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NUTRITIONAL COMPOSITION OF A FULL DIALLEL-CROSSED FORAGE PEARL MILLET OF NIGERIA ORIGIN

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ABSTRACT

The productivity of local cattle depends mainly on the quality of forage they consume, the search of which induces conflicts between herdsmen and farmers. The objective of this study was to evaluate the nutritional quality of 'maiwa' *Pennisetum glaucum*, for forage, in Ibadan, Nigeria. Three inbred lines, namely, 25-2, 28-1 and 94-2 were each sown in three rows in 2009. The inbred lines were crossed in all combinations including reciprocals, to generate six hybrids and three inbred lines. The hybrids and their inbred lines were then evaluated. 'Maiwa' plants were harvested by cutting at 30 cm above the ground level, at six weeks after sowing. The plants were allowed to regrow for 7 to 8 weeks to reach booting stage, and samples were collected for proximate analysis. The inbred lines had generally higher dry matter DM content (36.02%) than the hybrids (33.39%). Also, leaf had higher DM (29.67 to 41.11%) than the stem (17.59-24.75%), which was above 20% benchmark. Crude protein (CP) level ranged from 8.76 to 10.66%, which was above the 7% critical level, below which intake declines. Ca: P ratio ranged from 1: 0.89 to 1: 1.58 in 94-2 × 25-2 and 28-1 × 94-2 respectively in 'maiwa'. The Ca: P ratios reflect the higher content of P in all the lines, except 94-2 × 25-2 hybrid. This shows that the nutritional quality of 'maiwa' as forage is satisfactory for animal dietary requirement, except for lactating animal where supplementary CP might be provided.

Key Words: Crude protein, hybrids, proximate analysis

RÉSUMÉ

La productivité des bovins locaux dépend principalement de la qualité du fourrage consommé, dont la quête crée de conflits entre les bergers et les agriculteurs. L'objectif de cette étude était d'évaluer la qualité nutritionnelle du 'maiwa' *Pennisetum glaucum*, pour le fourrage, à Ibadan, Nigéria. Trois lignées inbreds ; à savoir, 25-2, 28-1 et 94-2 était chacune semée en trois lignes en 2009. Les lignées inbreds étaient croisées dans toutes les combinaisons y compris les réciproques ; pour générer six hybrides et trois lignées consanguines. Les hybrides et leurs lignées inbreds étaient donc évalués. Les plants de 'Maiwa' étaient récoltés par coupe à 30cm du niveau du sol, à six semaines après semis. Les plants étaient laissés pour donner des repousses pendant 7 à 8 semaines pour atteindre la période de démarrage, et des échantillons étaient collectés pour des analyses immédiates. Les lignées consanguines avaient généralement grande teneur en matière sèche DM (36,02%) que les hybrides (33,39%). Aussi, les feuilles avaient une grande GM (29,67 à 41,11%) que la tige (17,59 – 24,75%), qui était au-dessus de 20% de référence. Le niveau de la protéine brute (CP) variait entre 8,76 à 10,66% qui était au-delà du niveau de référence de 7%, en deçà duquel la prise est impossible. Le rapport Ca : P variait entre 1 : 0,89 à 1 : 1,58 en 94-2x25-2 et 28-1 × 94-2 respectivement dans 'maiwa'. Les rapports Ca : P reflètent la plus grande teneur en P dans toutes les lignées, sauf l'hybride 94-2x 25-2. Ceci montre que la qualité nutritionnelle de 'maiwa' comme fourrage

est satisfaisante pour les besoins alimentaires des animaux, sauf les animaux nourriciers où des suppléments CP doivent être apportés.

Mots Clés: Analyses immédiates, hybrides, protéine brute

INTRODUCTION

The genus, *Pennisetum*, is dispersed all over the tropics and subtropics of the world, with about 140 species belonging to the grass family - Poaceae being documented (Upadhyaya *et al.*, 2008). One African species, *Pennisetum glaucum* (L.), has been domesticated as pearl millet. It is a foremost cereal grown on about 25 million hectares, principally for grain production in the arid and semi-arid tropical (SAT) regions of Africa and Asia (Rai *et al.*, 2008), where it serves as a staple (Vetriventhan *et al.*, 2008). Pearl millet production is concentrated in developing countries, which account for over 95% of the global production (Basavaraj *et al.*, 2010). It is an important staple cereal in the drier parts of northern Nigeria, but utilised as forage in subtropical regions. Aken'Ova (1976) established that pearl millet could be grown for forage at Ibadan in the lowland forest zone where it is not normally cultivated and where rainy season lasts eight or more months.

