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# EVALUATION OF *VICIA* ACCESSIONS FOR FORAGE BIOMASS YIELD AND YIELD COMPONENTS

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## SUMMARY

A study was carried out to evaluate four *Vicia* accessions from three 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 leaf to stem ratio ($P < 0.05$) and plant height ($P < 0.01$), while the forage dry matter yield was significantly ($P < 0.01$) 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 shortest plant height at forage harvest was recorded for *V. sativa* 5172 at both locations. At Tongo, mean dry matter yield was significantly different ($P < 0.05$) among accessions, but not at Assosa ($P > 0.05$). *V. benghanlensis* 6798 gave a higher total dry matter yield followed by *V. villosa* 6792 at Tongo.

**Keywords :** Genotype, environment, G x E, agronomic traits, *vicia* accessions

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 (Ayele *et al*., 2002); 19% to the export earnings (Getachew, 2003); and 31% of the total employment (Gezahagn *et al*., 2016). 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 (Seyoum and Zinash, 1995; Assefa, 2005; Muriuki, 2003).

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 (FAO, 2003). 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. 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. 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 (Gezahagn *et al.*, 2014).

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 (Getinet and Ledin, 2001). 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 (Gezahagn *et al.*, 2014). 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.

## MATERIALS AND METHODS

### Study area

The trial was carried out on research fields of Assosa Agricultural Research Center in Assosa and Tongo districts of BGRS between 2013 and 2016. The test sites represent high and mid-altitude areas with altitude ranging from 1500 to 2200 mean above sea level. BGRS is located in the western end of the country located between geographical coordinates of 90 30'N to 110 39'N latitude and 340 20'E to 360 30'E longitude with a total land area of 50 thousand square kilometer. The region is composed of different land features, dominantly of plain lowlands. Rainfall is uni-modal and occurs for 6 to 7 months of the year usually between April and October. However, lowland areas like Kamash get rain for 3-4 months. The mean annual rainfall is about 1275mm. The region exhibits both mild and hot temperatures. Minimum and maximum temperature of the region varies between 140°C and 200°C and 25°C to 39°C, respectively. Major soil types include: dystricnitsol, orthicacrisols, chromic and orthicluvisols, and chromic and eutricfluvisols (AsARC, 2006). Agro pastoral farming is practiced in the study areas. Assosa Agricultural Research Center is located nearby Assosa town which is 670 km far way west to Addis Ababa. Kamash is 225 km north east of Assosa town. 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

| 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 |

### 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 13.0 m × 20.5 m (266.5 $m^2$) with an individual plot size of 12 $m^2$. The treatments were sown according to their recommended seeding rates (25-30 kg/ha). The space left between two plots and blocks were 1.0 and 1.5 meters, respectively. Di-ammonium phosphate (DAP) fertilizer was applied (100 kg/ha) at planting at each season. Weed was controlled periodically by hand removal and other managements which include disease control were done as required.

### 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 h at a temperature of 65°C to determine dry matter yield (ILCA, 1990).

**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:

$$Yijk = \mu + Gi + Ej + Yk + GEij + GYik + EYjk + Bk + GEYijk + eijk$$

Where, Yijk = measured response of treatment i in block k of location j,

μ = grand mean,

Ti = effect of treatment i,

Ej = Effect of environment j, j = Assosa and Tongo

GEij = is the interaction effect of genotype i and environment j

GYik = is the interaction effect of genotype i and year k

EYik = is the interaction effect of environment j and year k

GEYijk = is the interaction effect of genotype I, environment j and year k

Bk(j) = effect of block k j, and

eijk = random error effect of treatment i in block k of location j.

## RESULTS AND DISCUSSION

### 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 leaf to stem ratio ($P < 0.01$), plant height and forage dry matter yield leaf to stem ratio ($P < 0.001$) were significantly influenced by the year (Y), while plant height ($P < 0.001$) and leaf to stem ratio ($P < 0.05$) were significantly affected by genotype. The findings of this study revealed that the environment has a significant ($P < 0.01$) effect on the yield performance and adaptability of *Vicia* accessions, which could be due to differences in climatic conditions between environments. Getnet and Ledin (2001) also reported that soil type was found to be the most important factor affecting biomass yield. Forage dry matter yield didn't significantly ($P > 0.05$) influenced by genotype difference. Plant height and leaf to stem ratio were significantly ($P < 0.01$) different for environment. This result suggests that, in addition to genetic variability, soil fertility and environmental conditions could also contribute to the difference in height.

