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ORIGINAL ARTICLE

Agronomic performance and nutritive quality of some commercial and improved dual-purpose cowpea (*Vigna unguiculata* L. Walp) varieties on marginal land in Southwest Nigeria

Uchenna Y. Anele[1,2], Karl-Heinz Südekum[1], Oluwasanmi M. Arigbede[1,2], Gerd Welp[3], Adebayo O. Oni[4], Jimoh A. Olanite[2] and Olubunmi V. Ojo[2]

1 Institute of Animal Science, University of Bonn, Bonn, Germany
2 Department of Pasture and Range Management, University of Agriculture, Abeokuta, Nigeria
3 Institute of Crop Science and Resource Conservation, University of Bonn, Bonn, Germany
4 Department of Animal Nutrition, University of Agriculture, Abeokuta, Nigeria

Keywords
Biomass; cowpea; dual-purpose variety; marginal land; supplement.

Correspondence
Uchenna Y. Anele, Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409-2141, TX, USA.
Email: young.anele@ttu.edu

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Abstract

A field experiment was conducted between 2007 and 2008 to determine the agronomic performance and nutritive quality of some varieties of dual-purpose cowpea (*Vigna unguiculata* L. Walp) grown in marginal land without fertilization. The experiment was arranged in a 2×2 factorial design with two seasons (wet and dry) and two groups (commercial and improved) of cowpea varieties. The varieties were evaluated for biomass and grain yields, green leaf retention, chemical composition, secondary metabolites and *in vitro* organic matter digestibility (IVOMD). A group $\times$ season interaction was observed for biomass yield with higher yields recorded in the wet season. Grain yield and green leaf retention were also greater ($P < 0.001$) in improved varieties with an average yield of 467 kg ha^{-1} and over 50% of leaves retained during the wet season, respectively. Interaction between group and season was observed for crude protein ($P = 0.002$), lignin ($P = 0.003$) and hemicellulose ($P = 0.003$) contents of the cowpea haulms. The IVOMD of the haulms ranged from 585 to 802 g kg^{-1} OM. Quality indices (IVOMD, crude protein and non-fiber carbohydrates) of the cowpea varieties were better during the dry season. Results from the study showed that dual-purpose cowpea varieties can easily be grown by resource-poor small-holder farmers as it requires little or no input and will provide sufficient biomass that will be used as a supplement during the dry season while providing extra food for the households.

Introduction

Nutrition is one of the most important considerations in livestock management. Inability to supply feed in adequate quantity and quality is responsible for the low livestock productivity in the Sub-Saharan African (SSA) countries (Agyemang 2002). This situation is exacerbated by the seasonal shortages in the supply of forage from natural pastures that supply most of the feed for animals due to a prolonged annual dry season.

The expanding crop production activities and reduction in fallow periods in most of the SSA countries are already leading to competition between crop and livestock production. Land fallowing, a traditional agricultural system that helps to restore land fertility, is likely to disappear in the next 50 years (Thornton *et al.* 2002). As much of the arable land in these countries are already under cultivation, increased livestock productivity will have to come from improving the productivity per unit area or expansion of marginal lands that have traditionally supplied grazing resources to livestock (Delgado *et al.* 1999).

The resource-poor small-holder farmers produce considerable proportions of the milk and meat requirements under this poor feed situation (Agyemang 2002). Animal productivity could be increased by the introduction of low cost technologies that would improve the current systems of management. Acceptable and successful feeding systems are described as those that are simple, practical, consistently reproducible and within the limits of the farmer's resources (Douthwaite 2002). This underscores the importance of dual-purpose crops that provide food (grain) and feed (residues) in meeting household needs under the current and foreseeable future scenarios (Delgado *et al.* 1999).

Dual-purpose cowpea (*Vigna unguiculata* L. Walp) has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing N into the farming system through biological fixation (Giller 2001; FAO 2009). Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in regions characterized by systems for farming that make limited use of purchased inputs.

Cowpea is grown extensively in 16 African countries, with the continent producing more than two-thirds of the world's total. Two countries – Nigeria and Niger – produce 2 916 000 and 1 569 300 metric tons annually, which represent approximately 75% of the world crop (FAO 2009). The bulk of this production comes from smallholder farmers in semiarid zones of the region.

