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Forage Yield Performance of *Stylosanthes* Accessions in Benishangul-Gumuz Region of Western Ethiopia

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Abstract: Three *Stylosanthes hamata* accessions (*S. hamata* 167, *S. hamata* 75, and *S. hamata* 15876) and one accession of *S. scabra* (*S. scabra* 441) were evaluated for their agronomical performance under two environmental conditions of Benishangul-Gumuz region state, Western Ethiopia. The experiment was carried out at Kamash and Assosa Forage research station of Assosa Agricultural Research Center and the locations were purposively selected to represent lowland and mid-altitude agro-ecologies, respectively. The experiment was conducted in a randomized complete block design with three replications. Environment was significantly ($P < 0.001$) affecting dry matter yield, number of tillers, number of branches per plants, and leaf to stem ratio. The highest forage dry matter yield was obtained at Assosa. The results of the combined analysis revealed that plant height at forage harvesting ($P < 0.05$), number of tillers ($P < 0.01$) and leaf to stem ratio ($P < 0.01$) were significantly influenced by genotype. Taller plant height and higher leaf to stem ratio were obtained from *S. scabra* 441. Leaf to stem ratio was significantly ($P < 0.01$) different among genotypes of Assosa and the highest leave to stem ratio was recorded for *S. scabra* 441. The interaction effect of location and genotype was nonsignificant ($P > 0.05$) for all measured parameters and this indicated consistency in the performance of the genotypes across the environment and this leads to conclude no need for assessing performance to identify *Stylosanthes* genotypes with stable and superior yield across the environments.

Keywords: Stylosanthes, Dry Matter Yield, Environment, Genotype, Leaf to Stem Ratio

1. Introduction

Inadequate supply and quality of forage, particularly during the dry season, is a major constraint to livestock production in sub-Saharan Africa [1]. Poor management of the available feeds, seasonal variability in weather and climate change contributes to the high fluctuation of forage quality and quantity between seasons and years [2]. To improve livestock production, there is a need to improve both the quantity and quality of available feed through the use of alternative forage crops like *stylosanthes*. *Stylosanthes* is regarded as the most economic and significant pasture and forage legume in the tropical regions [3]. Consequently, as an attempt to improve livestock nutrition, it was introduced in West Africa in the 1960's after several new improved cultivars were developed in Australia [4].

Stylosanthes legume has been the forage of interest in Africa for pasture improvement, particularly West Africa. This is based on the merits of the genus, which include high yield of protein per hectare [5]. According to Mohammed-Saleem and de Leeuw, the genus *Stylosanthes* has provided ample germplasm for a wide variety of agro-ecological situations in the tropics [6]. *Stylosanthes* has fitted successfully to the dry land of African agriculture, particularly because of its drought-tolerant characteristics [7]. Therefore, based on the merits of *Stylosanthes* genus in improving feed quality and soil fertility, an evaluation of some major *Stylosanthes* species plays a paramount role to alleviate the feed problems in quality and quantity. Consequently, this study was conducted with the aim of determining the adaptability and agronomic potential of four *Stylosanthes* for age genotypes under the two agro-ecological zones of Benishangul-Gumuz regional state, Western Ethiopia.

Table 1. *Description of the test environments for geographical position and physico-chemical properties of the soil.*

Parameters	Study sites	
	Kamash	**Assosa**
Latitude	09°30′N	10°30’N
Longitude	35°45′E	034°20’E
Altitude (masl)	1000-1350	1500-1576
Annual rainfall (mm)	1150	1316
Daily minimum Temperature (°C)	25	16.75
Daily maximum Temperature (°C)	30	27.9

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 season of 2016/17 to 2018/19 (for three consecutive years) under rain fed conditions. The test locations represent the mid-and low altitude areas ranging in altitude from 1000 to 1576 m.a.s.l. The farming system of the study area is Agro pastoral. Descriptions of the test environments are indicated in Table 1.

2.2. Experimental Treatment and Design

The four genotypes of *Stylosanthes* (*S. hamata* 167, *S. hamata* 75, *S. hamata* 15876, *and S. scabra* 441) for this research experiment were collected from ILRI. The genotypes were planted in a 3 m x 4 m plots using a randomized complete block design (RCBD) with three replications at the beginning of the main rainy season. Seed was sown 30 cm spacing between rows by drilling at 3 cm depth. The total experimental area was 13 m × 20.5 m (266.5 m^2) with an individual plot size of 12 m^2 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: 2-10 kg ha^{-1} and fertilizers were not applied.

