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Fodder yield and nutritive value of browse species in west African humid tropics: response to age of coppice regrowth

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Abstract

Several indigenous and exotic browse species with potential for development of agroforestry technologies in the humid tropics of west Africa have been identified, but information on their fodder yield and quality, and how this is influenced by age of coppice regrowth is scanty and limited to a few species. The effect of age of coppice of regrowth (8, 12, 16, and 20 weeks) on fodder yield, and concentrations of crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (lignin), and acid detergent ash (ADF-Ash) in the fodder of 27 browse species was studied in the humid forest zone of southeastern Nigeria. The fodder yield, and concentrations of NDF, ADF and lignin increased ($p < 0.05$), while CP declined ($p < 0.05$) with increasing age of coppice regrowth for all the browse species. The ADF-Ash concentrations of eight browse species increased linearly ($p < 0.05$), while that of 19 species followed a quadratic ($p < 0.05$) trend in response to increasing age of coppice regrowth. *Bauhinia monandra, Calliandra calothyrsus, Dalbergia sissoo, Enterolobium cyclocarpum, Grewia pubescens, Gliricidia sepium, Leucaena leucocephala, Senna spectabilis*, and *Terminalia superba* were identified to have high potential for the development of integrated crop-livestock agroforestry technologies in the west African humid tropics based on fodder yield, concentrations of CP, NDF, ADF and lignin. Coppice regrowth of the promising species could be harvested between 16 and 20 weeks to maximize yield and quality of the fodder. The results showed that fodder yield and chemical composition could be used to identify browse species for the development of agroforestry technologies for smallholder crop-livestock farming systems.

Introduction

Browse species are important feed resources for trypanotolerant breeds of sheep and goats in the crop-based smallholder farming systems in the humid lowlands of west and central Africa (Le Houèrou 1980). Identification and integration of browse species, with potential for maintaining soil fertility and providing high quality fodder for livestock, into the farming systems is therefore a major focus of agroforestry research in the region (Kang et al. 1990), and other parts of the tropics (Gutteridge and Shelton, 1994). Although several indigenous and exotic browse species with potential for development of agroforestry technologies in the region have been identified over the past decade, information on their fodder potential (yield and quality), and how this is influenced by age of coppice regrowth is scanty and limited to a few species (Duguma et al. 1988; Kabiaja and Smith 1989; Cobbina 1995). The management of browse species for fodder and mulch requires frequent defoliation by cutting or grazing (Stur et al. 1994). Thus, coppice regrowth is one of the critical management decisions determining the fodder potential of browse species (Stur et al. 1994; Dzowela et al. 1995; Sereshine et al. 1998). This study was undertaken to determine the effect of coppice regrowth on fodder yield and chemical composition of 27 indigenous and exotic browse species evaluated previously for the development of agroforestry technologies in the humid lowlands of west and central Africa.

Materials and methods

Study site

The experiment was conducted at the International Institute of Tropical Agriculture (IITA) High Rainfall Station, Onne (04°5′ N, 07′ E) in the humid forest zone of southeastern Nigeria from 1998 to 1999. Average annual rainfall is about 2400 mm in a monomodal distribution lasting from March to December. The soil at the experimental site is a sandy-loam Ultisol with pH (H_2O) 5.9, organic carbon 12.2 g kg^{-1}, total nitrogen 0.8 g kg^{-1}, and Bray-1 phosphorus 67.1 mg kg^{-1} (Hulugalle et al. 1989).

Sampling for fodder yield

Twenty-seven brows species were studied, namely: *Afzelia bella, Albizia ferruginea, Albizia gummifera, Albizia noipoides, Anthonata macrophylla, Bauhinia monandra, Berlinia grandiflora, Calliandra calothyrsus, Dalbergia sissoo, Dialium guineense, Enterolobium cylocarpum, Gliricidia sepium, Grewia pubescens, Inga edulis, Leucaena leucocephala, Lonchocarpus sericeus, Millettia griffoniana, Millettia thonningii, Napoleonaea imperalis, Pletysepium violaleum, Parkia bicolor, Pterocarpus santalinoides, Senna spectabilis, Terminalia superba, Tetrapleura tetraptera, Treculia africana*, and *Xylia xylocarpa*.