Since not many studies have been carried out in marginal lands, this pilot study investigated the agronomic performance, green leaf retention and nutritive quality of some varieties of dual-purpose cowpea grown in marginal land which had not been used by crop farmers.

Materials and methods

Experimental site

The field experiment was conducted at the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria and laboratory analyses were carried out at the (Institute of Animal Science and Institute of Crop Science and Resource Conservation) University of Bonn, Germany. The experimental site lies within the savanna agro-ecological zone of southwest Nigeria (latitude: 7°N, longitude 3.5°E, average annual rainfall: 1037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of 2–3 weeks in August. Temperatures are fairly uniform with daytime values of 28–30°C during the rainy season and 30–34°C during the dry season with the lowest night temperature of around 24°C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 and 96% as compared to dry season values of 55–84%. The temperature of the soil ranges from 24.5–31.0°C (Source: Agrometeorology Department, UNAAB).

Forage establishment and management

The experimental area was ploughed twice and harrowed. The area was divided into six blocks and each block was sub-divided into six plots each measuring 5 × 4 m. Three improved (*i.e.* IITA 97 k-1069-6, IITA 98 k-311-8-2, IITA 98 k-476-8; hereafter designated ITA-6, ITA-2 and ITA-8) and three commercial (*i.e.* 'Oloyin', 'Peu', 'Sokoto') dual-purpose cowpea varieties constituted the treatments. The dual-purpose cowpea varieties were semi-erect type and had days to pod maturity of 70–86 days. The improved varieties (obtained from International Institute of Tropical Agriculture, Ibadan, Nigeria) were bred for greater agronomical yield. Treatments were randomly allocated to plots within each block. Samples collected from two blocks were bulked together to constitute one field replicate. As a result, three field replicates were obtained from the six blocks. The cowpea was planted in rows 0. 4 m wide with 0.3 m plant spacing in May 2007 for the wet season, and the second planting was carried out in August 2007 for the dry season. The experimental area was maintained weed-free throughout the first month to reduce competition. The cowpea formed a tight canopy within a short period after planting which smothered weeds. There was no fertilizer application.

Biomass and grain yields

Biomass and grain yields were determined using a 1 × 1 m quadrat. They were harvested approximately 3 months after planting. Plants within the quadrat were uprooted, weighed, sun-dried and then threshed (to gather the grains). The cowpea haulms, comprising the vine, leaves and roots were manually rolled and chopped into particles of 2–4 cm lengths for a feeding trial (Anele *et al.* 2010). Subsamples of the haulms were milled with a hammer mill (Model DFZH-Bühler, Uzwil, Switzerland) using a 3 mm sieve for chemical analyses.

Green leaf retention

The number of leaves on selected cowpea plants (using 1 × 1 m quadrat) was counted during the vegetative (30–40 days) stage. The leaves were later counted during the dough stage (prior to harvest) to determine the green leaf retention of the different cowpea varieties in both seasons. In counting these leaves, attention was paid to plants whose leaves changed color and were dry (senescent). The number of green leaves retained by each variety were ranked on a scale of 1–3, where 1, 0–25% leaves retained; 2, 25–50% leaves retained; 3, >50% leaves retained.

Soil collection and analyses

Soil samples were randomly collected from the site before establishing the plots in January 2007, and at the end of the experiment in May 2008 at the depth of 0–15 cm. Soil samples were taken with the aid of a stainless steel auger (75 mm in diameter). The samples were thoroughly mixed and sub samples taken for analyses to determine the pre- and post-planting nutrient status of the soils. Soil pH was measured in 0.01 mol L^{-1} $CaCl_2$ with glass electrode, particle size analyses was analyzed according to Köhn (ISO 11277 2002) by wet sieving and sedimentation. Total carbon (ISO 19694 1995) and nitrogen (ISO 13878 1998) were analyzed after dry combustion with Fisons NA 2000 elemental analyzer. Soil organic carbon was determined as total carbon minus inorganic carbon (Scheibler method).