Pearl millet grows well in marginal soils (Newman *et al.* 2010), where fodder crops are often cultivated. It has great yield potential and can produce more forage than either sorghum (*Sorghum bicolor*) or maize (*Zea mays*) (Kevin and Blaine, 1991). Pearl millet is extensively grown for forage as hay, silage, green-chop, and pasture in the southern U.S.A. (Lang, 2001) because of its drought tolerance and ability to produce grain under minimal inputs (Hanna and Cardona, 2001). Pearl millet is desirable for forage because it has high forage yield, heavy tillering ability, leafiness and succulent stems (Maiti and Rodriguez, 2010). This accounts for its superior forage quality, acceptability and intake by animals. The importance of chemical (crude protein, fibre, N-free extract) and essential minerals

such as calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) in animal health and performance, milk and meat production is beyond emphasis (Cecelia *et al.*, 2007). Cecelia *et al.* (2007) accentuated the importance of trace minerals: (sodium (Na), manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn) in cattle feed and production.

Although extensive trials have been conducted on agronomic traits of pearl millet, its response to fertiliser rates (Shahin *et al.*, 2013), yield potential of grain and forage potential of 'maiwa' type pearl millet in particular at Ibadan (Aken'Ova 1976), there is paucity of information on the nutritional quality of 'maiwa'. 'Maiwa', the pearl millet type used in this study is an indigenous, short-day, photoperiod-sensitive and late maturing type (Aken'Ova, 1976). The objective of this study was to assess the nutritional quality of 'maiwa' inbred lines and hybrids based on its chemical and mineral composition.

MATERIALS AND METHODS

Study site. The experiment was conducted in the Kwara State University, Agronomy Department garden (7° 26'N and 3° 54'E) at 218 m above the sea level within the rain forest zone of Nigeria. The physical and chemical properties of the experimental site are given in Table 1. Rainfall at the site is bimodal, reaching up to 8 months. Treatments were the inbred lines and corresponding hybrids from diallel cross namely: 25-2, 28-1, 94-2, 25-2 x 28-1, 25-2 x 94-2, 94-1 x 25-2, 28-1 x 94-2 and 94-2 x 28-1.

The experiment was laid down in a randomised complete block design, with three replications. Three promising inbred lines of 'maiwa' pearl millet, namely 25-2, 28-1 and 94-2, developed from several years of

TABLE 1. Chemical and physical properties of the experimental site

Soil characteristic	Value
pH (H ₂ O) 1:1	6.60
Organic carbon (g kg ⁻¹)	12.16
Total nitrogen (mg kg ⁻¹)	0.75
Available phosphorus (mg kg ⁻¹)	12.51
Exchangeable acidity (cmol kg ⁻¹)	0.50
Exchangeable bases (cmol kg⁻¹)	
K ⁺	0.30
Na ⁺	0.34
Ca ²⁺	2.88
Mg ²⁺	0.91
Micro nutrients (mg kg⁻¹)	
Mn ²⁺	74.70
Fe ²⁺	30.90
Cu ²⁺	1.31
Zn ²⁺	17.80
Particle size (g kg⁻¹)	
Textural class (USDA)	Loamy sand

^a Soil was sampled at 15cm depth; USDA= United States Department of Agriculture

inbreeding, top crossing and evaluation were obtained from the breeding unit of the Agronomy Department of the University of Ibadan in Nigeria. The three inbred lines were crossed in all possible combinations, following Griffing (1956), to generate F₁ hybrids and their reciprocal. The inbred parents were also included in the evaluation, using Griffing model 1. Three rows of each of the inbred lines were sown at a spacing of 90 cm × 90 cm, in a staggered manner. The pollen parents were planted three days earlier since millet is protogynous and self-fertilising. The 'head' of the 'maiwa' pearl millets were bagged and clipped prior to anthesis, in the morning, and pollen was collected the next day at about 10:00 am after sun rise. This allows for free flow of pollen.

Pollen was collected from a particular row of inbred line 25-2 and dusted on 28-1. The reciprocal crosses were obtained by changing previous pollen parents to female parents. This procedure was repeated for all inbred lines. In each case, the bags were labeled appropriately and dated. The seeds of each of the crosses were harvested separately, threshed and stored.