The browse species were planted in 1991 from 8-week-old seedlings, using a randomized block design with three replications. A unit plot consisted of two rows of each species, 6 m long, and spaced 2.4 m between rows and 0.25 m within rows. Prior to the start of the current experiments, the species had been pruned at 0.50 m above ground once a year from 1993 to 1997 to assess the potential of the prunings as green manure for soil fertility maintenance using maize and cassava as test crops.

All plots were cut back on 4 March 1998 and 8 March 1999. Thereafter, the coppice regrowth were harvested once in each year at 8,12,16, and 20 weeks of regrowth to estimate fodder yield. At each harvest, five plants of each species were pruned to 50 cm above ground in each replicate, weighed fresh, and separated into fodder (leaves plus stems less than 10 mm in diameter) and stem fractions. Subsamples of the fodder were oven-dried at 60 °C for 48 h to determine dry matter content.

Chemical analysis

Oven-dried samples of the fodder from the 1998 harvests were ground through a 1-mm screen for determination of total nitrogen (N) by the Kjeldahl method (AOAC 1990). Crude protein (CP) was calculated as N × 6.25. Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (lignin) and acid detergent ash (ADF-Ash) were analyzed according to (Van Soest et al. 1991).

Statistical analysis

All data were analyzed using the general linear models (GLM) procedures of SAS (1990). Model sums of squares were partitioned to test linear and quadratic trends of coppice maturity using species, coppice regrowth, year and their interactions as independent factors in the model. Average values for fodder yield and concentrations of CP, NDF, ADF, and lignin for each species were subjected to cluster analysis, using the average linkage method for the purpose of grouping the species into clusters for the development of integrated crop-livestock agroforestry technologies.

Results

Edible fodder yield

Fodder yield varied ($p < 0.05$) among browse species within age of coppice regrowth (Table 1). Twelve species produced less than 5 M t DM ha^{-1}, whilst four species recorded fodder yields greater than 10 t DM ha^{-1}. Averaged across browse species, the relationship between age of coppice regrowth and fodder yield could be described by the regression equation: $Y_{FY} = 0.35 + 2.38$ AGR, $r^2 = 0.91$, where FY and AGR refer to fodder yield and age of coppice regrowth respectively.

Table 1. Effect of age of coppice regrowth on fodder yield of browse species in the west African humid tropics.

Species	Age of coppice regrowth (weeks) (Mg DM ha^{-1})[a]				Mean	SEM
	8	12	16	20		
A. bella	2.1	3.23	3.88	5.84	3.76	1.56
A. ferruginea	0.81	1.28	1.33	1.38	1.20	0.26
A. gummifera	0.78	2.91	2.83	4.01	2.63	1.35
A. macrophylla	0.46	0.69	0.84	1.61	0.9	0.49
A. noipoides	0.77	2.44	3.05	4.96	2.81	1.73
B. grandiflora	3.8	4.71	5.9	9.63	6.01	2.56
B. monandra	6.07	6.99	9.27	17.51	9.96	5.20
C. callothyrsus	3.55	10.12	17.36	27.09	14.53	10.09
D. guineense	1.6	2.64	3.15	5.68	3.27	1.73
D. sissoo	2.32	3.18	6.51	12.67	6.17	4.69
E. cyclocarpum	8.58	8.76	12.11	17.21	11.67	4.04
G. pubescens	4.99	5.37	8.4	19.04	9.45	6.57
G. sepium	6.19	6.84	7.92	13.53	8.62	3.35
I. edulis	4.02	9.86	15.79	40.66	17.58	16.11
L. leucocephala	4.32	5.38	6.54	7.31	5.89	1.31
L. sericeus	3.49	5.65	5.73	12.58	6.86	3.95
M. griffoniana	0.84	1.42	1.66	2.02	1.49	4.90
M. thonningii	1.37	1.34	1.60	2.07	1.60	0.34
N. imperalis	0.75	0.76	0.97	1.29	0.94	0.25
P. bicolor	4.03	5.83	6.66	18.78	8.83	6.73
P. santalinoides	2.90	3.02	3.91	3.68	3.38	0.49
P. violaleum	1.35	2.27	2.33	4.24	2.55	1.21
S. spectabilis	11.15	16.45	15.99	21.49	16.27	4.22
T. africana	1.56	2.54	3.53	5.25	3.22	1.57
T. superba	4.91	5.90	7.40	11.9	7.53	3.08
T. tetraptera	3.59	5.57	7.10	8.69	6.24	2.17
X.xylocarpa	3.55	5.30	8.11	11.39	7.09	3.43
Mean	3.33	4.83	6.29	10.80		
SEM	2.55	3.52	4.62	9.19		

