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Research Article

Morphological Characters, Dry Matter Production, and Nutritional Quality of Cowpea (*Vigna unguiculata L.*) as Influenced by Genotype and Environment

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Cowpea is an important grain legume crop used as feed for livestock, and its dry beans provide protein. Consequently, the objective of this study was to evaluate selected cowpea genotypes for herbage dry matter yield and nutritional quality in two agro-ecologies of the Benishangul-Gumuz region. The study was conducted at Kamashi and Assosa forages research stations of Assosa Agricultural Research Center, and the sites were purposively selected to represent lowland and midland agro-ecologies, respectively. Four cowpeas' accessions (*V. Unguiculata* ILRI-11114, ILRI-12688, ILRI-12713, and ILRI-9333) and one check (Melka (ILRI-9334) as a check) were evaluated in a randomized complete block design with three replications. Herbage dry matter yield, plant height at forage harvesting, and days to maturity were significantly affected by location (*L*). Longer plant heights, shorter days to maturity, and higher dry matter yield ($P < 0.001$) were recorded at Kamashi than at Assosa. Herbage dry matter yield was significantly $P < 0.05$ affected by year (Y), Y∗L (Y and L interaction), G∗L∗Y (genotype (G), L and Y interaction), and G∗L. Hebage dry matter yield was similar between years at Assosa, whereas at Kamashi significantly ($P < 0.001$) different and more yields were obtained in 2015. The genotypes did not differ in nutritional quality parameters such as ash, acid detergent fibre, crude protein, and organic matter digestibility ($P > 0.05$). However, neutral detergent fibre and acid detergent fibre were significantly ($P < 0.05$) influenced by genotype. Thus, from the present study, it can be recommended that cowpea genotypes ILRI-12688 are suitable for Assosa and ILRI-11114 to Kamashi areas in terms of biomass production.

1. Introduction

In Ethiopia, the main constraint to livestock production is a lack of feed, both in quantity and quality. Natural pasture residues are the main feed resources. It is estimated that natural pastures provide 80-85% of livestock feed in Ethiopia [1], and most of these natural pastures exist in lowland areas of the country [2]. Benishangul-Gumuz Regional State (BGRS) is one of the country's lowlands characterized by a long rainy season, and 3% of its geographical areas are covered by grasslands [3]. Long grasses which include Hypernia species dominate these grasslands. Finding adequate feed in the dry season is a challenge almost every smallholder farmer faces in BGRS. The quality of grasses declines as plants mature and become more fibrous with low crude protein, resulting in the accumulation of poor-quality biomass, which is slowly digestible and low in nutrients. This biomass is commonly consumed by a wildfire in the dry season. This results in low productivity, long calving intervals, susceptibility to diseases, and high livestock mortality. Reference [4] indicated the possibility of conserving the available green feeds in the rainy season as silage, but the protein content of the ensiled material was below the physiological requirement of animals. Thus, leguminous forages like cowpea could be an important source of protein supplements to fill the gap in such livestock production systems.

Cowpea (*Vigna unguiculata* L.) is a dicotyledonous plant in the Fabaceae family and subfamily Faboideae. It is an important grain legume crop used as livestock feed, and its dry beans contain 22% to 25% protein [5]. It is one of the extensively grown crops in the lowlands and midaltitude regions of Africa sometimes as the sole crop but more often intercropped with cereals such as sorghum and millet [6]. The grains are a good source of human protein, and the haulms are valuable livestock protein sources [7]. Cowpea fixes atmospheric nitrogen through symbiosis with nodule bacteria, and it can withstand harsh environments such as low soil fertility, water scarcity, and extreme temperatures [8]. Despite having a significant potential for forage production, there are no studies on cowpea to investigate its forage yield, seed yield, and quality in BGRS. Information is not available regarding cowpea accessions that will best adapt to different agro-ecologies of the region. Thus, this study was intended to select cowpea accessions that perform well in the two agro-ecological environments of the region.