Exchangeable cations were extracted with 1 mol L^{-1} NH_4Cl according to Trüby and Aldinger (1989). Plant available macronutrients were extracted with CH_3COONH_4 at pH 7 according to Van Reeuwijk (2002). Plant available phosphate was extracted with a mixture of 0.03 mol L^{-1} CH_3COOH + 0.05 mol L^{-1} calcium acetate + calcium lactate (CAL method, Schüller 1969) while plant available micronutrients were extracted with 0.1 mol L^{-1} HCl according to Viets and Lindsay (1974).

Chemical analyses

The cowpea haulms were milled through a 1 mm sieve in a hammer mill. Prior to milling, samples were oven-dried at 60°C for 96 h while dry matter (DM) was determined by oven-drying at 100°C for 24 h. Samples were mixed separately and subsampled for analyses. The samples were later analyzed for crude protein (CP), ether extract (EE), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin. Crude protein (ID 984.13), ash (ID 942.05) and EE (ID 963.15) were analyzed according to standard methods of AOAC (1990). Mineral composition of the haulms was determined according to VDLUFA (2007). Lignin was determined by solubilization of cellulose with sulfuric acid in the ADF residue (Van Soest *et al.* 1991). The NDF and ADF were determined according to Van Soest *et al.* (1991), with NDF determined without use of α-amylase or sodium sulfite. Both NDF and ADF were expressed without residual ash. Non-fiber carbohydrates (NFC) were calculated as: NFC = 1000 – CP – ash – EE – NDF, with all variables expressed as g kg^{-1} DM.

In vitro organic matter digestibility (IVOMD) was determined according to Blümmel and Lebzien (2001). Incubated residues were refluxed with neutral detergent solution (prepared without sodium sulfite) for 1 h with subsequent recovery of the truly undegraded substrate in Dacron fiber bags (4 × 12 cm, 40 μm pore size: Ankom, Macedon, NY, USA). Total phenolics were estimated with the Folin-Ciocalteau reagent according to Makkar (2003) and expressed as tannic acid equivalents. Total tannins were determined as the difference in total phenolics after treatment with insoluble polyvinyl polypyrrolidone (Makkar 2003) and condensed tannins were determined by butanol-HCl method (Makkar 2003). Protein precipitable tannins were determined with bovine serum albumin according to Hagerman and Butler (1978).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the general linear method (GLM) procedure of SAS® (2002) in a 2 × 2 factorial arrangement. The model used was:

$$Y_{ijk} = \mu + G_i + V_j(G_i) + S_k + (GS)_{ik} + \varepsilon_{ijk}$$

where: Y_{ijk} = observation, μ = population mean, G_i = group effect (i = 1–2), $V_j(G_i)$ = varieties within group effect (j = 1–3), S_k = season effect (k = 1–2), $(GS)_{ik}$ = interaction between group and season, and ε_{ijk} = residual error.

Means were then compared by applying the probability of difference (PDIFF) option of the least squares means statement in the GLM procedure. Differences among means with $P < 0.05$ were accepted as representing statistically significant differences. Probability values <0.001 are expressed as "$P < 0.001$" rather than the actual value.

Correlation analysis was used to establish relationships between IVOMD and some chemical constituents. Prediction equations of IVOMD values of the cowpea haulms were developed by stepwise regression analysis, using the PROC REG of SAS (2002). The stepwise procedure only introduced variables in the model when they contributed to a significant improvement in the estimation of the dependent variable.

Results

Physicochemical properties of the soil

The physicochemical characteristics of the composite soil samples taken from 0–15 cm depth of the experimental site in 2007 and 2008 are shown in Table 1. Typically with tropical soils, the soil was low in organic C (4.06 and 4.49 g kg^{-1}), total N (0.25 and 0.27 g kg^{-1}) and in available macro and micronutrients (e.g. P: 5.91 and 5.33 mg kg^{-1}). The soil was slightly acidic with pH ranging between 5.40 and 5.45. Soil texture was characterized by a high proportion of sand (86%) and small proportions of silt (10%) and clay (4%). According to the Food and Agriculture Organization/World Reference Base (FAO/WRB) system, this grain size distribution is classified as loamy sand.

