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Research Article

Assessing the Fodder Potentials of Drought-Tolerant Maize (*Zea mays* L.) Hybrids in West Africa

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The study evaluated the fodder potential of 42 promising drought-tolerant (DT) three-way cross maize (*Zea mays* L.) hybrids, 11 commercial hybrid checks, and 1 local variety check under irrigation. Agronomic and laboratory trials were conducted to determine their morphological traits and fodder potential. Hierarchical cluster analysis (HCA) to group cultivars into clusters is based on quantity, quality, and the combination of both variables. Selection of potential food-feed cultivars was based on the quantity traits (grain and biomass yield) and quality traits crude protein (CP), *in vitro* organic matter digestibility (IVOMD), and metabolizable energy (ME). Variation was found for dry matter yield (DMY) at harvest as commercial hybrid recording the maximum DMY of 14.1 $t\,ha^{-1}$ and the highest grain yield of 1.4 $t\,ha^{-1}$ ($P < 0.01$), while local check produced a minimum grain yield of 0.54 $t\,ha^{-1}$ ($P < 0.01$) with grain moisture content range between 8.4 and 11.6%. The maximum mean ash content was 5.8% for DT hybrids. Average CP was the highest in commercial hybrids with a value of 6.1%. The mean values for ME were similar ($P > 0.01$) in both commercial hybrids (7.2 MJ/kg DM) and DT hybrid (7.2 MJ/kg DM), while the highest ME (7.6 MJ/kg DM) was recorded for the local check. Ranking of the hybrids based on grain yield, DMY, CP, ME, and IVOMD showed that cluster subgroup A3 (M1124–24, M1527-7, 30F32, and M1427-6) and A4 (M1427-3, SC637, and M1627-11) exhibited the best potential traits and can therefore be recommended for commercial cultivation following adoption trials by farmers.

1. Introduction

Feed and feeding issues are factors limiting successful ruminant production in sub-Saharan Africa (SSA). Seasonal variation often leads to extreme scarcity and low feeding value of feed resources during the dry season [1]. Seasonal scarcity of the major feed resources results in increased livestock susceptibility to diseases [2] and migration of flocks and herders, which contributes to conflict between farmers and herders in many West African countries [3]. Livestock farmers in these regions mostly feed their livestock with cereal residues (sorghum, millet, and maize stovers) as a basal diet, while cowpea and groundnut haulms are fed as protein supplements [4]. With the strong increase in demand for animal-sourced food in developing countries and the associated demand for more feed [5], food-feed crop cultivars that provide good fodder quantity and quality besides grain yield in mixed crop-livestock systems, where land and fodder are becoming increasingly scarce, maybe the best fit solution.

Maize (*Zea mays* L.), a staple food crop that is fast becoming an industrial crop in SSA, is grown in diverse environments and consumed by people with varying food preferences and socioeconomic status [6]. Because maize is highly responsive to production inputs, it is widely used for food and agroindustrial purposes (breweries, mills). The importance of maize cannot be overemphasized in the developing world, including the potential to mitigate present food insecurity concerns and alleviate poverty. It is estimated that by 2050, the demand for maize in developing countries will double [6].

Grazing whole maize plants also offers green fodder to livestock in periods of scarcity (dry and hot summers and winters) [7, 8]. In areas where conditions are harsh and forage is scarce, maize green forage is a valuable source of fodder for smallholder-owned stock [9]. Despite being a versatile crop, maize production and maize breeding efforts over time have typically focused on maize grain yield [10]. Maize stover is an important additional byproduct and benefits from maize cultivation. Several maize breeding programs in Nigeria focus on Striga resistance, drought tolerance, and low-N tolerant to increase and stabilize maize grain yield [11, 12]. However, crop breeders have given little attention to the improvement of stover quality and quantity. Findings from other regions strongly suggest the opportunity for exploiting existing genetic variation for maize stover quantity and quality [13, 14]. Maize cultivars with superior residue yield and fodder quality can have substantial impact on livestock productivity, especially where livestock densities are high and alternative feed resources are insufficient.

Optimization for one trait (grain) is inherently easier than for two traits (grain and fodder) and may be pursued in instances where the fodder/stover value is negligible. However, the widespread use of maize stover suggests it indeed has value as fodder. Given that both traits (grain and fodder) have value and improvement for each is likely subject to diminishing returns, dual-purpose breeding could potentially exploit these parallel economic objectives. Like many other kinds of cereal, maize varieties appear to have a wide range of grain and stover yields and stover quality for feeding ruminants, and, most interestingly, there are prospects within the range of stover quality to increase fodder quality without compromising grain yield [15].