[a]There was significant ($p < 0.05$) linear relationship between age of coppice regrowth and fodder yield of each species. The quadratic relationship was not significant ($p > 0.05$).

Crude protein content

Table 2 shows that the average CP concentration for all the browse species was greater than 130 g kg^{-1}, with 12 species recording CP concentrations above 200 g kg^{-1}. The CP concentration decreased linearly ($p < 0.05$) with increasing age of coppice regrowth in all species. For the 27 browse species, the relationship between CP concentration

Table 2. Effect of age of coppice regrowth on crude protein concentration in fodder of browse species in the west African humid tropics.

Species	Age of coppice regrowth (weeks) (g kg^{-1} DM)[a]				Mean	SEM
	8	12	16	20		
A. bella	253	240	228	195	229	24.9
A. ferruginea	222	215	196	165	200	25.9
A. gummifera	475	265	241	205	297	45.7
A. macrophylla	162	133	125	111	133	21.5
A. noipoids	283	269	225	199	244	38.9
B. grandiflra	233	191	153	141	180	41.5
B. monandra	202	198	197	162	190	18.6
C. callothyrsus	217	204	190	153	191	27.6
D. guineense	225	167	150	121	166	43.8
D. sissoo	223	164	163	161	178	30.2
E. cylocarpum	265	259	202	193	230	37.5
G. pubescens	26	260	193	153	217	53.4
G. sepium	268	208	183	160	205	46.5
I. edulis	256	188	181	115	185	57.6
L. leucocephala	317	226	211	186	235	57.1
L. sericeus	210	206	152	125	173	41.6
M. griffoniana	258	223	182	145	202	49.1
M. thonningii	215	215	171	107	177	51.1
N. imperalis	215	138	115	107	144	49.3
P. bicolor	204	153	106	104	142	47.3
P. santalinoides	181	172	167	131	163	21.9
P. violaleum	254	215	208	207	221	22.3
S. spectabilis	319	253	188	147	227	75.4
T. africana	204	152	139	139	159	30.9
T. superba	233	214	210	181	210	24.1
T. tetraptera	204	201	162	139	177	31.4
X.xylocarpa	185	184	164	133	167	24.3
Mean	242	204	177	151		
SEM	60.1	38.6	33.9	31.9		

[a]There was significant ($p < 0.05$) linear relationship between age of coppice regrowth and crude protein concentration of each species. The quadratic relationship was not significant ($p > 0.05$).

and coppice regrowth could be represented by the regression equation: $Y_{CP} = 262.5 - 28.1AGR$, $r^2 = 0.97$.

Cell wall concentration

Concentrations of the cell wall components varied ($p < 0.05$) among browse species within age of coppice regrowth (Tables 3–6). The NDF in 11 species was less than 400 g kg^{-1}, and greater than 500 g kg^{-1} in seven species (Table 3). Eight species had average ADF concentrations of less than 500 g kg^{-1}, while 10 species had ADF greater than 600 g kg^{-1} (Table 4). The lignin concentration in five species was lower than 100 g kg^{-1}, and greater than 200 g kg^{-1} in four species (Table 5).