2.3. Data Collection

Data was collected on number of tillers, plant height at harvesting (PHH), number of branches per plant, and forage dry matter yield. Number of tillers, plant height at harvesting, and number of branches per plant were taken for six plants randomly selected from each plot. Plant height at harvesting was measured using a steel tape from the ground level to the highest leaf. For determination of biomass yield, genotypes were harvested at the forage harvesting stage (50% blooming stage) in the laid quadrant which has 1 m^2 area. 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°C to determine dry matter yield.

2.4. Statistical Analysis

Analysis of variance (ANOVA) procedure of SAS general linear model (GLM) was used to compare treatment means [8]. LSD test at 5% significance will be used for comparison of means. The Pearson correlation analysis procedure of the SAS statistical package was applied to measure the strength of linear dependence between any two measured variables. The data was analyzed using the following model:

$$Yijk = \mu + Gi + Ej + GEij + Bk + e\ ijk$$

Where, Yijk = dependent variables,
μ = grand mean,
Gi = effect of genotype i,
Ej = effect of environment j, j = Assosa and Kamash
GEij = is the interaction effect of genotype i and environment j
Bk = effect of block k, and
e ijk = random error effect of genotype i, environment j, interaction effect of genotype i and environment j, and block k.

3. Results and Discussion

3.1. Environment and Interaction Effect on Stylosanthes Genotype Performance

Combined analysis of variance for measured agronomic traits of *Stylosanthes* genotypes tested over environment is presented in Table 2. The results of this study revealed that the environment was significantly ($P < 0.001$) influencing the forage dry matter yield, number of tillers, number of branches per plant, and leaf to stem ratio of the tested S*tylosanthes* genotypes. Plant height at forage harvesting ($P < 0.05$), number of tillers ($P < 0.01$) and leaf to stem ratio ($P < 0.01$) were significantly affected by genotype. Interaction of genotype and environment was not significantly ($P > 0.05$) affecting the measured agronomic traits except leaf to stem ratio ($P < 0.05$) and this indicated consistency in the performance of the genotypes across the environments and this leads to no need for assessing performance to identify *stylosanthes* genotypes with stable and superior yield across the environments. Statistically, G x E interactions are detected as significantly different patterns of response among genotypes across environments, this will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments [9].

The forage dry matter yield performance of the tested *Stylosanthes* genotypes was stable across the environment and this might be due to the interaction effect of genotype and environment that was non-significantly influencing the forage dry matter yield. In agreement with this study, [10] was reported that a major difference in genotype stability is due to the crossover interaction effect of genotype and environment. According to [11], 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 are able to effectively evaluate the germplasm with a minimum cost in a few locations for the ultimate use of the resulting varieties across wider geographic areas [12]. 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 [13]. Therefore, 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 [10]. Therefore, according to the finding of these authors, evaluation of yield, performance and adaptation patterns of *Stylosanthes* genotypes in multiple environments couldn't be important step in agronomic evaluation and selection of better adapted and high yielding species and varieties.

Table 2. *Combined analysis of variance for measured agronomic traits of four Stylosanthes accessions tested across two locations/environments.*

Traits	Mean square		G X E	Mean	CV
	Genotype	Environment			
Plant height (cm)	*	ns	ns	42.54	19.37
Forage DM yield (t/ha)	ns	ns	ns	3.67	51.70
Number of tiller	**	***	ns	3.90	36.24
No of branches per plant	ns	***	ns	9.44	23.99
Leaf to stem ratio	**	***	*	0.61	18.65

G X E = Interaction of genotype and environment; CV = Coefficient variation; ns= non-significant; * = P < 0.05; **=P < 0.01; ***=P < 0.001.

3.2. Leaf to Stem Ratio

The mean leaf to stem ratio at forage harvesting of the four tested *Stylosanthes* genotypes under the two agro-ecological zones of Benishangul-Gumuz is presented in Table 3. The result of combined (P < 0.05) and Assosa location (P < 0.01) analysis indicated that the leaf to stem ratio was significantly different among the tested genotypes and *S. scabra* 441 was given the highest value.

Mean leaf to stem ratios of the tested *Stylosanthes* genotypes were significantly (P < 0.001) affected by location. The results indicated that the highest mean leaf to stem ratio at forage harvesting stage was recorded from Kamash. This suggests that the *Stylosanthes* genotype grown at Kamash were more nutritious than *Stylosanthes* genotype grown at Asosa due to the leaf to stem ratio was higher at Kamash than Assosa location. Because the leaf to stem ratio has significant implications on the nutritive quality of the forage as leaves contain higher levels of nutrients and less fiber than stems. The leaf to stem ratio is associated with high nutritive value of forage because leaf is generally of higher nutritive value [14] and the performance of animals is closely related to the amount of leaf in the diet. Leaf to stem ratio is an important factor affecting diet selection, quality, and intake of forage [15].