The International Institute of Tropical Agriculture (IITA) has developed several maize cultivars with superior traits for disease resistance, drought tolerance, and grain yield in the West Africa tropics. These cultivars need to be evaluated as well for fodder potential, which may facilitate their adoption, particularly within the crop-livestock farming system. Hence, the main objective of this study was to assess the genetic variability of improved maize cultivars for fodder quantity and quality and determine the relationships of these with grain yield variables.

2. Materials and Methods

2.1. Genetic Materials, Experimental Layout, and Data Collection. The genetic materials used for this study were 53 maize cultivars consisting of 42 promising drought-tolerant (DT) three-way cross maize hybrids developed at IITA, 11 commercial hybrid checks, and 1 local variety check commonly grown by farmers in the region (Table 1). Eleven of these DT hybrids had been evaluated under combined drought and heat stress for 3 years [16]. In this study, we further assessed their morphological traits and fodder potential to determine their complementary potential for crop-livestock farmers as feed resources during the dry season under irrigated conditions.

The experiment was arranged in 9 × 6 Alpha Lattice design with three replications. Each replicate consisted of nine incomplete blocks with six plots in each block. The experiment was conducted at Ikenne (6°52′N, 3°43′ E, altitude 60 masl) Southwest Nigeria during the dry season (November 2018-March 2019) under irrigated conditions. Each cultivar was planted in a two-row plot with a row length of 4 m long, with intra- and interrow spacing kept at 50 × 75 cm apart. Three seeds were planted in a hole and thinned to two plants per hill three weeks after sowing to attain a population density of 53,000 plants per hectare (ha^{-1}).

Table 1: List of three-way cross drought-tolerant maize cultivars and a local check used for assessing fodder potential in Nigeria.

Entry	Name	Entry	Name	Entry	Name
	DT hybrids	19	M1427-19	38	M1627-6
1	M1124-16	20	M1427-2	39	M1627-7
2	M1124-17	21	M1427-20	40	M1627-8
3	M1124-24	22	M1427-3	41	M1627-9
4	M1124-27	23	M1427-4	42	M1227-5
5	M1124-29	24	M1427-6		*Commercial hybrids*
6	M1124-31	25	M1427-8	43	Oba super I
7	M1227-10	26	M1527-3	44	Oba super II
8	M1227-11	27	M1527-6	45	SAMMAZ 22
9	M1227-12	28	M1527-7	46	SAMMAZ 23
10	M1227-3	29	M1627-1	47	SC637
11	M1304-16	30	M1627-10	48	SC643
12	M1309-67	31	M1627-11	49	SC719
13	M1427-10	32	M1627-12	50	11C82
14	M1427-12	33	M1627-13	51	11C86
15	M1427-13	34	M1627-2	52	13C3
16	M1427-14	35	M1627-3	53	30F32
17	M1427-15	36	M1627-4	54	*Local check*
18	M1427-18	37	M1627-5		

Standard crop management practices recommended for maize production were used in this experiment. A compound fertilizer was applied at the rates of 60 kg N, 60 kg P, and 60 kg K ha^{-1} at the time of planting. An additional 60 kg N ha^{-1} was applied as top dressing four weeks later. Gramoxone and atrazine were applied as preemergence herbicides at the rates of 1.5 L gramoxone and 2.5 L atrazine in 200 L of water ha^{-1}. Subsequent manual weeding was done to keep the trials weed free. Fall armyworm attacks on maize crop were controlled by using Ampligo. A sprinkler irrigation system was used to provide sufficient water every week from planting until physiological maturity.

Data on both nutritive quality and yield traits were recorded on five randomly selected plants of each cultivar. Leaf length and breadth were measured to compute leaf area according to [17] as shown in the formula:

$$\text{Leaf area} = \text{maximum leaf length (cm)} \times \text{maximum leaf breadth (cm)} \times 0.75, \quad (1)$$

where 0.75 is correction factor.

Stay green characteristics were evaluated by measuring the percentage residual green leaf area at harvest. Biomass yield was determined by harvesting the ranked plant materials (comprising the leaf and stem) from each maize cultivar at maturity. Harvested materials were oven dried at

60–70°C, for two days, and weighed, and dry matter yield (DMY) was recorded in t ha^{-1}.

Agronomic data were recorded on plant and ear heights, days to anthesis and silking, leaf senescence, number of plants at harvest, number of ears harvested, grain moisture content, and grain yield on a per plot basis. Plant and ear heights were measured in centimetres (cm) from the base of the plant to the insertion of the first tassel branch and to the top ear of the same plant, respectively, three weeks after flowering. Days to anthesis and silking were estimated as the period between planting to when 50% of the plants produced pollen and visible silks, respectively. Anthesis to silking interval (ASI) was computed as a difference between days to silking and anthesis. Leaf senescence score (LSS) was on a scale of 1 to 10, where 1 = 10% dead leaf area. Cultivars with lower LSS would be desirable for fodder production. The total number of plants at harvest was counted, while the total number of ears with at least one fully developed grain was counted after harvest and recorded as the number of harvested ears. All ears harvested from each plot were shelled and used to determine percentage grain moisture (moisture content) and grain weight. Grain yield was then adjusted to 15% moisture computed from the grain weight recorded from each plot.