Table 3. Effect of age of coppice regrowth on neutral detergent fibre concentration in fodder of browse species in the west African humid tropics.

Species	Age of coppice regrowth (weeks) (g kg^{-1} DM)[a]				Mean	SEM
	8	12	16	20		
A. bella	344	347	354	426	368	39.1
A. ferruginea	290	373	373	453	372	66.6
A. gummifera	366	455	476	549	462	75.3
A. macrophylla	575	674	675	675	650	49.8
A. noipoides	281	370	385	467	376	76.2
B. grandiflora	449	511	525	543	507	40.8
B. monandra	404	417	423	426	418	9.8
C. callothyrsus	347	389	406	483	406	56.9
D. guineense	419	465	473	485	461	28.9
D. sissoo	306	334	340	354	334	20.2
E. cylocarpum	294	314	345	457	353	72.8
G. pubescens	249	289	320	396	314	68.2
G. sepium	324	390	404	404	381	38.2
I. edulis	531	541	596	625	573	44.7
L. leucocephala	227	317	343	343	308	55.0
L. sericeus	496	576	595	661	582	67.9
M. griffoniana	414	497	509	535	489	52.3
M. thonningii	443	485	499	508	484	28.9
N. imperalis	374	474	494	529	468	66.5
P. bicolor	545	566	583	591	571	20.4
P. santalinoides	431	440	505	517	473	44.0
P. violaleum	437	514	550	507	502	47.3
S. spectabilis	337	349	362	387	359	21.4
T.Africana	314	315	327	375	333	28.8
T.superba	242	242	277	303	266	29.7
T. tetraptera	362	403	428	556	437	88.7
X.xylocarpa	497	508	509	519	508	8.9
Mean	381	428	447	484		
SEM	117.2	127.0	129.1	128.0		

[a]There was significant ($p < 0.05$) linear relationship between age of coppice regrowth and neutral detergent fibre concentration. The quadratic relationship was not significant ($p > 0.05$).

Table 4. Age of coppice regrowth effects on acid detergent fibre concentration in fodder of browse species in the west African humid tropics.

Species	Age of coppice regrowth (weeks) (g kg^{-1} DM)[a]				Mean	SEM
	8	12	16	20		
A. bella	497	506	559	616	545	54.9
A. ferruginea	431	464	553	610	515	81.9
A. gummifera	598	618	654	706	644	47.4
A. macrophylla	662	690	703	704	690	19.6
A. noipoides	402	416	523	588	482	88.8
B. grandiflora	638	651	681	682	663	22.1
B. monandra	550	556	576	599	570	22.2
C. callothyrsus	454	454	472	489	467	16.8
D. guineense	573	576	589	619	589	21.1
D. sissoo	427	437	510	559	483	62.6
E. cylocarpum	420	450	464	616	488	87.6
G. pubescens	392	443	479	578	473	78.6
G. sepium	428	476	490	506	475	33.6
I. edulis	603	621	646	665	634	27.3
L. leucocephala	329	391	467	498	421	76.2
L sericeus	634	670	737	771	703	62.3
M. griffoniana	582	590	621	627	605	22.3
M. thonningii	573	592	609	637	603	27.2
N. imperalis	496	565	567	584	553	38.9
P.bicolor	591	598	619	661	617	31.5
P. santalinoides	585	586	615	617	601	17.6
P. violaleum	583	610	643	692	632	46.9
S. spectabilis	436	453	505	543	484	48.9
T. africana	443	456	489	622	503	81.9
T. superba	299	399	374	588	415	122.9
T. tetraptera	475	518	555	695	561	95.3
X. xylocarpa	634	648	648	650	645	7.3
Mean	509	534	568	619		
SEM	101.3	903	86.1	67.2		

[a]There was significant ($p < 0.05$) linear relationship between age of coppice regrowth and acid detergent fibre concentration. The quadratic relationship was not significant ($p > 0.05$).