Table 1 Pre- and post-physicochemical characteristics of the composite soil samples taken from the experimental site at 0–15 cm in 2007 and 2008

Soil properties	2007	2008
pH ($CaCl_2$)	5.40	5.45
Total N (g kg^{-1})	0.25	0.27
Organic carbon (g kg^{-1})	4.06	4.49
Exchangeable cations (cmol kg^{-1})	21.3	21.6
Plant available macro nutrients (mg kg^{-1})		
Calcium	211	225
Phosphorus	5.91	5.33
Sodium (Na)	0.91	1.06
Potassium (K)	57.7	65.3
Magnesium (Mg)	42.7	41.0
Plant available micro nutrients (mg kg^{-1})		
Copper	0.35	0.39
Iron	3.82	4.06
Manganese	47.5	40.1
Zinc	0.59	1.51
Particle size distribution (%)		
Coarse sand (2–0.63 mm)	28.6	–
Middle sand (0.63–0.2 mm)	40.3	–
Fine sand (0.2–0.063 mm)	17.5	–
Coarse silt (0.063–0.02 mm)	6.17	–
Middle silt (0.02–0.0063 mm)	2.53	–
Fine silt (0.0063–0.002 mm)	1.07	–
Clay (<0.002)	3.54	–

n = 6.

Biomass, grain yield and green leaf retention

A group (improved *versus* commercial) × season interaction was observed for the biomass yield of the cowpea with improved varieties harvested during the wet season having the greatest ($P = 0.003$) DM yield of 8755 kg ha^{-1}. On the average (of both seasons), the biomass yield of the improved varieties was superior ($P < 0.05$) to the commercial varieties. Higher ($P < 0.001$) biomass yields were observed in varieties harvested in the wet season.

Grain yield of the cowpea followed a similar trend observed in the biomass yield with values ranging between 390 and 475 kg ha^{-1} (Table 2). There was no interaction between group and season. The grain yields of the improved varieties were superior ($P < 0.001$) to those of the commercial varieties. Season did not affect grain yield of the varieties.

There was no interaction between group and season for the green leaf retention of the varieties. Improved varieties harvested during the wet season were able to retain more than 50% of their leaves into the dry season. On average, they were able to retain between 25 and 50% of their leaves. The improved varieties retained more ($P < 0.001$) leaves than the commercial varieties.

Chemical composition

The DM contents of the haulms ranged from 931 to 948 g kg^{-1} (Table 3). Group × season interactions were observed for CP, lignin and hemicellulose contents of the haulm varieties. Crude protein content of the haulms was higher ($P < 0.001$) in the commercial varieties than improved varieties during the dry season. The NDF content though not significant (group × season) was greater ($P < 0.05$) in the improved than commercial haulms with values of 612 vs. 569 and 403 vs. 379 g kg^{-1} DM during the wet and dry seasons, respectively. Despite their high fiber contents, haulms from both varieties contained significant amounts of NFC, which were higher ($P < 0.05$) in improved varieties.

Group × season interactions were observed for all the macro elements with the exception of sodium (Table 4). No interaction was observed for the trace elements.

In vitro organic matter degradability and secondary metabolites

No interaction was observed for IVOMD and secondary metabolites of the haulms (Table 5). Condensed and protein precipitable tannins were not detected. Greater ($P < 0.001$) IVOMD and total phenol were observed in the dry season while tannins values were greater ($P < 0.001$) in the wet season.

Relationships and prediction of IVOMD from chemical composition

Positive relationship existed between CP and IVOMD in both seasons (Table 6). These variables (CP and IVOMD) were negatively correlated with the secondary metabolites. The NDF was positively correlated with the commercial haulms in both seasons but negatively correlated with the

Table 2 Seasonal biomass dry matter (DM) and grain yields (kg ha^{-1}) and green leaf retention of the cowpea varieties

Variable	Wet season commercial	Improved	Dry season commercial	Improved	SEM	*P* group	V (group)†	Season	G × S
Biomass	6461[b]	8755[a]	3711[c]	3194[c]	466.5	*	NS	***	**
Grain	403	475	390	460	11.0	***	NS	NS	NS
Green leaf retention‡	2	3	2	2	0.3	***	***	NS	NS

Means with different letters within a row differ ($P < 0.05$). NS, non-significant.; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
†V (group), varieties within group. ‡Values based on a scale of 1–3, where 1, 0–25% leaves retained; 2, 25–50% leaves retained; 3, >50% leaves retained.