2.2. Chemical Analysis. In all the analyses (both chemical and statistical analyses), one of the 42 DT hybrids, M1227-5, had very poor performance and therefore was removed, bringing down the total number of entries in this study to 53. Fodder samples from five randomly selected plants in each plot were collected in paper bags at physiological maturity and oven dried. Dried samples were ground to pass through a 1 mm mesh and then scanned with Near-Infrared Reflectance Spectroscopy (NIRS) instrument FOSS Forage Analyzer 2500 installed with software package WinISI II. Predicted variables were straw nitrogen content (N), neutral detergent fibre (NDF) and acid detergent fibre (ADF), acid detergent lignin (ADL), *in vitro* organic matter digestibility (IVOMD), and metabolizable energy (ME). Crude protein was estimated from nitrogen (N) content (crude protein = $N \times 6.25$), while IVOMD represents the potential digestibility of fodder.

2.3. Selection and Cluster Analysis. Our selection for potential food-feed cultivars among the cultivars in the present study was largely based on the grain yield and biomass quantity traits (DMY and LSS). We also used laboratory-based biomass quality traits: CP, IVOMD, and ME which have been used previously in assessing forage and residue feedstuffs and are widely used in routine feed analysis [18].

A hierarchical cluster analysis (HCA) was performed based on aforementioned quantity, quality, and the combination of both variables. To get the best possible grouping, this was exhaustively analyzed using different agglomeration methods; however, the agglomeration method that provided the best result was the Ward method [19]. The multivariate analysis of variance was used to determine the number of optimal classes. Both quality and quantity traits were clustered and separated according to similar performance among the cultivars presented in the dendrogram.

2.4. Statistical Analysis. Analysis of variance (ANOVA) for yield data and other desirable agronomic traits was computed using SPSS version 25 [20]. The mean comparison among the cultivars was determined using Fisher's least significance difference (LSD) test at 95% level of significance. The results presented the mean values and the P values only due to the large number of cultivars under trial. Relationships among traits (Pearson correlations) were computed from the mean using (SPSS, 2017). Genetic diversity analysis is based on agronomic grain yield, dry matter yield (DMY), leaf senescence score, crude protein (CP), metabolizable energy (ME), and *in vitro* organic matter digestibility (IVOMD) using a hierarchical algorithm with Euclidean distances and Ward's method. This procedure was thence used to construct dendrogram and the resulting tree was used to determine the association between the 42 drought-tolerant (DT), 11 commercial hybrid checks, and one local variety check both for the grain/fodder yield and the aforementioned qualitative traits.

3. Results

3.1. Yield and Yield Components. Significant differences ($P < 0.01$) were found among the values of maize cultivar groups, as well as variation in DMY at harvest. Dry matter yield (14.1 t ha^{-1}) was recorded for commercial hybrids with a range of 10.9–19.5 t ha^{-1}, followed by an average DMY of 13.9 t ha^{-1} and 13.6 t ha^{-1} recorded from DT hybrid and local check, respectively. The least leaf and stem yields were recorded from local check while maximum corresponding yield was recorded from commercial hybrids followed by DT hybrids (Table 2). On average, similar grain yield values (1.4 t ha^{-1}) were recorded for commercial hybrids and DT hybrids, which were higher than grain yield (0.5 t ha^{-1}) recorded in local check. The highest grain moisture content (11.6%) was recorded among the commercial hybrids, with a range of 10.8–12.1% while the least (8.4%) was recorded in local check (Table 2). DT hybrids had a shorter interval of 3 days between anthesis and silking while local check had longer days (4.3 days) before silking from the date of anthesis (Table 2).

Generally, among the maize cultivar groups in the current study, a close margin in the number of plants at harvest was observed (Table 2). A number of 32.5 plants per plot was recorded for commercial hybrids, with a range of 28.7–35.3. The numbers of ears at harvest were 17.9 and 17.2 for commercial hybrids and DT hybrids, respectively.

Significant variations were observed for plant height among the cultivar groups. A maximum of 154 cm was recorded for both commercial hybrids and DT hybrids, while tallest plants (171 cm) were recorded among the local check. Values for ear height at harvest were 86, 82, and 96 cm for commercial hybrids, DT hybrids, and local check, respectively. Leaf area ranged from 505 to 644 for commercial hybrids and from 449 to 584 for DT hybrids, and the least leaf area of 375 was recorded for local check maize (Table 2).

