American Journal of BioScience
2021; 9(5): 175-179
http://www.sciencepublishinggroup.com/j/ajbio
doi: 10.11648/j.ajbio.20210905.14
ISSN: 2330-0159 (Print); ISSN: 2330-0167 (Online)

Evaluation of *Vicia* Species and Their Accessions for Forage Biomass Yield in Benishangul-Gumuz Region of Western Ethiopia

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To cite this article:
Mulisa Faji, Alemayehu Abebe, Kedija Ahmed, Workeneh Tezera, Diribi Mijena, Gezahagn Mengistu, Gmerium Terefe. Evaluation of *Vicia* Species and Their Accessions for Forage Biomass Yield in Benishangul-Gumuz Region of Western Ethiopia. *American Journal of BioScience*. Vol. 9, No. 5, 2021, pp. 175-179. doi: 10.11648/j.ajbio.20210905.14

Received: August 24, 2021; **Accepted**: September 15, 2021; **Published**: October 30, 2021

Abstract: A study was carried out to evaluate four *Vicia* accessions from 3 species for forage biomass yield performance under two environmental conditions of the Benishangul-Gumuz Region of Western Ethiopia. The evaluated *Vicia* species and accessions were one *V. benghanlensis* (6798), two *V. villosa* (6213 and 6792) and one *V. sativa*, (5172) accessions. The experiment was conducted at Tongo and Assosa forage research station of Assosa Agricultural Research Center and the locations were purposively selected to represent highland and mid-altitude agro-ecologies, respectively. The experiment was set up with a randomized complete block design with three replications. Main effects differences among genotypes and environments significantly influenced forage dry matter yield ($P < 0.05$) and plant height ($P < 0.01$), while the leaf to stem ratio was significantly ($P < 0.001$) influenced by the environment. Tongo had the highest forage dry matter yield ($P < 0.01$) compared to Assosa. Plant height was significantly different among accessions at both locations and the tallest plant height at forage harvest was recorded for *V. villosa* 6213 followed by *V. benghanlensis* 6798 and *V. villosa* 6792 at both locations. At Tongo, total dry matter yield was significantly different ($P < 0.05$) among accessions, but not at Assosa ($P > 0.05$). *V. benghanlensis* 6798 gave a relatively higher total dry matter yield followed by *V. villosa* 6792 and *V. villosa* 6213 at Tongo. Therefore, based on forage dry matter yield data *V. benghanlensis* 6798, *V. villosa* 6792 and *V. villosa* 6213 recommend as alternative legume forage crops from evaluated *Vicia* accessions for study areas and comparable agro-ecologies.

Keywords: *Vicia* Accessions, Genotype, Environment, Agronomic Traits

1. Introduction

Livestock is an integral component of the agricultural activities in Ethiopia. The share of the livestock sub-sector contribution in the national economy is estimated to be 12-16% to the total Gross Domestic Product (GDP), 30-35% to the agricultural GDP [1]; 19% to the export earnings [2]; and 31% of the total employment [3]. Despite the enormous contribution of livestock to the livelihood of farmers, poor availability of good quality feed remains to be the major bottleneck to livestock production in Ethiopia. Much of the available feed resources are derived from fragmented native pastures, transient pastures between cropping cycles, crop residues and crop aftermath. Feed supplies are constrained mainly by shrinkage of grazing land, soil fertility and unreliable seasonal rainfall pattern in most areas. In general, available feed resources exhibit significant seasonal fluctuations in both quantity and quality (digestibility and protein content), as well as mineral deficiencies. Reasonable levels of increases in body weight of animals gained during the wet season are lost dramatically during the long dry season [4-6].

Inadequacy of land for food crop production is also another problem in Ethiopia. The Food and Agricultural Organization of the United Nations (FAO) also reported that, currently with the rapid increase in human population and demand of food, grazing lands are steadily shrinking in favor of their conversion to arable lands [7]. For the reason stated above scarcity of grazing land and livestock feed shortages are critically severe in Ethiopia in general and in the Benishangul-Gumuz region in particular. Keeping in mind efficient utilization of locally available feed resources, there have to be means of introducing forage production in to the existing farming system so that both crop and livestock production can supplement each other. Berhanu et al. (2003) contend that improved nutrition through the use of sown forage could significantly increase livestock productivity [8]. Getnet et al (2003) also reported that food-forage crops integration with different methods (non-conventional forage production systems) are important and appropriate in areas where the land shortage is a problem and the agricultural production system is subsistence [9]. Therefore, to reduce the problems of feed shortage in the Benishangul-Gumuz region, introducing multipurpose forage legumes like *Vicia* would enhance forage availability in the region.

Vicia grows well on the reddish-brown clay soils and the black soils of the highland areas. It has been grown successfully in areas of acid soil with a pH of 5.5-6. It is reported that *Vicia* is rich in protein, minerals, and has lower fiber content. With the highest level of crude protein (CP), *Vicia* could be used as a supplement to roughages for dairy cows. Forages that are moderate to high in CP reduce the need for supplemental purchased protein [10].