Table 3 Chemical composition (g kg^{-1} dry matter (DM) unless stated) of the cowpea haulms

Variable	Wet season commercial	Improved	Dry season commercial	Improved	SEM	*P* group	V(group)†	Season	G × S
DM(g kg^{-1})	948	942	933	931	2.3	NS	NS	***	NS
CP	181[b]	147[c]	217[a]	212[a]	4.0	***	NS	***	**
EE	18.9	16.3	42.2	28.6	3.34	*	NS	***	NS
Ash	94.3	30.5	71.4	30.5	10.35	***	NS	NS	NS
NDF	569	612	379	403	14.9	*	NS	***	NS
ADF	399	419	208	233	15.1	NS	NS	***	NS
Lignin	206[a]	162[b]	107[c]	113[c]	8.1	*	*	***	**
Hemicellulose	169[b]	193[a]	171[b]	170[b]	5.4	*	NS	*	*
Cellulose	194	257	101	120	11.9	**	NS	***	NS
NFC	136	193	289	325	12.7	***	NS	***	NS

Means with different letters within a row differ ($P < 0.05$).
NS, non-significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. †V(group), varieties within group.
ADF, acid detergent fiber expressed exclusive residual ash; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber expressed exclusive residual ash; NFC, non-fiber carbohydrates; SEM, standard error of means.

Table 4 Mineral composition (g kg^{-1} DM) of the cowpea haulms

Variable	Wet season commercial	Improved	Dry season commercial	Improved	SEM	*P* group	V(group)†	Season	G × S
Calcium	13.34[b]	9.03[c]	23.15[ab]	25.09[a]	0.982	NS	***	***	**
Phosphorus	2.79[a]	1.83[b]	2.05[b]	1.98[b]	0.097	***	***	**	***
Magnesium	3.47[b]	2.76[b]	5.56[a]	6.01[a]	0.276	NS	NS	***	*
Sodium	0.37	0.44	0.23	0.24	0.027	NS	NS	***	NS
Potassium	11.26[b]	14.79[a]	15.45[a]	16.11[a]	0.521	***	***	***	**
Zinc	0.76	0.65	0.62	0.67	0.059	NS	NS	NS	NS
Iron	1.01	0.44	0.67	0.57	0.126	*	**	NS	NS
Manganese	6.63	6.85	7.65	7.16	0.266	NS	***	*	NS

Means with different letters within a row differ ($P < 0.05$).
NS, non-significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
†V(group), varieties within group. SEM, standard error of means.

Table 5 *In vitro* organic matter degradability and secondary metabolites (g kg^{-1} DM unless stated) of the cowpea haulms

Variable	Wet season commercial	Improved	Dry season commercial	Improved	SEM	*P* group	V(group)†	Season	G × S
IVOMD (g kg^{-1} OM)	635	585	665	802	24	NS	**	***	NS
Total phenol	7.96	7.45	9.51	9.31	0.25	NS	NS	***	NS
Tannins	3.83	3.31	2.11	1.86	0.22	NS	NS	***	NS
Condensed tannins	ND	ND	ND	ND	–	–	–	–	–
PPT	ND	ND	ND	ND	–	–	–	–	–

NS, non-significant; **$P < 0.01$; ***$P < 0.001$. †V(group), varieties within group. ND, not detected; PPT, protein precipitable tannins; SEM, standard error of means.

improved haulms. Total phenol and tannins were positively ($P < 0.001$) correlated in both varieties and seasons.