Table 2: Mean phenotypic parameters of commercial hybrid ($n = 11$), drought-tolerant (DT) hybrid (41), and local check different cultivar maize group.

	Grain yield (t ha^{-1})	DMY (t ha^{-1})	ASI	Plant height (cm)	Ear height (cm)	LSS	GMc	NPH	NEH	Leaf (t ha^{-1})	Stem (t ha^{-1})	Leave area
Commercial hybrid												
Mean	1.4 (<0.00001)	14.1 (<0.00001)	3.25 (<0.00001)	154.1 (<0.0020	86.4 (<0.001)	5.8 (<0.0001)	11.6 (<0.0001)	32.5 (<0.00001)	17.9 (<0.0001)	4.1 (<0.00001)	10.3 (<0.00001)	553.3 (<0.00001)
SEM	0.11	0.73	0.26	3.10	3.06	0.16	0.13	0.61	1.06	0.19	0.58	11.34
Range	0.9–1.9	10.9–19.5	2–4.7	139–173.3	73.3–101.7	4.7–6.3	10.8–12.1	28.7–35.3	11.7–24.3	3–5.2	7.8–14.5	504.8–644.4
DT hybrid												
Mean	1.4 (<0.00001)	13.9 (<0.00001)	3 (<0.00001)	154.1 (<0.002)	82.3 (<0.001)	6.1 (<0.0001)	10 (<0.0001)	31.1 (<0.00001)	17.2 (<0.00001)	3.7 (<0.00001)	10.2 (<0.00001)	515.7 (<0.00001)
SEM	0.20	0.48	0.26	2.02	1.31	0.19	0.62	2.12	1.86	0.23	0.40	11.31
Range	0.3–2.5	11–15.8	2.3–5	181.8–123.3	96.7–63.3	5.3–7.3	5.2–12.3	11.3–35.3	5.3–26.7	2.7–5.2	8–11.9	449.3–584.3
Local check	0.5	13.6	4.33	171.3	96.7	6.7	8.4	31	10.3	3.5	10	374.7

DMY = dry matter yield, ASI = anthesis-silking interval, PH = plant height, LSS = leaf senesces score, GMc = grain moisture content, NPH = numbers of plants at harvest, NEH = numbers of ear at harvest, SEM = standard error of mean.

TABLE 3: Means of nutritional characteristics of commercial hybrid ($n = 11$), drought-tolerant (DT) hybrid (41), and local check of different cultivar maize group.

	DM	Ash	CP	NDF	ADF	ADL	Cell	Hemcel	IVOMD	ME (MJ/kg DM)
Commercial hybrid										
Mean	90.9 (<0.00001)	5.7 (<0.00001)	6.1 (<0.00001)	81.1 (<0.00001)	50.1 (<0.00001)	6.2 (<0.00001)	43.9 (<0.00001)	31 (<0.00001)	46.2 (<0.00001)	7.2 (<0.00001)
SEM	0.12	0.19	0.28	0.63	1.07	0.11	1.02	1.07	0.56	0.08
Range	90.2–91.6	4.9–7.1	4.9–7.5	78.5–85.9	43.5–56.8	5.6–6.9	37.6–50.2	23.1–35.3	43.3–48.8	6.8–7.6
DT hybrid										
Mean	90.9 (<0.00001)	5.8 (<0.00001)	6.0 (<0.00001)	79.7 (<0.00001)	49.7 (<0.00001)	6.2 (<0.00001)	43.5 (<0.00001)	30 (<0.00001)	46.2 (<0.00001)	7.2 (<0.00001)
SEM	0.17	0.19	0.25	0.87	1.06	0.21	0.95	0.70	0.57	0.09
Range	89.7–91.5	4.4–6.6	4.8–7.3	73.7–84.5	44.2–54.9	5.3–7.5	38.6–47.9	27.3–34.4	43.8–50.0	6.8–7.7
Local check	90.8	5.7	8.2	77.1	39.9	5.2	34.72	37.3	49.2	7.6

CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ME = metabolizable energy, IVOMD = *in vitro* organic matter digestibility, DM = dry matter, ADL = acid detergent lignin, Cell = cellulose, Hemcel = hemicellulose.

Substantial variations were observed in the nutrient composition of the different maize cultivars. The results showed that the dry matter (DM) percentage within and between the cultivars was similar (91%), besides the ash content (6%). Similarly, the CP contents (6%) within and between the cultivar group were similar for both commercial and DT hybrids. The result however showed that the CP contents (8.2%) for the local check was higher than the CP recorded in both commercial and DT hybrids.