Averaged across browse species, the relationships between age of coppice regrowth and the NDF, ADF and lignin concentrations could be represented by the following significant ($p < 0.05$) regression equations:

$$Y_{NDF} = 353 + 32.9AGR, r^2 = 0.98, Y_{ADF} = 467 + 36.3AGR, r^2 = 0.97, \text{ and } Y_{lignin} = 2.38 + 0.35AGR, r^2 = 0.98.$$

The ADF-Ash concentration in the edible fodder of 19 out of 27 browse species (70%) showed a quadratic ($p < 0\ .05$) trend, while that of the remaining eight followed a linear ($p < 0.05$) trend

Table 5. Effect of age of coppice regrowth on lignin concentration in fodder of browse species in the west African humid tropics.

Species	Age of coppice regrowth (weeks) ($g\ kg^{-1}$ DM)[a]				Mean	SEM
	8	12	16	20		
A. bella	104	107	111	144	91	18.6
A. ferruginea	95	111	132	137	95	19.4
A. gummifera	181	185	189	204	145	10.1
A. macrophylla	289	343	345	356	261	30.0
A. noipoides	109	131	141	192	116	35.1
B. grandiflora	201	203	216	277	174	35.8
B. monandra	98	104	107	146	89	21.8
C. callothyrsus	110	142	149	221	128	46.9
D. guineense	158	188	191	194	143	16.7
D. sissoo	87	97	98	118	78	12.9
E. cylocarpum	71	75	87	146	77	34.8
G. pubescens	62	67	72	115	64	24.3
G. sepium	68	112	160	168	110	46.5
I. edulis	217	250	277	286	203	31.0
L. leucocephala	69	108	140	141	97	23.9
L. sericeus	193	223	254	305	196	47.8
M. griffoniana	131	155	169	174	125	19.3
M. thonningii	141	142	150	168	115	12.5
N. imperalis	121	157	165	165	122	21.0
P. bicolor	215	223	227	275	181	27.1
P. santalinoides	158	167	202	202	143	23.1
P. violaleum	161	168	180	192	135	13.7
S. spectabilis	79	80	90	118	72	18.2
T. africana	85	88	87	120	74	16.7
T. superba	39	58	69	75	51	15.8
T. tetraptera	126	156	160	238	139	47.8
X. xylocarpa	158	164	214	210	147	29.5
Mean	130	148	162	188		
SEM	58.6	63.8	66.1	66.7		

[a]There was significant ($p < 0.05$) linear relationship between age of coppice regrowth and lignin concentration. The quadratic relationship was not significant ($p > 0.05$).

Table 6. Effect of age of coppice regrowth on acid detergent fibre ash concentration in fodder of browse species in the west African humid tropics.