A stepwise regression analysis was used to establish regression models for predicting IVOMD. The results showed that IVOMD of the cowpea haulms could be predicted from the chemical composition via regression models:

Commercial haulms (wet season): $Y_{IVOMD} = -3703 + 19.95_{CP} + 92.31_{Total\ phenol}$, $R^2 = 0.66$

Commercial haulms (dry season): $Y_{IVOMD} = 586 - 2.01_{NDF} + 3.71_{ADF} + 0.69_{NFC}$, $R^2 = 0.74$

Improved haulms (wet season): $Y_{IVOMD} = -1563 + 4.64_{NDF} + 2.86_{ADF} + 2.59_{NFC}$, $R^2 = 0.93$

Table 6 Correlations between the chemical compositions of the cowpea haulms

Season	Variety	Composition	CP	NDF	IVOMD	TP	Tannins
Wet	Commercial	CP	1	-0.20^{NS}	0.61*	-0.31^{NS}	−0.65*
		NDF		1	0.09^{NS}	0.53^{NS}	0.63*
		IVOMD			1	-0.32^{NS}	-0.23^{NS}
		TP				1	0.80***
		Tannins					1
	Improved	CP	1	−0.69*	0.06^{NS}	-0.52^{NS}	-0.35^{NS}
		NDF		1	-0.32^{NS}	0.58*	0.47^{NS}
		IVOMD			1	−0.75**	−0.79**
		TP				1	0.97***
		Tannins					1
Dry	Commercial	CP	1	-0.26^{NS}	0.36^{NS}	-0.09^{NS}	-0.03^{NS}
		NDF		1	0.17^{NS}	0.47^{NS}	0.50^{NS}
		IVOMD			1	-0.02^{NS}	-0.24^{NS}
		TP				1	0.93***
		Tannins					1
	Improved	CP	1	-0.29^{NS}	0.83***	−0.67**	-0.42^{NS}
		NDF		1	-0.08^{NS}	0.07^{NS}	0.23^{NS}
		IVOMD			1	−0.63*	−0.60*
		TP				1	0.86***
		Tannins					1

NS, non-significant; $*P < 0{\cdot}05$; $**P < 0{\cdot}01$; $***P < 0{\cdot}001$.
CP, crude protein; IVOMD, *in vitro* organic matter degradation; NDF, neutral detergent fiber expressed exclusive residual ash; TP, total phenol.

Improved haulms (dry season): $Y_{IVOMD} = -113 + 5.65_{CP} - 1.21_{ADF}$, $R^2 = 0.86$

Discussion

Physicochemical properties of the soil

Nitrogen, phosphorus and potassium are the major determinants of soil fertility, forage yield and quality. Low levels of these elements in most tropical soils have been the major cause of low dry matter yields of tropical forages and have prompted attention to inorganic fertilizer usage in Nigeria. Particle size distribution was only reported for 2007 because this is a stable soil parameter. Not much inference was drawn from the soil data because of the length of the study but it showed that cowpea can do well in most of the marginal lands that are not being used and will help to restore such lands over time through fixation of nitrogen (Giller 2001). The main reason why no fertilizer was used was to reduce the cost of production as much as possible and the perceived reluctance on the part of the resource-poor small-holder farmers to spend money on inorganic fertilizer. This can easily be addressed by the use of dung from the animals.

Biomass, grain yield and green leaf retention

It is worthy to note that this was a pilot study into utilization of marginal land for forage cultivation and may have some short-comings which will be adequately dealt with in future studies. Biomass yield of the cowpea varied between the two varieties and in both seasons. Improved varieties had greater herbage yields in both seasons. Similar results on greater yield of improved varieties over local varieties had been reported by Singh *et al.* (2003). Seasonal differences in the biomass yield of the varieties might be linked to seasonal variation in the amount and distribution of rainfall which played a significant role with greater yields recorded during the wet season compared to lower yields during the dry season. Wet season biomass yield was about threefold greater than dry season yield in improved cowpea and approximately 74% greater in commercial cowpea.

As observed in the biomass yield, grain yield of the cowpea varied between the two groups but the magnitude of the variation was less than that observed in the biomass yield. Differences in the seasonal grain yield of the cowpea were not significant, which showed that some climatic factors like sun radiation or day-length may have influenced grain yield more than rainfall. Singh *et al.* (2003) reported 70% higher grain yield in improved cowpea over local varieties.

The range of values for green leaf retention of the varieties showed that the improved varieties were more efficient in retaining their leaves. The annual long dry season between November and March is the most critical or stressful period for ruminant animals under the tropical condition as most grasses are dried and are generally low in nutritive quality (Nuru 1988). So any feed resource that could retain its leaves during the dry season will be invaluable in addressing the seasonal shortages in forage production. The varieties did not only retain significant leaves, the quality of the haulms was also high.