The NDF contents within the cultivar group showed a sequence as indicated: commercial hybrid > DT hybrids > local check, while the ADF, ADL, and cellulose indicated similar values for both commercial and DT hybrids. The values for IVOMD (49.2%) and ME (7.6 MJ/kg DM) recorded in the local check were higher than the values recorded for both commercial and DT hybrids (Table 3).

3.2. Correlation Analysis. Correlation analysis for nutritive and selected phenotypic traits for each cultivar group was performed and presented in Tables 4 and 5. There appeared to be a similar trend in the results. Grain yield was negatively and significantly correlated with leaf senescence score, both cultivar groups produced a significant and positive correlation between dry matter yield and leaf yield. Nutritionally, CP was negatively and significantly correlated with NDF and ADF, but positively significantly correlated with ash (for DT Hybrid). Similarly, IVOMD was negatively and significantly correlated with NDF and ADF but positively and significantly correlated with metabolizable energy from both cultivar groups. The results of relationships between the phenotypic and the nutritive traits had no significant correlations between CP, ash, ME, IVOMD, and evaluated phenotypic traits (Tables 4 and 5).

3.3. Cultivar Grouping and Cluster Analysis. A dendrogram generated from the standardized data of both quality and quantity traits presented in Figure 1 showed that the hybrids were classified into three major groups (A, B, and C) based on the Euclidean distance matrix. Group A consisted of 40 hybrids, including thirty DT hybrids and ten commercial hybrids (Figure 1). Group B consisted of six DT hybrids and the local check while group C had five DT hybrids and one commercial hybrid.

Fifty-three cultivars were clustered into three different groups based on related values of grain yield, DMY, LSS, CP, ME, and IVOMD of the individual cultivars. Mean values of those selected traits in each cluster were presented in Table 6. Group A comprised 22 cultivars containing 9 subgroups with grain and dry matter yields ranging from 0.54 to 2.0 t ha^{-1} and 13.6 to 18.9 t ha^{-1}, respectively. The range of CP among the cultivars within the group was 5.2–8.2%. Values of ME and IVOMD recorded in group A ranged from 7.1 to 7.3 MJ/kg and from 45 to 50%, respectively. Group B included 14 cultivars and had an average grain yield of 2 t ha^{-1} across individual cultivars. Three cultivars in cluster group B2 produced DMY lower than 10 t ha^{-1}. The CP among the cultivars within the group ranged from 5.3 to 6.4%, with their ME values ranging from 6.9 to 7.0 MJ/kg DM and a maximum IVOMD of 44.6% (Table 6). Group C consisted of 17 cultivars with 8 subgroups. This group recorded the highest grain yield (more than 2 t ha^{-1}). Dry matter yields of 10.2–13.4 t ha^{-1} and least (4.7) LSS were recorded from this cluster. The range of CP within this cluster was 5.2–6.9%, while the ME was similar to that of cluster A and IVOMD similar to cluster B. Generally, a total of 15 cultivars from cluster groups A3, A4, B1, C7, and C8 all within the DT hybrids produced grain yield above 2 t ha^{-1} and DMY largely above 12 t ha^{-1}. Among these groups, cluster subgroup A3 and A4 combined higher values from grain yield (2 t ha^{-1}) and DMY (14 – 16 t ha^{-1}) with CP content ranging from 6.9% to 7.9% and IVOMD of 46–48% (Figure 1).

4. Discussion

When considering important traits in maize genotypes for regions prone to drought as occasioned by climate change, screening for its fodder potentials could be a way of

Table 4: Coefficient of correlations between nutritive and some phenotypic parameters of commercial hybrid maize cultivars evaluated for fodder yield.

	Grain yield (t ha^{-1})	LSS	NPH	NEH	Leaf (t ha^{-1})	Stem (t ha^{-1})	DMY (t ha^{-1})	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ME (MJ/kg)
LSS	−0.649*												
NPH	0.295	−0.301											
NEH	0.492	−0.681*	0.815**										
Leaf (t ha^{-1})	−0.400	0.358	−0.383	−0.247									
Stem (t ha^{-1})	−0.120	0.264	−0.540	−0.365	0.705*								
DMY (t ha^{-1})	−0.060	0.227	−0.450	−0.283	0.763**	0.977**							
DM (%)	−0.063	0.323	−0.110	−0.349	0.111	−0.053	−0.050						
Ash (%)	0.208	−0.017	0.259	0.251	−0.134	−0.113	−0.142	0.074					
CP (%)	0.146	−0.241	0.001	0.321	0.265	0.474	0.509	−0.696*	0.067				
NDF (%)	−0.479	0.496	−0.235	−0.518	0.439	0.254	0.278	0.566	−0.600	−0.485			
ADF (%)	0.015	0.141	0.360	0.021	−0.308	−0.637*	−0.599	0.246	−0.150	−0.614*	0.289		
ME (MJ/kg)	0.105	−0.433	−0.294	0.127	−0.026	−0.007	−0.103	−0.163	−0.263	−0.050	−0.133	−0.063	
IVOMD (%)	0.184	−0.440	−0.119	0.294	−0.011	0.071	−0.022	−0.274	−0.152	0.118	−0.224	−0.069	0.945**

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Table 5: Coefficient of correlations between nutritive and some phenotypic parameters of DT hybrid maize cultivars evaluated for fodder yield.