Species	Age of coppice regrowth (weeks) ($g\ kg^{-1}$ DM)				Mean	SEM	Probability[a]	
	8	12	16	20			L	Q
A. noipoides	1.20	1.34	1.86	4.20	2.15	1.39	**	ns
B. monandra	1.94	0.55	2.83	5.07	2.60	1.89	*	*
D. sissoo	1.97	0.67	2.42	3.03	2.02	1.01	**	**
I. edulis	2.08	1.98	4.16	4.96	3.30	1.29	**	*
N. imperalis	1.08	1.33	4.92	5.11	3.11	2.20	**	ns
P. santalinoides	2.17	0.77	3.59	4.90	2.86	1.78	**	*
T. tetraptera	1.97	0.56	2.97	3.12	2.16	1.18	**	*
X. xylocarpa	0.87	1.30	2.07	3.28	1.88	1.05	**	ns
A. bella	2.94	1.19	8.25	2.27	3.66	3.14	*	*
A. ferruginea	1.19	1.64	3.58	2.49	2.23	1.05	*	**
A. gummifera	1.51	10.41	1.39	2.99	4.08	4.29	ns	**
A. macrophylla	1.32	0.86	3.59	0.33	1.53	1.43	*	*
B. grandiflora	2.82	0.54	3.35	2.49	2.30	1.23	*	**
C. callothyrsus	2.41	1.86	6.37	0.56	2.80	2.50	*	**
D. guineense	6.47	13.67	21.30	15.58	14.26	6.12	*	**
E. cyclocarpum	3.56	1.53	5.95	0.78	2.96	2.32	*	**
G. pubescens	2.72	2.95	4.97	1.50	3.04	1.64	ns	**
G. sepium	1.21	1.33	4.65	1.59	2.20	1.64	*	**
L. leucocephala	5.11	9.63	3.22	4.42	5.60	2.80	ns	**
L. sericeus	0.32	1.98	6.83	2.72	2.96	2.77	ns	**
M. griffoniana	8.46	9.48	13.51	12.24	10.92	2.35	*	*
M. thonningii	0.54	1.56	7.63	6.04	3.94	3.43	*	*
P. bicolor	1.31	0.44	6.22	2.66	2.66	2.54	ns	*
P. violaleum	6.37	10.26	17.80	16.33	12.69	5.33	*	*
S. spectabilis	2.69	3.80	4.43	3.30	3.56	0.74	*	**
T. africana	12.67	18.94	21.82	14.91	17.09	4.09	ns	**
T. superpa	0.55	0.66	5.96	3.35	2.63	2.57	ns	**
Mean	2.87	3.75	6.51	4.82				
SEM	2.78	4.87	5.58	4.50				

[a]Probability for linear (L) and quadratic (Q) trends of age of coppice regrowth.
*$p < 0.05$, **$p < 0.01$.

in response to increasing age of coppice regrowth (Table 6). Averaged across browse species, these relationships could be represented by the following regression equations: $Y_{\text{ADF-Ash}} = 2.17 - 1.09\,\text{AGR} + 6.27\text{AGR}^2 r^2 = 0.77$, and $Y_{\text{ADF-Ash}} = 0.085 + 0.969\text{AGR}, r^2 = 0.77$.

Classification of browse species

Grouping of the browse species based on the average fodder yield, CP, and cell wall concentrations (NDF, ADF and lignin) is presented in Table 7. Low fodder yield, high CP contents, and intermediate cell wall contents characterized Cluster 1. Cluster 2 had high fodder yield, intermediate CP contents, and low cell wall contents, while Cluster 3 had intermediate fodder yield, low CP contents, and high cell wall contents.

For each cluster, fodder yield, NDF, ADF and lignin increased, while CP declined ($p < 0.05$) with increasing age of coppice regrowth (Table 8).

Discussion

Edible fodder yield

The differences in fodder yield among browse species may reflect variations in growth habit,

Table 7. Classification of browse species based on fodder yield and chemical composition, and mean concentrations of crude protein, neutral detergent fibre, acid detergent fibre, and lignin in the west African humid tropics.

Average fodder yield and composition	Cluster		
	1	2	3
	A. bella *A. ferruginea* *A. ferruginea* *A. noipoides* *A. macrophylla* *D. guineense* *M. griffoniana* *M. thonningii* *N. imperalis* *P. violaleum* *P. santalinoides* *T. africana*	*B. monandra* *C. calothyrsus* *D. sisso* *E. cyclocarpum* *G. pubescens* *G. sepium* *L. leucocephala* *S. spectabilis* *T. superba*	*B.grandiflora* *I. edulis* *L. sericeus* *P. bicolor* *T. tetraptera* *X. xylocarpa*
EFY (Mg DM ha^{-1})	3.5 (1.74)	16.4 (5.85)	16.9 (12.14)
CP (g kg^{-1})	153 (39.8)	166 (16.3)	1269 (14.5)
NDF (g kg^{-1})	502 (73.9)	409 (51.1)	605 (50.3)
ADF (g kg^{-1})	635 (42.3)	553 (46.6)	687 (43.9)
Lignin (g kg^{-1})	187 (59.5)	139 (38.3)	265 (34.8)
ADF-Ash (g kg^{-1})	7.3 (5.54)	2.6 (1.59)	3.2 (0.91)

