kamash testing site, and the highest plant height at harvesting was recorded for *C. gayana* cv, 6627, followed by *C. gayana* accession 6336. Soil variation in the tested locations significantly ($P < 0.001$) influenced mean plant height at forage harvesting.

Plant height at forage harvesting was taller at Kamash red soil than Assosa black soil and this might be due to the black soil which is mostly waterlogged and the soil inhibits soil aeration, nutrient absorption, and root growth which results stunted and reduced growth rate in plants. In agreement with this study, [26] reported that plant height at forage harvesting of vetch species produced at Holetta red soil was higher than the forage yield recorded at Ginchi black soil.

3.5 Forage Dry Matter Yield

The mean forage dry matter yield of five tested *C. gayana* accessions under the two agro-ecological zones of the Benishangul-Gumuz region is indicated in Table 6. The result of combined and each location analysis showed that dry matter yield differences were non-significant ($P > 0.05$) among the tested genotypes. Forage dry matter yield was significantly ($P < 0.001$) affected by location differences and this might be due to the variation of edaphic, climatic, and biotic factors among the testing locations. The higher forage dry matter yield obtained at Kamash red soil might be due to the higher days to forage harvest and plant height at Kamash red soil than Assosa black soil, while leaf to stem ratio was higher for Assosa black soil than Kamash red soil. As days to forage harvest increase, the leaf to stem ratio values decrease and this leads to an increase in forage dry matter yield. This could be explained in terms of the longer duration of growth which probably enabled the late-maturing varieties to take full advantage of the better-growing conditions [27]. Also in agreement with this study, Muluneh (2006) reported that the yield of vetch species produced at Holetta red soil was more than double compared to the results recorded at Ginchi black soil since the soil at Ginchi was waterlogged which inhibits soil aeration, nutrient absorption, and root growth which made plants stunted and reduced in growth rate. [28] also reported that soil type was found to be the most important factor affecting biomass yield and hence herbage production on

Table 5. Mean plant height at forage harvesting stage (cm) of five Rhodes grass (*C. gayana*) accessions

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Kamashi	
1	*C. gayana* 6627	95.98	154.47^{a}	125.23
2	*C. gayana* 7384	92.17	138.04^{b}	115.10
3	*C. gayana* 6336	98.70	146.50^{ab}	122.60
4	*C. gayana* 6633	91.49	118.48^{c}	104.98
5	*C. gayana* Massaba	96.16	135.52^{b}	115.84
	Mean	94.90^{b}	138.60^{a}	116.75
	CV	15.19	10.67	23.35
	P-value	0.8121	0.0001	0.2090

Table 6. Mean forage DM yield (t/ha) of five Rhodes grass (*C. gayana*) accessions

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Kamashi	
1	*C. gayana* 6627	**4.28**	**6.31**	5.29
2	*C gayana* 7384	3.23	5.29	4.26
3	*C gayana* 6336	5.06	6.69	5.87
4	*C. gayana* 6633	2.96	5.94	4.45
5	*C. gayana* Massaba	4.35	8.22	6.28
	Mean	3.97^{b}	6.49^{a}	5.23
	CV	26.82	21.85	56.60
	P-value	0.1218	0.4452	0.1861

well-drained red soils was almost double compared to waterlogged black soils.

4. CONCLUSION

The result of the combined analysis of this study revealed that the five tested *C. gayana* accessions were not varied in plant height at forage harvesting, leaf to stem ratio, and forage dry matter yield. However, days to forage harvest was significantly different among the five tested *C. gayana* accessions and *C. gayana* cv. massaba was early matured accessions. Late plant maturity, taller plant height, better dry matter yield, and lower leaf to a ratio of *C. gayana* were observed for low-altitude than mid-altitude.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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