	Grain yield (t ha^{-1})	LSS	NPH	NEH	Leaf (t ha^{-1})	Stem (t ha^{-1})	DMY (t ha^{-1})	DM (%)	Ash (%)	CP (%)	NDF (%)	ADF (%)	ME (MJ/kg)
LSS	−0.659**												
NPH	0.503**	−0.110											
NEH	0.895**	−0.516**	0.588**										
Leaf (t ha^{-1})	0.120	−0.183	0.163	0.138									
Stem (t ha^{-1})	0.006	0.056	0.092	0.054	0.412**								
DMY (t ha^{-1})	0.012	0.020	0.117	0.060	0.554**	0.979**							
DM (%)	−0.128	0.144	0.040	−0.082	0.350*	0.447**	0.446**						
Ash (%)	−0.146	0.109	−0.091	−0.082	−0.083	−0.092	−0.096	−0.116					
CP (%)	0.087	−0.127	−0.135	0.147	−0.263	−0.394*	−0.398**	−0.341*	0.438**				
NDF (%)	0.083	−0.048	0.092	0.013	0.365*	0.287	0.328*	0.570**	−0.672**	−0.404**			
ADF (%)	0.161	−0.218	−0.004	−0.011	0.353*	0.110	0.151	0.386*	−0.473**	−0.439**	0.647**		
ME (MJ/kg)	−0.057	−0.078	−0.322*	−0.129	−0.169	−0.233	−0.212	−0.464**	0.244	0.220	−0.359*	−0.148	
IVOMD (%)	−0.119	−0.017	−0.321*	−0.178	−0.184	−0.189	−0.166	−0.448**	0.377*	0.240	−0.462**	−0.283	0.947**

CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ME = metabolizable energy, IVOMD = *in vitro* organic matter digestibility, DM = dry matter, DMY = dry matter yield, LSS = leaf senesces score, NPH = numbers of plants at harvest, NEH = numbers of ear at harvest. **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