However, species of *Vicia* have different characteristics in terms of growth habits, days to maturity, morphological fractions, and climatic adaptation. In general, the growth habit of *Vicia* species can be broadly grouped as erect, creeping, or climbing. For instance, *Vicia dasycarpa*, *V. villosa*, and *Vicia atropurpurea* have creeping or climbing growth habits, whereas *Vicia narbonensis* and *Vicia* sativa have erect growth habits. These genetic differences are the basis for variation in nutritive values, as well as the production, utilization, and various management practices [11]. This shows that the different *Vicia* species and their accessions need to be assessed for the nutritional quality differences under the different soil types and climatic conditions [10]. Therefore this study was executed with the objectives to evaluate biomass yield performance of *Vicia* species and accessions at Assosa and Tongo, under two climatic conditions of the Benishangul-Gumuz region.

2. Materials and Methods

2.1. Study Area

The trial was carried out in the field at the Assosa and Tongo forage research stations of the Assosa Agricultural Research Center from 2016/17 to 2018/19 (three consecutive years) under rain fed conditions. The test sites represent high and mid-altitude areas with altitude ranging from 1500 to 2200 meter above sea level. Agro pastoral farming is practiced in the study areas. Descriptions of the test environments are indicated in Table 1.

Table 1. *Descriptions of the test environments for geographical position.*

Parameters	Study sites	
	Tongo	Assosa
Latitude	09.9°45′N	10°30’N
Longitude	34°44′E	034°20’E
Altitude (masl)	1600-2200	1500-1550
Annual rainfall (mm)	1316	1316
Daily minimum Temperature (°C)	17.5	16.75
Daily maximum Temperature (°C)	28	27.9

2.2. Experimental Treatments and Design

Four *Vicia* accessions from three *vicia* species (*V. benghanlensis* acc. 6798*, V. villosa* acc. 6213 and 6792 and *V. sativa* acc. 5172) 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 (in mid-June). The seed was sown at 10 cm and 30 cm spacing between plants and rows respectively and 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 (25-30 kg ha^{-1}).

2.3. Data Collection

Data were collected on a number of tillers, plant height at harvesting, and forage dry matter (DM) yield. A number of tiller and plant heights were taken on six plants randomly selected from each plot. Plant height 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 stage (50% blooming stage) inlaid quadrant which has a 1m^2 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°C to determine dry matter yield [12].

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. Environment and Interaction Effect on Vicia Accessions Performance

The result of the combined analysis of variance for measured agronomic traits of *Vicia* species tested across environments is indicated in Table 2. The result revealed that plant height ($P < 0.01$), forage dry matter yield ($P < 0.05$), and leaf to stem ratio ($P < 0.001$) were significantly influenced by the environment (E), while plant height ($P < 0.001$) and forage dry matter yield ($P < 0.05$) were significantly affected by genotype. The findings of this study revealed that the environment has a significant effect on the yield performance and adaptability of *Vicia* accessions, which could be due to differences in climatic conditions between environments. This finding suggests that different *Vicia* species/accessions have different responses to various edaphic, climatic, and biotic factors.

Genotype (G) and environment interaction (G x E) had non-significant ($P > 0.05$) differences for plant height, forage dry matter yield, and leaf to stem ratio. This implies that the dry matter yield performance of the tested *Vicia* accessions was stable over the environment. In contrast to the result of this study [10] reported that selection of better performing *Vicia* genotypes at one location may not enable the identification of genotypes that can repeat nearly the same performances at another location. The variation among the reports might be due to the difference of evaluated species/accessions/, environment, etc. As a result of the findings of this study, evaluating the yield performance and adaptability potential of *Vicia* genotypes in a variety of environments is unlikely to be important for proper management and utilization.

Table 2. *Combined analysis of variance for measured agronomic traits Vicia accessions tested across two locations.*

SN	Traits	Mean square		G X E	Mean	CV
		Genotype	Environment			
1	Plant height (cm)	***	**	ns	149.61	29.06
2	Forage DM yield (t/ha)	*	*	ns	1.88	26.93
3	Leaf to stem ratio	Ns	***	ns	0.36	38.42

CV: coefficient variation; G x E= Interaction of genotype and environment; ns= non-significant, * = $P < 0.05$, **=$P < 0.01$, ***=$P < 0.001$.

3.2. Leaf to Stem Ratio

Leaf to stem ratio at forage harvesting stage was significantly ($P > 0.001$) influenced by genotype at Assosa, however non-significantly ($P > 0.05$) influenced at Tongo (Table 3). The leaf to stem ratio was highest for *V. sativa* acc. 5172 and least for *V. villosa* acc. 6213 at Assosa. The result of combined analysis indicated that leaf to stem ratio was not significantly ($P > 0.05$) influenced by genotype. Leaf to stem ratio was significantly ($P < 0.01$) influenced by the environment and the highest leaf to stem ratio value was recorded at Tongo and this might be due to variation in edaphic, climatic, and biotic factors among the testing environments. The cooler condition has the highest leaf to stem ratio in this study, which could be due to the longer periods of physiological growth of plants in a cooler environment combined with increased defoliation frequency, which stimulates leaf growth at the expense of stem production.