2. Materials and Methods

2.1. Study Areas. This study was conducted from 2013 to 2016 in the Assosa Agricultural Research Center's research fields in the BGRS districts of Assosa and Kamashi. BGRS is located in the western part of Ethiopia, between 90 30′N and 110 39′N latitude and 340 20′E and 360 30′E longitude, with a total land area of 50 thousand square kilometres. The region's land features are diverse, with plain lowlands being the most prominent. Rainfall is unimodal and usually lasts 6 to 7 months, from April to October. Lowland areas, such as Kamashi, however, receive rain for 3-4 months. The average annual rainfall is approximately 1275 mm. Temperatures in the region range from mild to hot. The region's minimum and maximum temperatures range from 14°C to 20°C and from 25°C to 39°C, respectively. Dytric nitisol, orthic acrisols, chromic and orthic luvisols, and chromic and eutric fluvisols are the major soil types [9]. The Assosa Agricultural Research Center is located near the town of Assosa, which is 670 kilometres west of Addis Ababa. Kamashi is located 225 kilometres north-east of Assosa. The description of the locations is indicated in Table 1.

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

Parameter	Location	
	Kamashi	Assosa
Longitude	034°20′E 35°45′E	034°20′E 35°45′E
Latitude	09°30′N	10°30′N
Altitude (m)	1000-1350	1500-1550
Annual rainfall (mm)	1150	1316
Daily minimum temperature (°C)	30	27.9
Daily maximum temperature (°C)	25	16.75
Soil type	Nitisol	Nitisol

2.2. Experimental Design and Crop Management. The source of the cowpea accessions (ILRI-11114, ILRI-12688, ILRI-12713, ILRI-9333, and ILRI-9334) is International Livestock Research Institute (ILRI) which is in Addis Ababa. These genetic materials were planted in the main rainy season of each year in the two locations. A randomized complete block design (RCBD) with three replications was used for the experiment. The plot was 12 m^2 in size, with 25 cm and 5 cm between rows and plants, respectively. The spaces between plots and blocks were 1 and 1.5 meters, respectively. At each season of planting, a di-ammonium phosphate (DAP) fertilizer was applied at 100 kg/ha rate. Weeds were controlled on a regular basis by hand removal, and other management, such as disease control, was carried out as needed.

2.3. Data Collection and Sampling Techniques. The sample for herbage yield at the 10% blooming stage was taken from 0.5 m^2 from the central part of the plot. Total fresh biomass from this area is measured using sensitive balance and subsampled to 500 grams. These subsamples were further partitioned into leaf and stem. Then, the fresh leaf and stem parts of the sample were used for determination of the dry matter content and further laboratory analysis. Number of branches per plant and plant height were measured on six randomly selected plants from the sampling area. The number of days to flowering was calculated as the number of days from emergence to 50% flowering.

Seed yield and seed-related traits were collected from another area of 0.5 m^2 in the central part of the plot. At the flowering stage 6, randomly selected plants were tagged from each plot within this sampling area. These sample plants were used to record data which include plant growth habit, flower color, root length, number of nodules per plant, nodule color, number of pod per plants, pod length, number of seeds per pod, and 100-seed weight. Seed moisture content and 100-seed weight were determined using the seed-test method of the International Seed Testing Association. Then, the total seed yield and 100-seed weight were adjusted to 10 percent moisture.

The dry matter content was determined by oven drying for 72 hours at 63°C. Dried samples were analyzed for ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), and in vitro organic matter digestibility (IVOMD). CP and Ash were analyzed according to Reference [10] procedures. The ADF, NDF, and lignin contents were analyzed according to Reference [11]. IVOMD was determined according to Reference [12].

2.4. Data Analysis. R software was used for data management and analysis. Descriptive and ANOVA techniques were used in data analysis. The least mean difference was employed for mean separation when $P < 0.05$. A general linear model was employed to understand the effects of genotypes, location, and year of production on yield and yield components. The model is indicated below:

$$Yijkl = \mu + Gi + Lj + Yk + GLij + GYik + LYjk + GLYijk + eijkl, \quad (1)$$

where $Yijkl$ is the dependent variable; μ is the overall mean; Gi is the effect of genotype I; Lj is the effect of location j, j = Assosa and Kamashi; Yk is the effect of year of production

Table 2: Combined analysis of variance for agronomic traits of cowpea accession tested across two locations.