Table 3. *Mean leaf to stem ratio of four Stylosanthes genotypes tested across two locations/environments at forage harvesting stage.*

Genotypes	Location/Environments		Combined analysis
	Assosa	Kamash	
S. hamata 167	0.46^{b}	0.69	0.58^{b}
S. hamata 75	0.38^{b}	0.75	0.56^{b}
S. hamata 15876	0.42^{b}	0.73	0.57^{b}
S. scabra 441	0.69^{a}	0.76	0.72^{a}
Mean	0.49^{b}	0.73^{a}	0.61
CV	25.35	14.79	29.73
P-value	0.0017	0.7315	0.0142

CV = Coefficient variation; $^{a, b,}$ means with different superscripts in a column and rows are significantly different.

3.3. Plant Height at Forage Harvesting

The mean plant height at forage harvesting of the four tested *Stylosanthes* genotypes is presented in Table 4. Mean plant height at forage harvesting was non-significantly (P > 0.05) different across the testing environments. The results of the combined analysis indicated that the mean plant height at forage harvesting was significantly (P < 0.05) different among the tested genotypes. Among the tested *Stylosanthes* genotypes, the highest mean plant height at forage harvesting was obtained from *S. scabra* 441. Mean plant height at forage harvesting was not significantly (P > 0.05) different among the locations. The taller plant heights recorded for *S. scabra* 441 genotypes resulted in better biomass yields. This is due to the fact that longer plants possess relatively more leaves and branches that may result in an increase in biomass yield.

Table 4. *Mean plant height (cm) of four Stylosanthes genotypes tested across two locations/environments at forage harvesting stage.*

Genotypes	Location/Environments		Combined analysis
	Assosa	Kamash	
S. hamata 167	40.39	37.64	39.02^{b}
S. hamata 75	44.66	38.13	41.39^{b}
S. hamata 15876	42.43	38.52	40.47^{b}
S. scabra 441	48.06	50.49	49.27^{a}
Mean	43.88	41.19	42.54
CV	18.68	20.97	19.17
P-value	0.4315	0.0528	0.0167

CV = Coefficient variation; $^{a, b,}$ means with different superscripts in a column are significantly different.

3.4. Forage Dry Matter Yield

The forage dry matter yield of four tested *Stylosanthes* under two agro-ecological zones of Benishangul-Gumuz is indicated in Table 5. The result of each location and combined analysis showed that forage dry matter yield was non-significantly (P > 0.05) different among the genotypes. The main effect difference among testing environments was significantly affect the forage dry matter yield (P > 0.05). The highest forage dry matter yield was obtained at Asssosa and this might be due to soil characteristics (Assosa soil is red, while Kamash soil is black). This might be due to the black soil being water logged which inhibits soil aeration, nutrient absorption, and root growth that made plants stunted and reduced growth rate. The result also might be attributed to due to the leaf to stem ratio of the value recorded for genotypes was higher at Kamash than Assosa testing environment. This leads to as the leaf to stem ratio increases, the forage dry matter yield decreases, however the nutrient content will be increase and this might be due the leaf part of the forage is more nutritious than stem. The overall mean (3.67 t ha^{-1}) for forge dry matter yield of the four *Stylosanthes* accessions in the present study was in line with the overall mean value (3.05 t ha^{-1}) reported by [16] for tested *Stylosanthes* accessions (for 166 *Stylosanthes hamata and* 34 *Stylosanthes scraba* accessions) tested on an acid soil, Soddo, southern Ethiopia.

Table 5. *Mean forage DM yield (t/ha) of four Stylosanthes accessions tested across two locations/environments.*

Genotypes	Location/Environments		Combined analysis
	Assosa	Kamash	
S. hamata 167	4.10	1.99	3.04
S. hamata 75	5.10	2.05	3.58
S. hamata 15876	4.04	1.99	3.02
S. scabra 441	4.67	3.02	3.84
Mean	4.47^{a}	2.26^{b}	3.67
CV	30.04	28.68	60.99
P-value	0.8214	0.3203	0.7053

CV = Coefficient variation; $^{a, b,}$ means with different superscripts in a row are significantly different.

4. Conclusion

Stylosanthes accessions responded non-significant variations in forage dry matter yield across the testing environments, however, leaf to stem ratio showed significant variation among the accessions and *S. scabra* 441 gave the highest leaf to stem ratio. Measured agronomic traits showed significant variations among the testing environments. The overall performance of *Stylosanthes* genotypes was better in Assosa than Kamash. This suggests that this location has better soil and climatic conditions for cowpea growing for forage purposes. Generally, *S. scabra* 441 relatively showed the best performance for all measured agronomic traits across the testing environment and recommended for the study area and similar agro-ecologies.

Authors' Contributions

All authors contributed from the onset of the study and approved of the final version.

Conflict of Interest Declaration

All the authors do not have any possible conflicts of interest.

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