Table 3. *Mean leaf to stem ratio of four Vicia accessions tested across two locations.*

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Tongo	
1	*V. benghanlensis* 6798	0.27^{b}	0.46	0.36
2	*V. villosa* 6213	0.22^{c}	0.46	0.34
3	*V. villosa* 6792	0.23^{bc}	0.38	0.31
4	*V. sativa* 5172	0.36^{a}	0.51	0.43
	Mean	0.27^{b}	0.45^{a}	0.36
	CV	14.80	31.97	26.21
	P-value	0.0002	0.7018	0.2997

CV: coefficient variation; Means with different letters are significantly different.

3.3. Plant Height

The plant height at the forage harvesting stage of the tested *Vicia* accessions is indicated in Table 4. At Assosa ($P < 0.01$) and Tongo ($P < 0.001$), plant height for *Vicia* accessions at forage harvest varied. At both locations, *V. villosa* acc. 6213 had the tallest plant height, followed by V. *benghanlensis* acc. 6798 and *V. villosa* acc. 6792. In agreement to this study [10] reported that *V. sativa* (erect growth habit) was shorter than *V. villosa* (creeping or climbing growth habit) accessions at the central high land of Ethiopia. The combined analysis revealed that plant height at forage harvesting differed significantly ($P < 0.001$) among the genotypes tested, with *V. villosa*, acc. 6213 having the tallest plant height, followed by *V. benghanlensis*, acc. 6798. In agreement to this study [13] reported variations in plant height to be linked to genotypic differences and explained this trait to be influenced by differential response of genotypes to prevailing site and crop management conditions.

Table 4. *Mean plant height at harvesting (cm) of Vicia accessions tested across two Locations.*

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Tongo	
1	*V. benghanlensis* 6798	199.22^{a}	150.03^{a}	174.63^{a}
2	*V. villosa* 6213	203.53^{a}	160.75^{a}	182.14^{a}
3	*V. villosa* 6792	193.86^{a}	145.42^{a}	169.64^{a}
4	*V. sativa* 5172	71.14^{b}	72.93^{b}	72.03^{b}
	Mean	166.94	132.28	149.61
	CV	31.52	11.99	31.22
	P-value	0.0033	0.0000	0.0000

3.4. Forage Dry Matter Yield

The forage dry matter yield was significantly different (P < 0.05) at Tongo, however non-significant (P > 0.05) at Assosa (Table 5). *V. benghanlensis* acc. 6798 gave relatively higher total dry matter yield followed by *V. villosa* acc. 6792 and *V. villosa* acc. 6213 at Tongo. The result of the combined analysis revealed that the total forage dry matter yields were significantly (P < 0.05) different among the genotypes. The highest forage dry matter yield was obtained from V. *benghanlensis* acc. 6798 followed by *V. villosa* acc. 6792 and V. villosa acc. 6213. The highest (P < 0.01) forage dry matter yield was obtained at Tongo than Assosa and this might be due to the Assosa soil was more acidic than (pH < 5.5) than Tongo soil (PH > 5.5) and in concurrence to this study [14] was reported that *Vicia* species most adapted to the black soils of the highland areas they have been grown successfully in areas with an acid pH of (5.5 - 6.0).

Table 5. *Forage dry matter yield (t/ha) of the Vicia accessions tested across two locations.*

SN	Accessions	Location/Environments		Combined analysis
		Assosa	Tongo	
1	*V. benghanlensis* 6798	1.92	2.54^{a}	2.23^{a}
2	*V. villosa* 6213	1.65	1.96^{ab}	1.80^{ab}
3	*V. villosa* 6792	1.58	2.33^{a}	1.96^{ab}
4	*V. sativa* 5172	1.63	1.44^{b}	1.53^{b}
	Mean	1.69^{b}	2.07^{a}	1.88
	CV	21.83	30.73	29.56
	P-value	0.4078	0.0372	0.0291

CV: coefficient variation; Means with different letters are significantly different.

4. Conclusion

Vicia accessions respond to significant variation for forage dry matter yield and plant height at forage harvesting due to differential responses of the genotypes to various edaphic, climatic and biotic factors. The highest mean dry matter yield was obtained at Tongo than Assosa, indicating that *Vicia* expressed its genetic potential under cooler than hotter environmental conditions in the Benishangul-gumuz region. In conclusion, based on forage dry matter yield data *Vicia benghanlensis* 6798, *V. villosa 6792* and *V. villosa* 6213 recommended as alternative legume forage crops from evaluated *Vicia* accessions for study areas and comparable agro-ecologies.

Acknowledgements

The field research was fully financed by Ethiopian Institute of Agricultural Research (EIAR). The authors would like to thank Assosa Agricultural Research Center for facilitating the field research works.

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