Genotype (G) and environment interaction (G x E) had significant differences for plant height ($P < 0.001$) and forage dry matter yield ($P < 0.05$). This finding suggests that different *Vicia* species/accessions have different responses to various edaphic, climatic, and biotic factors. This indicated that the two locations were distinctly different for some of the characters and that better *Vicia* species and their accessions at one location may not also be better performing at another (Gezahagn *et al*., 2013). While Ceccarelli (1997) pointed out that, high genotype by location interaction effects, genotypes selected for superior performance under one set of environmental conditions may perform poorly under different environmental conditions. Therefore, the results of this study could be implicated that selection of better performing genotypes at one location may not enable the identification of genotypes that can repeat nearly the same performances at another location. The forage dry matter yield performance of the tested *Vicia* genotypes wasn't stable across the environment and this might be due to the interaction effect of genotype and environment that was significantly influencing the forage dry matter yield. In agreement with this study, Gezahagn *et al*., (2016) was reported that a major difference in genotype stability is due to the crossover interaction effect of genotype and environment. According to Dixon and Nukenine (1997), 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. Concurrent to the result of this study (Gezahagn *et al*., 2014) 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. Leaf to stem ratio was not significantly (P > 0.05) influenced by G x E. This result suggests that, the leaf to stem ratio of the tested *vicia* 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 leaf to stem ratio.

Plant height, forage dry matter yield and leaf to stem ratio were significantly (P < 0.001) influenced by interaction of environment and year (E x Y), but non-significantly (P > 0.05) influenced by interaction of genotype and year (G x Y). The interaction of genotype, year and environment (G x Y x E) had significant effect on the plant height. Forage dry matter yield and leaf to stem ratio were not significantly influenced by G x Y x E. The mean value of plant height obtained for the tested *Vicia* species in this study was slightly higher than the mean value (122.40 cm) reported by Gezahagn *et al*. (2013) for twenty vicia accessions tested at Holetta and Ginchi, Ethiopia. However, the mean forage dry matter yield value obtained in this study was lower than the mean value (5.13 t/ha) reported by Gezahagn *et al*. (2013) for twenty *Vicia* accessions tested at Holetta and Ginchi, Ethiopia. The variation among the reports might be due to the difference of evaluated species/accessions, environment and agronomic management.

**Leaf to stem ratio**

Leaf to stem ratio was significantly (P > 0.001) influenced by genotype at Assosa during the second year and combined analysis, however non-significantly (P > 0.05) influenced at Tongo (Table 3). The leaf to stem ratio was highest for *V. sativa* acc. 5172 at Assosa. The result of over all locations 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

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

| Traits | Year | Genotype | Environment | G x E | G x Y | E x Y | G x Y x E | Mean |
|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | *** | *** | *** | ** | ns | *** | ** | 153.07 |
| Forage DM yield (t/ha) | *** | ns | ** | * | ns | *** | ns | 1.70 |
| Leaf to stem ratio | ** | * | *** | ns | ns | *** | ns | 0.36 |

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

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

| Accessions | Locations | | | | | | Combined analysis | | |
|---|---|---|---|---|---|---|---|---|---|
| | Assosa | | | Tongo | | | 2018 | 2019 | Mean |
| | 2018 | 2019 | Mean | 2018 | 2019 | Mean | | | |
| *V. sativa* 5172 | 0.30 | 0.41[a] | 0.35[a] | 0.69 | 0.33 | 0.51 | 0.50 | 0.37 | 0.43 |
| *V. benghanlensis* 6798 | 0.26 | 0.27[b] | 0.27[b] | 0.55 | 0.37 | 0.46 | 0.41 | 0.32 | 0.36 |
| *V. villosa* 6213 | 0.22 | 0.21[c] | 0.22[b] | 0.59 | 0.34 | 0.46 | 0.40 | 0.27 | 0.34 |
| *V. villosa* 6792 | 0.23 | 0.23[bc] | 0.23[b] | 0.43 | 0.33 | 0.38 | 0.33 | 0.28 | 0.31 |
| Mean | 0.25 | 0.28 | 0.27[b] | 0.57 | 0.34 | 0.45[a] | 0.41 | 0.31 | 0.36 |
| C.V. | 15.28 | 11.10 | 15.93 | 33.74 | 36.02 | 43.14 | 52.23 | 31.51 | 46.57 |
| P-value | 0.11 | 0.0002 | <.0001 | 0.46 | 0.97 | 0.72 | 0.61 | 0.34 | 0.31 |

C.V.: coefficient variation; Means with different letters are significantly different.

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, hence, Tongo location was cooler than Assosa.