F₁ hybrids, their reciprocals and parents

Field establishment and management. The experimental seed beds were prepared manually to allow for easy germination of the small grains of pearl millet. Each inbred and hybrid was sown in single row plots, laid out in randomised complete block design, with three replicates. Each plot was 1.5 m long with a 30 cm gap between plots in the same block; while blocks were 90 cm apart. Sowing was by hand-drilling at the rate of 10 kg ha⁻¹ on 16 June, 2010 when rain was stable. Seeds had been dressed with triazoles before sowing. Owing to insufficiency of seeds of 94-2 × 28-1, it was only sown in blocks I and II. This was taken into consideration during statistical analysis as missing plots.

Weeds were effectively controlled through hand-weeding and NPK 15-15-15 fertiliser was applied at 100 kg N ha⁻¹ in split dose of 50 kg, three weeks after sowing, and 25 kg after each of the first and second harvests. The regrowth after the second harvest was allowed to boot stage, i.e. when 50% of the plants in a plot had reached booting stage. This is the stage when millet is harvested for silage production. The harvested herbage was separated into leaf and stem portions. The leaf portion was composed of lamina; while the stem portion included leaf sheath and its stem.

Chemical composition of 'maiwa' pearl millet. Boot stage was reached 20 weeks after sowing (WAS), and representative samples of each of the hybrids and inbred lines were taken from block II with both block I

and III serving as border row. The samples were oven-dried at 70 °C to a constant weight and, thereafter, milled to pass through 1 mm sieve. A portion of the sample was used for proximate analysis to determine: crude protein (CP), ash, crude fibre (CF), ether-extract (EE) and N-free extract (NFE) contents according to the methods of the Association of Official Analytical Chemists, AOAC (2016).

Mineral composition of ‘maiwa’ pearl millet. The other portion of the dried milled samples were subjected to wet digestion oxidation in order to determine the mineral content of the resulting solution measured through atomic absorption spectrophotometer (AOAC, 2016). The following essential and trace minerals, Ca, P, Mg, K, Na, Mn, Fe, Cu and Zn, were determined.

RESULTS AND DISCUSSION

Leaf and dry matter (DM) content. Inbred 28-1 had the highest proportion of leaf on dry weight (77%) basis (Table 2). All hybrids with 28-1 as female parent had higher proportions of leaf than hybrids without 28-1 as seed parent. Thus, 28-1 × 94-2 had 75% on dry basis; while 28-1 × 25-2 had 76%. Inbred 94-2 had the lowest proportion of leaf. Generally, these results confirmed the high leaf to stem ratio and leafiness of pearl millet (Kevin and Blaine, 1991; Newman *et al.*, 2010). The proportion of leaf observed in the present study is in consonance with the values of 67 and 63% reported by Ogbaji and Aken’Ova (1995) for ‘maiwa’ x ‘maiwa’ and ‘maiwa’ x ‘dauro’ crosses, respectively; implying that the assessed ‘Maiwa’ was leafy.

The inbred lines had generally higher DM content (36.02%) than the hybrids (33.39 %) (Table 2). Also, leaf DM content ranged from 29.67 to 41.11%, and was higher than stem DM content (17.59-24.75%) in all hybrids and inbred lines. This indicates lower moisture level in the leaf compare to stem. Aguiar *et al.*

(2006) and Fulkerson *et al.* (2008) reported 19.4% in pearl millet. Obok *et al.* (2012), who harvested pearl millet at an early stage, reported DM of 18% in an interspecific hybrid between maiwa and elephant grass. Overall, the DM content of both the leaf and stem were above 20%, the minimum DM content considered suitable for animals with high dietary requirement, like cattle (Nutrient Requirements of Dairy Cattle (NRDC), 2001). The relatively high DM content at boot stage could be as a result of water decline, associated with aging i.e. maturity (Maria *et al.*, 2010). The higher the DM the less succulent the forage tends to be, thus negatively imparting palatability and digestibility (Schank *et al.*, 1993; Wadi *et al.*, 2004). However, ‘maiwa’ with high DM is of essence in quality silage production (Aganga and Tshwenyane, 2003).