Trait	Year (Y)	Location (L)	Genotype (G)	Y * L	Y * G	L * G	Y * L * G	Mean
Plant height (cm)	* **	* **	ns	* **	ns	* **	ns	73.92
Number of branches	*	ns	ns	*	ns	ns	ns	7.75
Dry-leaf-to-stem ratio	ns	* *	ns	* **	ns	ns	ns	0.47
Days to flowering	* **	* **	ns	* **	* **	* **	* **	79.80
Dry matter yield (t/ha)	* **	* **	ns	* **	ns	*	ns	4.02

k, $k = 2014$, 2015, and 2016; $GLij$ is the genotype i and location j interaction effect; $GYik$ is the genotype i and year k interaction effect; $LYjk$ is the location j and year k interaction effect; $GLYijk$ is the genotype i, location j, and year k interaction effect; and $eijkl$ is a random error.

3. Results

Location had a significant effect ($P < 0.001$) on plant height, days to maturity, and forage dry matter yield of cowpea. Genotype had no significant ($P > 0.05$) effect on growth parameters, days to maturity, and dry-leaf-to-stem ratio. Similarly, no significant location and genotype interaction ($P > 0.05$) effect was observed for number of branches per plant and dry-leaf-to-stem ratio (Table 2). The average plant height at Assosa was 52.5 cm, whereas at Kamashi it was 93.3 cm. Mean days to harvest were 76 and 67 for Assosa and Kamashi, respectively (Table 3).

Dry biomass yield (tone per hectare) of cowpea genotypes under the two agro-ecologies between 2014 and 2016 is presented in Table 4. There was no significant difference ($P > 0.05$) for dry biomass yield among the genotypes, but location and year of production had a significant effect. The cowpea accessions yielded better biomass in Kamashi than Assosa, but the yields were not consistent for the genotypes over the production years (Figure 1). That means, some accessions which yielded better in Kamashi are not consistently better yielded in Assosa and vice versa. In three years, the mean biomass yields of the cowpea accessions were 3.0 tone/ha and 5.1 to/ha for Assosa and Kamash, respectively. Cowpea genotypes ILRI-12688 and ILRI-9333 better performed in Assosa relative to others. In the same manner, genotypes ILRI-11114, ILRI-9334, and ILRI-12688 yielded better biomass in Kamashi in that order. The dry matter yield of the genotypes was significantly ($P < 0.001$) influenced by the location, and this result suggests that there was not any stable and high-yielding accession across the locations.

The mean biomass yields of the genotypes were similar to overproduction years at Assosa. However, at Kamash, the highest mean biomass was attained in 2015. Considering the production years, the overall mean biomass yields of the genotypes were 4.2, 4.4, and 3.5 ton/ha (DM) in 2014, 2015, and 2016, respectively. Thus, the least yield was harvested in 2016.

The nutritional qualities of biomass from the cowpea genotypes are presented in Table 5. Genotypes significantly ($P < 0.05$) were different in neutral detergent fibre (NDF) and acid detergent fibre (ADF). Accession ILRI-11114 had greater NDF content than those of ILRI-12688 and ILRI-9334; but not significantly different from ILRI-12713 and ILRI-9333. Similarly, ILRI-11114 had greater ADF content than the other 4 genotypes. Nutritional quality parameters such as ash, crude protein (CP), acid detergent lignin (ADL), and organic matter digestibility (OMD) were not significantly different ($P > 0.05$) among the genotypes. Location and year of production had no effect on forage quality parameters as well as seed and seed-related parameters and therefore were excluded from the statistical analysis.

In terms of seed yield and seed yield components, there were no significant ($P > 0.05$) differences between genotypes in the number of nodules per plant, pod length, number of pods per plant, and number of seeds per pod. However, there was a significant difference in grain yield ($P < 0.05$) and thousand seed weight ($P < 0.001$) among the genotypes. A greater yield was attained from ILRI-12688 than ILRI-9333 and ILRI-9334. The highest 100-seed weight was recorded for ILRI-12688 and ILRI-12713 followed by ILRI-933; on contrary, the lowest 100-seed weight was recorded for ILRI-9334 (Table 6).