**Plant height**

The plant height at the forage harvesting stage of the tested *vicia* accessions is indicated in Table 4. Plant height for tested *Vicia* accessions at forage harvest showed significant variation ((P < 0.001) at both locations and combined analysis. *V. sativa* 5172 was the shortest at both testing sites and combined analysis. In agreement to this study (Gezahagn *et al*., 2014) reported that *V. sativa* (erect growth habit) was shorter than *V. villosa* (creeping or climbing growth habit) accessions at the central high land (Holetta and Ginchi) of Ethiopia. In agreement to this study (Ullah *et al*., 2009) 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.

**Forage dry matter yield**

Total dry matter yields were not significantly (P > 0.05) different among genotypes at both locations and combined analysis except significantly different (P < 0.05) for the mean at Tongo (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 might be attributed to due to the leaf to stem ratio of the value recorded for genotypes was numerically higher *V. sativa* 5172 than the other tested genotypes. 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. While the lower forage dry matter yield obtained from *V. sativa* 5172 might be due to the shorter plant height for *V. sativa* 5172 than the other tested genotypes. The forage dry matter yield is directly related to plant height at forage harvesting stage, because when the plant height at forage harvesting increases forage dry matter yield also increase (Mulisa *et al*., 2020).

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 Kebede (2016) 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).

## CONCLUSION

*Vicia* accessions responded 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

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

| Accessions | Locations | | | | | | Combined analysis | | |
|---|---|---|---|---|---|---|---|---|---|
| | Assosa | | | Tongo | | | 2018 | 2019 | Mean |
| | 2018 | 2019 | Mean | 2018 | 2019 | Mean | | | |
| *V. sativa* 5172 | 82.33[b] | 68.11[b] | 75.22[b] | 77.75[c] | 68.11[b] | 72.93[b] | 80.04[b] | 68.11[c] | 74.08[b] |
| *V. benghanlensis* 6798 | 248.67[a] | 167.39[a] | 208.03[a] | 132.67[b] | 167.39[a] | 150.03[a] | 190.67[a] | 167.39[a] | 179.03[a] |
| *V. villosa* 6213 | 251.33[a] | 159.67[a] | 205.50[a] | 161.83[a] | 159.67[a] | 160.75[a] | 206.58[a] | 159.67[ab] | 183.13[a] |
| *V. villosa* 6792 | 262.00[a] | 151.33[a] | 206.67[a] | 139.50[ab] | 151.33[a] | 145.42[a] | 200.75[a] | 151.33[b] | 176.04[a] |
| Mean | 211.08 | 136.63 | 173.85[a] | 127.94 | 136.63[a] | 132.28[b] | 169.51 | 136.63 | 153.07 |
| C.V. | 16.75 | 9.50 | 29.48 | 9.70 | 9.50 | 11.64 | 33.88 | 8.49 | 28.66 |
| P-value | 0.0007 | <.0001 | 0.0003 | 0.0002 | <.0001 | <.0001 | 0.0029 | <.0001 | <.0001 |

C.V.= coefficient variations; Means with the same letter are not significantly different.

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

| Accessions | Locations | | | | | | Combined analysis | | |
|---|---|---|---|---|---|---|---|---|---|
| | Assosa | | | Tongo | | | 2018 | 2019 | Mean |
| | 2018 | 2019 | Mean | 2018 | 2019 | Mean | | | |
| *V. sativa* 5172 | 1.96 | 0.90 | 1.43 | 1.29 | 1.58 | 1.43[b] | 1.63 | 1.24 | 1.43 |
| *V. benghanlensis* 6798 | 2.14 | 0.72 | 1.43 | 2.55 | 2.53 | 2.54[a] | 2.35 | 1.62 | 1.98 |
| *V. villosa* 6213 | 1.72 | 0.70 | 1.21 | 2.06 | 1.85 | 1.60[ab] | 1.89 | 1.27 | 1.58 |
| *V. villosa* 6792 | 1.76 | 0.72 | 1.24 | 2.15 | 2.51 | 2.33[a] | 1.95 | 1.61 | 1.78 |
| Mean | 1.89 | 0.76 | 1.33[b] | 2.01 | 2.12 | 2.06[b] | 1.95 | 1.44 | 1.7 |
| C.V. | 17.22 | 13.88 | 49.95 | 24.65 | 38.29 | 29.88 | 23.38 | 65.34 | 44.74 |
| P-value | 0.42 | 0.14 | 0.90 | 0.07 | 0.43 | 0.0290 | 0.09 | 0.82 | 0.32 |

C.V.: coefficient of variation; Means with different letters are significantly different.

environmental conditions in the Benishangul-gumuz region. In conclusion, *V. 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.

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