Numbers in parentheses are standard error of the means.
EFY = edible fodder yield, NDF = neutral detergent fibre, ADF = acid detergent fibre and CP = crude protein.

residual buds, leaf area index, and storage carbohydrates among the species (Stur et al. 1994). The linear increase in fodder yield agrees with earlier reports (Duguma et al. 1988; Stur et al. 1994; Cobbina 1995; Heering 1995; Seresinhe et al. 1998), and could be partly attributed to increases in the number of growing buds and new shoots (Perez and Mendelez 1980; Ezenwa and Cobbina 1991) and, greater light interception and stem carbohydrate reserves (Duguma et al. 1988; Erdmann et al. 1993) with longer age of coppice regrowth. This observation suggests that the browse species could produce more fodder at age of coppice regrowth greater than 20 weeks.

Crude protein content

The significant variation in the CP concentration among the browse species in the current study is in agreement with other reports (Larbi et al. 1998; Kaitho et al. 1998). The linear decline in CP concentration with increasing age of coppice regrowth could be partly due to the higher NDF, ADF, and lignin concentrations with maturity (Tables 3–5). A similar trend has been reported (Cobbina 1995; Dzowela et al. 1995; Trujillo et al. 1996). Other reasons for the decline include reduced leaf to stem ratio in the analyzed samples and dilution due to higher DM accumulation. For tropical forages, digestibility is depressed and forage intake drops when CP content is lower than 80 g kg^{-1} (Minson 1990), partly because nitrogen is insufficient to meet the needs of rumen bacteria. The CP concentration of all the browse species in the current study was greater than the above minimum, suggesting that the browse species could effectively provide supplemental nitrogen for ruminants fed basal diets of low nitrogen cereal crop residues. It should be noted that the availability of nitrogen in the fodder of browse species is dependent on the concentration of secondary compounds, such as condensed tannins (Broderick 1995).

Cell wall concentration

In agreement with other reports (Dzowela et al. 1995) the NDF, ADF and lignin concentrations in

Table 8. Regression equations for predicting fodder yield, neutral detergent fibre, acid detergent fibre, lignin, and crude protein of browse species from the age of coppice regrowth in the west African humid tropics.

Cluster	Independent variable	Intercept	Regression coefficient	r^2
1	Fodder yield	0.55	0.71	0.96
	NDF	366	35.1	0.95
	ADF	496	33.8	0.91
	Lignin	132	13.3	0.90
	CP	256	-26.2	0.98
2	Fodder yield	1.41	3.439	0.92
	NDF	277	32.4	0.97
	ADF	364	44.5	0.98
	Lignin	54	20.3	0.96
	CP	283	-19.7	0.92
3	Fodder yield	1.65	4.17	
	NDF	477	32.5	0.98
	ADF	561	30.4	0.97
	Lignin	154	26.1	0.95
	CP	226	-18.1	0.75

Cluster 1: *Afzelia bella, Albizia ferruginea, Albizia gummifera, Albizia noipoides, Anthonata macrophylla, Dialium guineense, Millettia griffoniana, Millettia thonningii, Napoleonaea imperalis, Pletysepium violaleum, Pterocarpus santalinoides, Treculia africana*. Cluster 2: *Bauhinia monandra, Calliandra calothyrsus, Dalbergia sissoo, Enterolobium cylocarpum, Gliricidia sepium, Grewia pubescens, Leucaena leucocephala, Senna spectabilis, Terminalia superb*. Cluster 3: *Berlinia grandiflora, Inga edulis, Lonchocarpussericeus, Parkia bicolor, Tetrapleura tetraptera, Xylia xylocarpa*.
NDF = neutral detergent fibre, ADF = acid detergent fibre and CP = crude protein.