Chemical composition. Chemical analysis of ‘maiwa’ cut at boot stage revealed that the hybrids and inbred lines had crude protein (CP) contents between 8.76 and 10.66% (Table 2). These were above 7%, the critical level below which intake of tropical forage declines significantly (NRDC, 2011). Inbred line 25-2 had the highest CP of 10.66%; while F₁ hybrid 28-1 × 94-2 had a CP of 10.58% and recorded the highest level among the hybrids.

The CP level (8.76 to 10.66%) obtained in the present study are lower than the CP of 17.41 and 15.78% reported by Aken’Ova (1976), when ‘maiwa’ was harvested after 4 and 5 weeks regrowth, respectively. The difference could be due to the latter harvesting age and the subsequent decline in CP that accompanies aging (Erarome, 2005; Maria *et al.*, 2010). The CP values of the inbred lines and hybrids also fell within the acceptable levels for forage pearl millet (Ogbaji and Aken’Ova, 1995). For animals such as dairy cattle with higher CP requirements, pearl millet at earlier growth stages of 8 to 12 weeks would be needed. It may be noted that when inbred 28-1 served as female parent in the hybrids, the

TABLE 2. Dry matter (DM) content, proportion of leaf and chemical composition of 'maiwa' at boot stage harvest in Ibadan, Rainforest zone of Nigeria

Lines	DM Leaf	DM Stem	Leaf fresh	Leaf dry	CP	CF	EE	Ash	NFE
F₁ hybrids	----- % -----								
25-2 x 28-1	29.67	19.70	45.00	68.00	8.76	34.28	3.97	10.57	32.89
28-1 x 25-2	30.00	17.59	44.00	76.00	9.65	32.79	4.25	10.96	32.97
25-2 x 94-2	30.77	17.94	38.00	66.00	10.47	31.54	3.89	11.35	33.19
94-2 x 25-2	37.73	20.42	31.00	56.00	9.28	32.59	4.11	11.14	32.52
28-1 x 94-2	41.11	24.75	45.00	75.00	10.58	30.34	4.58	10.89	33.62
94-2 x 28-1	31.07	19.09	42.00	69.00	9.89	32.28	3.75	10.67	34.20
F ₁ average	33.39	19.92	40.83	68.33	9.77	32.30	4.09	10.96	33.23
Inbreds									
25-2	37.22	19.77	41.00	77.00	10.66	30.38	4.67	11.08	33.62
28-1	32.5	20.20	48.00	77.00	8.95	33.37	4.06	11.24	33.20
94-2	38.33	22.80	36.00	61.00	10.39	30.47	4.82	11.44	32.46
Inbred average	36.02	20.92	41.67	71.67	10.00	31.41	4.52	11.24	30.09
Overall average	34.71	20.42	41.25	70.00	9.85	31.99	4.23	11.06	33.19
CV (%)	12.60	11.19	12.90	10.85	7.40	4.40	8.80	2.70	1.70

CV = coefficient of variation

CP content was higher than when it was the pollen parent, reflecting the presence of maternal effect for CP in 'maiwa'.

Although CP is a critical quality parameter in silage production, crude fibre (CF), ether extract (EE), ash and nitrogen free extract (NFE) are also important (Comerford, 2017). The CF ranged from 30.34 to 34.28% in 28-1 × 94-2 and 25-2 × 28-1, respectively. This range is close to 29-34% CF reported by Erarome (2005) and NRDC (2011) and it is within the desirable limits (NRDC (2011)). The CF values were higher than the CF of 26.06 and 27.96% (Aken'Ova, 1976) of open pollinated 'maiwa' after 4 and 5 weeks regrowth, respectively. The higher CF at boot stage in the present study could be attributed to increased lignification that accompanies physiological maturity in plants (Erarome, 2005; Maria *et al.*, 2010).

The EE values ranged between 3.75 and 4.82% in 94-2 × 28-1 and 94-2, respectively (Table 2). Inbred line 94-2 had the highest EE (4.82%) among all the entries; while 28-1 had the least EE (4.06%), among the inbred lines. 28-1 × 94-2 had the highest EE (4.58%) among the F₁ hybrids; while its reciprocal, 94-2 × 28-1 had the least EE (3.75%).

The ash content of inbred lines and their hybrids ranged from 10.67 to 11.44% in 94-2 × 28-1 and 94-2, respectively. Among the hybrids, 25-2 × 94-2 had the highest ash content (11.35%); while 94-2 × 28-1 had the least. The ash content provides an indication of the mineral content such Na, P, K, Ca and Mg of the forage.