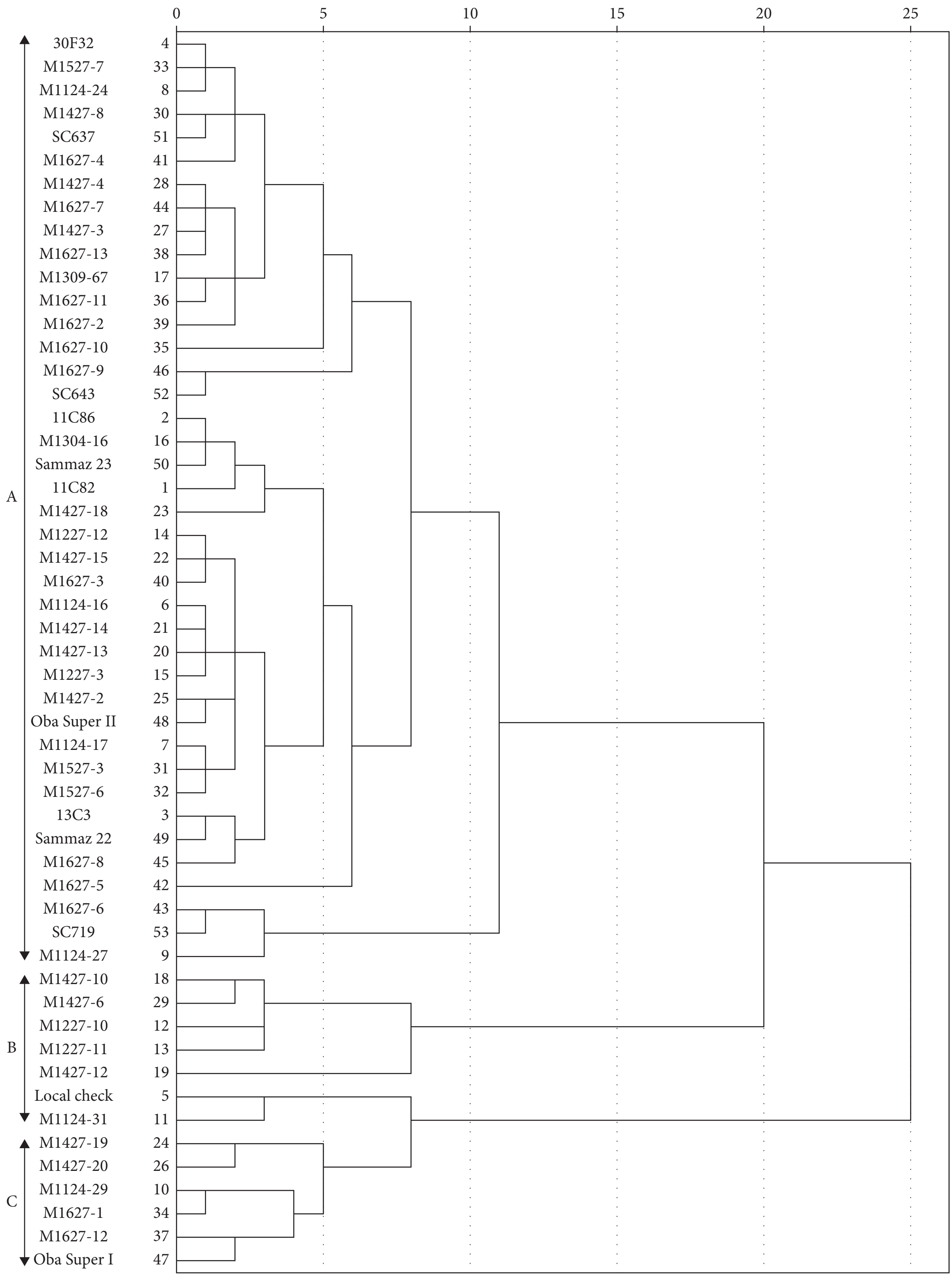

Figure 1: Dendrogram of 42 DT hybrids, 11 commercial hybrids, and a local check obtained for quality and quantity traits using cluster analysis of Euclidean distance matrix.

Table 6: Clustering of three-way cross DT maize hybrids based on grain yield, dry matter yield, leaf senescence score, CP, ME, and IVOMD.

Cluster group	Cultivars	Mean					
		Grain yield (t ha^{-1})	DMY (t ha^{-1})	LSS	CP DM %	ME (MJ/kg DM)	IVOMD (%)
A1	M1124–17, M1304-16, 11C86	1.2	15.4	6.0	5.8	7.3	46.7
A2	M1427–8, M1527-3	1.5	15.1	5.3	5.6	7.1	45.5
A3	M1124–24, M1527-7, 30F32, M1427-6	*2.0*	*14.3*	*7.0*	*7.6*	*7.3*	*47.9*
A4	M1427-3, SC637, M1627-11	*2.0*	*16.3*	*5.4*	*6.9*	*7.1*	*46.0*
A5	M1627-4, SAMMAZ 23	1.3	14.5	6.7	7.6	7.3	47.5
A6	Local check	0.5	13.6	6.7	8.2	7.6	49.1
A7	M1427-18	1.2	14.8	6	5.6	7.9	50.1
A8	M1427–20, M1527–6, M1427-19	1.4	17.1	6.7	5.2	7.1	46.1
A9	M1309–67, M1627-9, SC643	1.6	18.9	5.9	5.6	7.2	46.8
B1	M1227–10, M1627–7, M1227–11, M1427–4, M1627-13	2.0	12.8	5.6	5.3	6.9	44.6
B2	M1427–13, M1427-2, Oba super II,	1.3	9.9	6.2	6.4	6.9	44.0
B3	M1627-2, Oba super I, M1124–16, M1427–14, M1627–1, M1124-29	1.0	13.9	6.7	5.3	7.0	44.6
C1	M1627–5, M1627-6	1.6	10.2	6.2	6.8	7.4	47.5
C2	11C82, M1124-31	0.6	12	5.7	6.3	7.6	48.7
C3	M1124-27, SC719	1.8	10.5	5.7	5.4	7.6	49.4
C4	13C3, SAMMAZ 22	1.5	11.7	6.0	5.5	7.0	44.7
C5	M1427–15, M1627–3, M1627–12, M1227-12	1.2	12.6	6.4	5.2	7.1	46.1
C6	M1227–3, M1627-8	1.3	12.7	6.2	7.4	7.0	44.5
C7	M1627–10, M1427-10	2.1	12.5	4.8	6.9	7.1	45.0
C8	M1427-12	2.5	13.4	4.7	6.0	7.1	45.3

CP = crude protein, DMY = dry matter yield, LSS = leaf senescence score, ME = metabolizable energy, IVOMD = *in vitro* organic matter digestibility. The values in italics are promising drought-tolerant hybrids showing cluster subgroups.

improving the overall resilience of smallholders in such regions. The results of screening promising drought-tolerant hybrids showed cluster subgroups A3 (M1124–24, M1527-7, 30F32, and M1427-6) and A4 (M1427-3, SC637, and M1627-11) had higher values of grain and biomass yield combined with higher CP contents and IVOMD.