the edible fodder for all the browse species increased in response to increasing age of coppice regrowth. This observation could be partly due to a decline in leaf to stem ratio and cell wall thickening (Wilson 1994). The increase in cell wall concentration with maturity could translate into low intake of digestible nutrients because preference, voluntary DM intake, and potential DM degradability of browse species are negatively correlated with cell wall concentrations (Kaitho et al. 1998; Larbi et al. 1998).

The ADF-Ash concentration in the edible fodder showed both linear and quadratic responses with age of coppice regrowth (Table 6). We are not aware of any published report on the effect of age of coppice regrowth on ADF-Ash in browse species to compare with our results. However, Kabiaja and Smith (1989) reported both linear and quadratic trends in the concentration of minerals with age of regrowth in *G. sepium* and *L. leucocephala*, which partly agrees with our results. Further studies are therefore needed to confirm the observed responses of ADF-Ash concentration to age of coppice regrowth.

Classification of browse species

The groupings in Table 7 suggest that fodder yield and chemical composition could be used to identify promising browse species for the development of agroforestry technologies in smallholder crop-livestock farming systems. The classification of the browse species in the current study should, however, be interpreted with caution because although some of the browse species recorded a high fodder yield, there is very little documentation on their potential as livestock feed in the tropics. Secondly, the browse species could differ in critical determinants of fodder quality, such as palatability, voluntary intake, digestibility, and other anti-nutritional factors that were not measured in the current study.

We recognize that the age of coppice regrowth required to maximize fodder yield and chemical composition could vary with browse species due to differences in morphology. However, the increases in fodder yield and cell wall concentrations, coupled with the decline in CP with maturity suggest that regrowth of the browse species in the current study could be harvested at 16–20 weeks to produce appreciable amounts of quality edible fodder. The recommended cutting interval is comparable to the range of 8–16 weeks suggested for some tropical forage tree legumes (Stur et al. 1994; Seresinhe et al. 1998).

The feed value of a fodder species, defined as animal output per unit intake of digestible DM, is a function of both the quantity and quality of the fodder on offer. Furthermore, the NDF and ADF contents in the edible fodder of browse species are negatively correlated with preference, voluntary DM intake, and potential DM degradation (Kaitho et al. 1998; Larbi et al. 1998). Thus, the high EFY, intermediate CP, and low cell wall contents of Cluster 2 compared with the other clusters could result in a relatively high digestible dry matter intake. This observation suggests that the MPTS in Cluster 2 have relatively higher feed value than those in Clusters 1 and 3. Further studies are needed to determine whether the high ranking of the browse species in Cluster 2 could be translated into animal output, which is a better measure of forage quality (More et al. 1990). The promising browse species could be effectively introduced into smallholder crop-livestock farming systems in the humid lowlands of west and central Africa and similar environments in a number of ways. They could be used in live fences, feed gardens, fodder banks, improved fallows, alley farms, and multi-strata systems as sources of home-grown fodder for ruminants or green manure for soil fertility maintenance.

Conclusions

Fodder yield and chemical composition could be used to identify promising browse species for development of integrated crop-livestock agroforestry technologies. Based on fodder yield, and concentrations of CP, NDF, ADF and lignin, *B. monandra, C. calothyrsus, D. sisso, E. cyclocarpum, G. pubescens, G sepium, L. leucocephala, S. spectabilis*, and *T. superba* were identified as having a high potential for integrated crop-livestock agroforestry technologies in the humid lowlands of west and central Africa. The coppice regrowth of these browse species could be harvested at 16–20 weeks to produce appreciable quantities of quality fodder. For all the browse species, the CP concentration in the edible fodder declined, whilst fodder yield and cell wall contents increased in response to increasing age of coppice regrowth.

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