4. Discussion

The overall performance of cowpea genotypes was better in Kamashi than in Assosa. This suggests that this location has better soil and climatic conditions for cowpea growing for forage purposes. Kamashi is a lowland area that gets rainfall within a short period of time, but in Assosa areas the rainy season is long and lasts for about 6 months. In agreement with this finding, Reference [13] reported that changes in rainfall have a positive or negative impact on the performance of forage species. Likewise, higher plant height was recorded at Kamash than in Assosa, and this variation between locations could be attributed to differences in rainfall and temperature levels, as well as soil physicochemical properties of the study areas. This result of this study is supported by the findings of References [13, 14], who reported that temperature, rainfall, and soil physicochemical properties are the major environmental factors that significantly affect plant height. Similarly, other authors have also mentioned soil nutrients, soil pH [15], and air temperature [16] as environmental factors that influence plant height.

Taller plant heights in Kamashi resulted in better biomass yields. This is because longer plants possess relatively more leaves and branches which may result in an increase in biomass yield. According to annual Basque Research (Cited in [13]), plants grown in water-stressed conditions tend to grow taller to compete for nutrients in the growing environment. An increase in plant height at the Kamashi

Table 3: Effect of genotype on growth parameters, leaf-to-stem ratio, and maturity of cowpea accessions (Mean ± SE).

Genotype	Plant height (cm)			Number of branches			Dry-leaf-to-stem ratio			Days to flowering		
	Assosa	Kamashi	Mean	Assosa	Kamashi	Mean	Assosa	Kamash	Mean	Assosa	Kamash	Mean
ILRI-11114	50.4 ± 3.9	91.3 ± 10.6	70.8 ± 7.4	6.9 ± 1.0	7.3 ± 1.3	7.1 ± 0.6	0.44 ± 0.06	0.52 ± 0.06	0.48 ± 0.04	74.1 ± 3.1	67.4.0 ± 2.4	70.7 ± 2.0
ILRI-12688	42.5 ± 3.5	97.3 ± 12.6	69.9 ± 9.2	7.3 ± 1.3	6.6 ± 0.6	7.0 ± 0.7	0.38 ± 0.05	0.55 ± 0.05	0.46 ± 0.04	76.4 ± 3.1	66.3 ± 2.4	71.4 ± 2.0
ILRI-12713	56.7 ± 5.2	94.8 ± 12.9	75.8 ± 8.2	7.5 ± 1.3	7.0 ± 0.9	7.2 ± 0.8	0.44 ± 0.05	0.48 ± 0.04	0.46 ± 0.03	76.4 ± 3.1	66.3 ± 2.4	71.4 ± 2.0
ILRI-9333	51.9 ± 3.8	98.6 ± 11.0	75.2 ± 8.0	7.2 ± 1.1	7.7 ± 1.0	7.4 ± 0.7	0.53 ± 0.14	0.53 ± 0.10	0.53 ± 0.08	76.4 ± 3.1	66.3 ± 2.4	71.4 ± 2.0
ILRI-9334	61.2 ± 9.1	84.3 ± 7.6	72.7 ± 6.4	5.6 ± 0.8	6.3 ± 0.8	5.9 ± 0.6	0.45 ± 0.06	0.42 ± 0.02	0.43 ± 0.03	74.6 ± 3.2	69.0 ± 1.2	71.8 ± 2.1
Sign.	ns	*	ns	ns	*	ns	ns	ns	ns	ns	ns	ns

ns = nonsignificant ($P > 0.05$).

Table 4: Dry biomass yield (ton/ha) of cowpea genotypes under Assosa and Kamashi environments from 2014 to 2016 (mean ± SD).

Genotype	Assosa			Mean	Kamash			Mean
	2014	2015	2016		2014	2015	2016	
ILRI-11114	3.0 ± 0.74[ab]	3.1 ± 0.10[a]	3.0 ± 0.13[ab]	3.0 ± 0.38[ab]	5.4 ± 1.71	7.0 ± 1.18	4.2 ± 1.51[b]	5.5 ± 1.76
ILRI-12688	3.6 ± 0.18[a]	3.0 ± 0.00[a]	3.5 ± 0.29[a]	3.4 ± 0.35[a]	4.8 ± 0.38	5.5 ± 0.20	5.2 ± 1.55[a]	5.2 ± 0.86
ILRI-12713	3.1 ± 0.27[a]	2.9 ± 0.53[a]	2.8 ± 0.42[bc]	2.9 ± 0.38[b]	4.6 ± 0.33	5.9 ± 1.01	3.9 ± 0.37[b]	4.8 ± 1.06
ILRI-9333	3.4 ± 0.30[a]	3.2 ± 0.27[a]	3.3 ± 0.05[ab]	3.3 ± 0.28[a]	6.0 ± 1.90	4.9 ± 0.31	3.1 ± 0.18[b]	4.7 ± 1.62
ILRI-9334	2.4 ± 0.55[b]	2.1 ± 0.52[b]	2.5 ± 0.60[c]	2.3 ± 0.52[c]	5.7 ± 1.11	6.4 ± 1.45	3.8 ± 1.32[ab]	5.3 ± 1.63
Mean	3.1 ± 0.58	2.9 ± 0.52	3.0 ± 0.47		5.3 ± 1.21	6.0 ± 1.10	4.0 ± 1.21	
Significance	*	*	*	***	ns	ns	*	ns