The NFE content ranged from 32.46 to 34.20% in 94-2 and 94-2 × 28-1, respectively (Table 2). This is lower than 41-52% range reported by Erarome (2005), reflecting genetic and environmental differences.

Mineral content at booting stage. Table 3 shows that mineral content was variable. The Ca: P ratio ranged from 1: 0.89 for 94-2 × 25-2 to 1: 1.58 for 28-1 × 94-2 in 'maiwa' inbreds and hybrids. Ca: P ratios reflected the higher content of P in all the lines except 94-2 × 25-

TABLE 3. Mineral content of 'maiwa' inbreds and hybrids harvested at boot stage (20 WAS) in Ibadan, Rainforest zone of Nigeria

Lines	Ca:P	Ca	P	Mg	K	Na	Mn	Fe	Cu	Zn
25-2 x 28-1	0.637	1.950	3.062	2.610	3.275	0.019	0.048	0.304	0.003	0.051
28-1 x 25-2	0.931	2.180	2.341	2.205	3.080	0.018	0.049	0.313	0.003	0.041
25-2 x 94-2	0.659	1.500	2.275	1.659	3.260	0.018	0.027	0.291	0.002	0.042
94-2 x 25-2	1.126	2.070	1.838	1.759	5.000	0.023	0.044	0.347	0.002	0.036
28-1 x 94-2	0.633	1.800	2.844	1.814	3.300	0.021	0.043	0.331	0.003	0.046
94-2 x 28-1	0.840	1.930	2.297	1.853	3.515	0.021	0.050	0.333	0.004	0.039
25-2	0.654	1.230	1.881	1.602	3.360	0.020	0.028	0.311	0.003	0.036
28-1	0.727	1.750	2.406	1.773	3.130	0.019	0.048	0.344	0.004	0.053
94-2	0.785	2.060	2.625	1.737	3.560	0.026	0.041	0.314	0.004	0.047
CV (%)		8.67	8.44	8.07	7.80	156.3	11.12	2.95	408.9	7.11

CV = coefficient of variation

2 hybrid. The ratios do not conform to the desired 1: 1 to 2: 1 ratios for ruminant nutrition as in tropical forage (Rubanza *et al.*, 2005). A balanced ratio between Ca and P is critical in forage breeding as it affects important physiological processes in animals (Comerford, 2017).

The P content ranged from 1.838 to 3.062 g kg⁻¹, with 25-2 × 28-1 having the highest P content (3.062 g kg⁻¹). Also, Ca content of 'maiwa' ranged from 1.230 to 2.180 g kg⁻¹, with 28-1 × 25-2 having the highest Ca content (2.180 g kg⁻¹). The Ca and P content of both the hybrids and their inbred lines were well above 0.32 and 0.17%, recommended for maintenance of domestic livestock, as well as 0.16-0.60% Ca and 0.16-0.43% P for beef and dairy cattle (Rubanza *et al.*, 2005). Ca and P variations among the inbred lines and their hybrids were relatively low (CV = 8.67 and 8.44%, respectively).

The Mg content fell between 1.602 and 2.610 g kg⁻¹, with 25-2 × 28-1 having the highest (2.610 g Mg kg⁻¹ (Table 3). The Mg (1.602 to 2.610 g kg⁻¹) and Ca (1.230 to 2.180 g kg⁻¹) contents in the present study were much higher than the dietary Mg and Ca requirements of beef and dairy cattle which are between 0.4 and 1.8 g kg⁻¹ (Makeri and Ugherughe, 1992). Also, the variability among inbred lines and their hybrids followed similar trends as P and Ca, with CV value of 8.07%.

The Na concentration ranged from 0.018 to 0.026 g kg⁻¹ (Table 3), which meets the levels recommended for beef cattle (0.06–0.10%; NRC, 1984), dairy cattle (0.18%; NRC, 1978, Rubanza *et al.*, 2005) and those for sheep (0.04–0.10%; NRC 1976). Lactating dairy cows could, however, be given salt supplement if only fed with 'maiwa' alone as it might not meet its nutritional needs.

CONCLUSION

The study indicates that nutrient composition of maiwa is above the nutritional requirements of livestock, though, mild supplements should be added especially for lactating animals.

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