The grain yields among these cluster groups are within the average annual grain yield of most local and improved varieties in the region [21] and some improved open-pollinated varieties [22]. However, the grain yields are higher than the range (1.2 to 1.9 t ha^{-1}) reported for drought-tolerant maize evaluated in Benin, Mali, and Nigeria [23]. The performance of the evaluated cultivars in this study under combined drought and heat stress predicts their adaptation to erratic rains and increased temperatures which is frequent in the subregion where most cropping activities are under a rainfed system. With this level of grain yield obtained under moisture stress, when produced under an optimum commercial system, grain yield would be higher and contribute to the ever-increasing demand for maize both for domestic and industrial uses. High grain yield has been identified as the most desirable food trait according to farmers' preference in selection and promotion of any potential drought-tolerant dual-purpose maize [10].

The cultivars within subgroup A3 and A4 also combined higher grain yield, among others, with higher stover dry matter yield. High dry matter yield from these hybrids will contribute significantly to livestock feed resources and increase overall farm productivity, particularly in "mixed crop-livestock systems" either through direct use as livestock fodder and/or through sales of stover [24]. In areas where the DMY of natural pasture could be as low as 2 t ha^{-1}, especially the northern savannahs of Nigeria [25], drought-tolerant maize cultivars with DMY of 14 t ha^{-1} in the dry season will reasonably be considered as a potential feed resource. In regions with higher livestock densities and limited feed resources from rangeland, maize cultivars with superior stover yield and fodder quality can have a substantial impact on livestock productivity [14]. In addition, it could be an income diversification strategy through the sales of stover [25, 26] where there is evidence of a potential fodder market.

The major factor limiting cereal straws and stovers as feed resources is their low-N content which could be below the required threshold (1–1.2%) for rumen microbes [18, 27]. Cluster subgroup A3 (M1124–24, M1527-7, 30F32, and M1427-6) and A4 (M1427-3, SC637, and M1627-11) with higher grain and biomass DM yield recorded CP values above the minimum required N for the ruminal environment. Although there were few hybrids with higher CP contents within clusters A and C, they did not combine this potential with higher grain yield, which is a premium factor for farmers. In combination with relatively higher CP, cultivars in cluster subgroups A3 and A4 had ME values (7.0 MJ/kg DM) similar to what is available in the fodder market around the region (Amole and Ayantunde, 2016). Cluster subgroups A3 and A4 also combined higher IVOMD values with other desirable traits (CP, ME, DMY, and grain yield). IVOMD is an important trait in identifying good quality cereal stover residues and should not be less 45% [28–30] from the same region.

The correlation analysis showed that some traits are related and could guide in the selection of superior drought-tolerant dual-purpose maize cultivars in maize breeding programmes. The positive correlation between grain yield, number of ears at harvest, number of plants at harvest, and leaf area suggests that these factors influence grain yield [31]. The negative correlation between CP and the fibre fractions could have been adjunct to the relationships that exist between IVOMD and the fibre fractions. Such a negative correlation between CP and the fibre fractions has been reported by other authors [32]. Generally, these correlated traits could be used as an index for selecting dual-purpose maize cultivars. Efforts towards breeding and selection for fodder without compromising grain yield will be an important game-changer for areas with high demand for livestock feed resources owing to the prolonged dry season and dwindling biomass production.

5. Conclusion

This study reveals sufficient genetic diversity in the maize cultivars understudy for different traits. Different maize hybrids displayed potential for selection of the desired characters (grain and fodder yields) that could sufficiently satisfy crop and livestock farmers. Based on grain yield, dry matter yield, leaf senescence score, crude protein, metabolizable energy, and *in vitro* organic matter digestibility; maize hybrids in cluster subgroup A3 (M1124–24, M1527-7, 30F32, and M1427-6) and A4 (M1427-3, SC637, and M1627-11) exhibited high potential for quality and quantity fodder traits. These hybrids can be recommended for commercial cultivation after multilocation trials to confirm the consistency of their performance. Furthermore, the genetic potential of these hybrids can be exploited in maize breeding programs including the conduct of acceptability trials for the ruminants.

Data Availability

Data used in the manuscript could be accessible upon request made to the institutes data management committee of the authors.

Conflicts of Interest

The authors declare there are no conflicts of interest regarding the publication of this paper.

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