ns = nonsignificant ($P > 0.05$), * = $P < 0.05$, *** = $P < 0.001$.

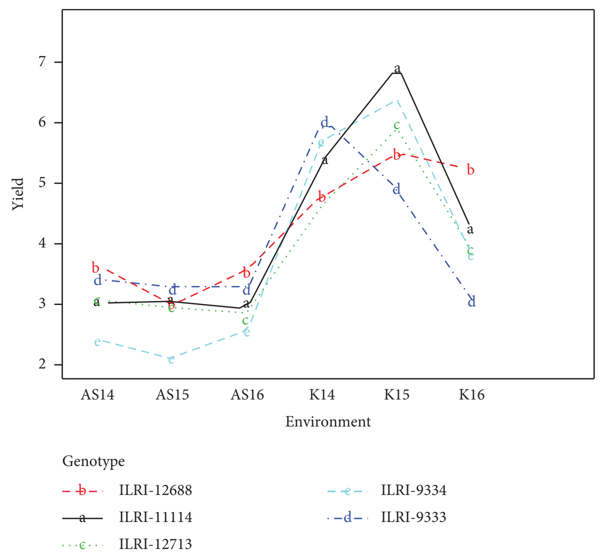

Figure 1: Interaction plot of 5 cowpea accessions in 6 environments (where AS 14 is Assosa in 2014, AS15 is Assosa in 2015, AS16 is Assosa in 2016, K14 is Kamashi in 2014, K15 is Kamashi in 2015, and K16 is Kamashi in 2016).

Table 5: Nutrient content of cowpea biomass from 100% DM (mean ± SE).

Accession	Ash%	NDF%	ADF%	ADL%	CP%	%OMD
ILRI-11114	10.4 ± 0.38	65.4 ± 2.71[a]	53.4 ± 1.81[a]	10.4 ± 0.28	16.0 ± 0.12	43.3 ± 3.37
ILRI-12688	10.6 ± 0.25	56.9 ± 0.31[b]	46.4 ± 2.27[b]	10.2 ± 0.90	14.1 ± 0.77	49.3 ± 2.17
ILRI-12713	10.5 ± 1.13	60.3 ± 1.61[ab]	44.0 ± 1.77[b]	9.3 ± 0.76	17.1 ± 1.30	50.5 ± 4.61
ILRI-9333	10.4 ± 2.07	60.2 ± 1.50[ab]	46.1 ± 0.78[b]	10.6 ± 0.76	16.1 ± 1.51	50.9 ± 6.08
ILRI-9334	10.6 ± 1.25	56.6 ± 1.73[b]	47.0 ± 1.75[b]	11.9 ± 0.14	14.6 ± 0.64	54.1 ± 2.19
Sign.	ns	*	*	ns	ns	ns

NDF = Neutral detergent fibre; ADF = Acid detergent fibre; ADL = Acid detergent lignin; CP = Crude protein; OMD = Organic matter digestibility; * = $P < 0.05$ and ns = nonsignificant.

location, however, did not come with increased seed yield. This is because increased plant height at the harvest stage under water stress conditions was recorded at the expense of seed yield. The result of this study was consistent with previous findings presented by authors in Reference [14] who carried out a similar experiment on cowpea under water stress conditions. The shorter maturity period in Kamashi is mainly attributed to the shorter rainy season in the area.