Chemical composition

Although the haulms of the commercial varieties had greater CP content than the improved varieties, the range of 147–217 g CP kg^{-1} DM of both groups of cowpea haulms is above the range of 110–130 g CP kg^{-1} DM, which is adequate for maintenance and growth of beef cattle National Research Council (NRC 1996).

The haulms used in this study had higher CP content than those used by Savadogo *et al.* (2000a,b). Such variation in quality of crop residues may be due to factors such as genetic characteristics (Singh and Schiere 1995), environment (soil characteristics, rainfall) and crop management (level of fertilization, plant density, stage of maturity at harvest, methods of harvesting, and storage) (Walli *et al.* 1994). Kaasschieter *et al.* (1998) reported CP values for cowpea ranging from 78 to 217 g kg^{-1} DM. FAO (1981) reported 37 ± 4.3, 144 and 99 g CP kg^{-1} DM for sorghum stover, cowpea and groundnut haulms, respectively.

Fiber concentrations were greater in improved than in commercial haulms. Despite the greater fiber concentration in improved haulms, significant proportion was in form of NFC, which is easily degraded unlike the commercial haulms, which had greater lignin concentration.

Higher NFC contents of improved haulms indicate that they should stimulate ammonia-N utilization in the rumen better than the commercial haulms (Tylutki *et al.* 2008). As N utilization by rumen microorganisms is related to the amount of available fermentable energy, the NFC in the haulms could improve the efficiency of microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Ørskov and Grubb 1978).

Calcium and phosphorus make up to 70% of the total mineral elements in the body and have vital functions in almost all tissues in the body and must be available to livestock in proper quantities and ratio. They play special roles in the proper functioning of the rumen microorganisms especially those which digest plant cellulose, utilization of energy from feeds, protein metabolism amongst other functions (McDowell *et al.* 1993). The range of values recorded for Ca (9.03–25.09 g kg^{-1} DM) in the present study is above the critical level of 3 g kg^{-1} DM recommended for ruminant needs in the warm wet climates (McDowell *et al.* 1993). Only the *P* level of commercial haulms (during the wet season) was above the critical level of 2.5 g kg^{-1} DM for ruminant animals.

In vitro organic matter degradability and secondary metabolites

The observed differences in the IVOMD of the haulms may be due to differences in their content of potentially digestible materials. Less fiber content (especially lignin) of the haulms during the dry season may have contributed to higher IVOMD values observed in the dry season. Lignin is known to interfere with digestibility by limiting the surface area for microbial attachment.

The values of total phenol and tannins reported for the haulms in this study are considered low and of no nutritional significance (Mueller-Harvey 2006). The inability to detect condensed and protein precipitable tannins showed that the secondary metabolites will not have any negative effect on digestion.

Relationships and prediction of IVOMD from chemical composition

The IVOMD could be predicted from the chemical composition of the haulms in both seasons. The stepwise regression equation obtained for improved haulms in the dry season had a high coefficient of determination ($R^2 = 0.93$). The prediction of IVOMD of the haulms was improved when any of the fiber fractions was included in the model (0.93, 0.86 and 0.74, compared to 0.66 when no fiber fraction was included with root mean square of 21.3, 26.4, 25.7 and 10.5, respectively).

Conclusions

Results from this study and an earlier paper (Anele *et al.* 2010) showed that these dual-purpose cowpea varieties can easily be grown on marginal land as it requires little or no input and will ensure sufficient biomass as supplement during the dry season while providing extra food (grains) for human consumption. Yields (especially grain) can be increased by introducing the improved varieties. This will in addition ensure sufficient green leaf in the harvested biomass as demonstrated by higher green leaf retention ability observed in the improved varieties. The sustainability of this cropping is not yet clear. While nitrogen input can be assured by biological fixation, the long-term support of plants with further macro- and micronutrients will have to be investigated. A recycling of nutrients in terms of fertilization with dung or manure is highly recommended in order to avoid a decline in soil fertility.

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