The inconsistent biomass yield of cowpea genotypes under Kamashi and Assosa locations could be attributed to variations in rainfall and related climatic and agro-pedology factors over the production years. This could be due to the interaction effect of genotype and environment, which had a significant impact on forage dry matter yield. The result of this study is supported by the finding of Reference [17], that a significant difference in genotype stability is caused by the crossover interaction effect of genotype and environment. Likewise, Reference [18] reported that the interaction results from differences in a genotype relative performance across environments caused by genotype differences in response to various climatic, edaphic, and biotic factors. In accordance with the findings of this study, Reference [19] reported that

Table 6: Seed yield and yield components of cowpea genotypes (mean ± SE).

Genotype	Number of nodule/ plant	Pod length	Number of pod/ plant	Number of seed/ pod	Grain yield/ha (kg)	100-Seed weight (gm)
ILRI- 11114	8.4 ± 1.26	12.4 ± 1.83	6.9 ± 1.68	9.5 ± 0.66	1194.4 ± 237.61^{ab}	9.9 ± 0.08^{c}
ILRI-12688	12.0 ± 3.13	13.2 ± 2.02	5.1 ± 1.26	9.8 ± 1.98	1524.3 ± 280.73^{a}	13.3 ± 1.13^{a}
ILRI-12713	10.4 ± 3.15	13.9 ± 1.44	5.2 ± 1.16	10.9 ± 2.46	1043.8 ± 437.58^{ab}	12.9 ± 0.17^{a}
ILRI-9333	10.7 ± 3.96	13.3 ± 1.48	5.8 ± 1.50	10.61.06	854.2 ± 173.37^{b}	11.6 ± 0.62^{b}
ILRI-9334	8.8 ± 1.51	12.6 ± 1.12	7.5 ± 2.25	10.9 ± 1.29	714.6 ± 178.63^{b}	6.2 ± 0.22^{d}
Sign.	ns	ns	ns	ns	*	* **

genotypes selected for superior performance under one set of environmental conditions may perform poorly under another set of environmental conditions due to high genotype-by-location interaction effects. There were significant differences in biomass yield among tested genotypes, implying specific adaptation and the need for location-specific recommendations. Thus, from the present study, it can be recommended that cowpea genotypes ILRI-12688 are suitable for Assosa and ILRI-11114 to Kamashi areas in terms of biomass production. However, a firm conclusion cannot be reached in this regard because of the lack of feeding trials using these genotypes. Genotype ILRI-12688 had a better grain yield than others so it can be grown as a dual-purpose crop; that means, it can be used as a source of human food and as fodder for animals.

In the Benishangul-Gumuz region, livestock is mainly dependent on grasses, and hence these feeds are deficient in protein. Farmers in the region do not have access to commercial diets to feed their livestock. Thus, as cowpea is a good source of protein and own reasonable digestible energy, it can be a good supplement to feed livestock under subsistence farming systems of the region. However, the nutrient content and indicators of feed intake and digestibility of genotypes at present were inferior to some of the previous findings elsewhere in the tropical areas [20, 21]. This could be associated with seasonal variation and stage of maturity at harvest, infestation, intensity of pests, and variation in genetics.

5. Conclusion

From this research, it can be concluded that cowpea is an important forage crop with good yield and quality in the Benishangul-Gumuz region of Ethiopia. So, this crop can play an important role to fill the forage gap in the dry season by making hay from it. The overall performance of all cowpea genotypes was better in Kamashi than Assosa. Genotype ILRI-11114 was well adapted to Kamashi compared to other genotypes, and genotype ILRI-12688 was relatively good in Assosa. Thus, these genotypes can be recommended to specific locations. More research on the performance of animals fed these genotypes is needed before making firm recommendations.

Data Availability

The data used to support the findings of this study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References

[1] G. Kidane, *Effect of Cutting Date on Botanical Composition and Nutritive Value of Native Pasture in the Central Ethiopian Highlands*, Alemaya University, Dire Dawa, Ethiopia, 1993.

[2] A. Mengistu, *The Borana and the 1991-92 Drought: A Rangeland and Livestock Resource Study*, Institute for Sustainable Development, Winnipeg, Canada, 1998.

[3] A. Alemayehu and T. Woldegabriel, "Condition, species composition and productivity of natural pastures of benishangul-Gumuz regional state, western Ethiopia," *African Journal of Basic and Applied Science*, vol. 8, no. 4, pp. 220–231, 2016.

[4] A. Abebe, H. Alebachew, M. Faji, D. Almaw, and W. Tesfamariam, "Effect of growth stage at harvest and type of additives on nutritional quality and fermentative characteristics of Hypernia rufa silage," *African Journal of Basic and Applied Science*, vol. 9, no. 5, pp. 286–291, 2017.

[5] R. Goenaga, A. Quiles, and A. G. Gillaspie, "Assessing yield potential of cowpea genotypes grown under virus pressure," *HortScience*, vol. 43, no. 3, pp. 673–676, 2008.

[6] O. M. Agbogidi, "Screening six cultivars of cowpea (Vignia unguiculata L.) walp for adaptation to soil contaminated with spent engine oil," *Journal of Environmental Chemical Ecotoxicology*, vol. 2, no. 7, pp. 103–109, 2010.

[7] C. A. Fatokun, "Breeding cowpea for resistance to insect pests: attempted crosses between cowpea and Vigna vexillata," *Challenges Opportunity Enhancing Sustained Cowpea Production*, International Institute of Tropical Agriculture, Ibadan, Nigeria, 2002.

[8] R. P. Shiringani and H. A. Shimelis, "Yield response and stability among cowpea genotypes at three planting dates and test environments," *African Journal of Agricultural Research*, vol. 6, no. 14, pp. 3259–3263, 2011.

[9] B. Teklu, T. Negesse, and A. Angassa, "Effect of farming systems on livestock feed resources and feeding systems in Benishangul-Gumuz region, western Ethiopia," *International Research Journal of Agricultural Science*, vol. 1, no. 1, pp. 20–28, 2011.

[10] A. Oac, *Official Methods of Analysis*, AOAC International, Washingt. DC, USA, 15th edition, 1990.
[11] P. Van Soest, J. B. Robertson, and B. A. Lewis, "Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition," *Journal of Dairy Science*, vol. 74, no. 10, pp. 3583–3597, 1991.
[12] J. M. A. Tilley and R. A. Terry, "A two-stage technique for the in vitro digestion of forage crops," *Grass and Forage Science*, vol. 18, no. 2, pp. 104–111, 1963.
[13] S. Mishra, R. Singh, R. Kumar, A. Kalia, and S. R. Panigrahy, "Impact of climate change on pigeon pea," *Economic Affairs*, vol. 62, no. 3, pp. 455–457, 2017.
[14] S. K. Behera, A. K. Shukla, P. K. Tiwari et al., "Classification of pigeonpea (Cajanus cajan (L.) Millsp.) genotypes for zinc efficiency," *Plants*, vol. 9, no. 8, p. 952, 2020.
[15] F. S. Sekhon, T. Singh, and S. Singh, "Growth, phenology and yield of pigeonpea (Cajanus cajan) as affected by intercropping systems and application of nutrients level to intercrops," *Indian Journal of Agricultural Science*, vol. 88, pp. 509–514, 2018.
[16] T. D. Abney and V. M. Russo, "Factors affecting plant height and yield of eggplant," *Journal of Sustainable Agriculture*, vol. 10, no. 4, pp. 37–48, 1997.
[17] G. Kebede, F. Feyissa, G. Assefa et al., "Evaluation of Napier grass (Pennisetum purpureum (L.) Schumach) accessions for agronomic traits under different environmental conditions of Ethiopia," *International Journal of Advanced Research*, vol. 4, no. 4, pp. 1029–1035, 2016.
[18] A. G. O. Dixon and E. N. Nukenine, "Statistical analysis of cassava yield trials with the additive main effects and multiplicative interaction (AMMI) model," *African Journal of Root Tuber Crop,* vol. 3, no. 1, pp. 46–50, 1997.
[19] S. Ceccarelli, "Adaptation to low/high input cultivation," *Euphytica*, vol. 92, no. 1-2, pp. 203–214, 1996.
[20] S. N. Heinritz, S. Hoedtke, S. D. Martens, M. Peters, and A. Zeyner, "Evaluation of ten tropical legume forages for their potential as pig feed supplement," *Livest Research and Rural Development*, vol. 24, no. 1, 2012.
[21] B. Kambashi, G. Kalala, D. Dochain et al., "Nutritive value of three tropical forage legumes and their influence on growth performance, carcass traits and organ weights of pigs," *Tropical Animals and Health Productions*, vol. 48, no. 6, pp. 1165–1173, 2016.