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Full Length Research Paper

Effects of variety and stage of grain maturity at harvest on the yield and quality of maize stover

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A study was conducted to examine the effects of variety and stage of grain maturity at harvest on the yield and quality of maize stover obtained from 15 varieties sampled from three locations. There were significant vatrietal differences in the yield and quality of maize stover. However, there was no significant varietal effect on grain yield. On the other hand, the yield and quality of maize stover markedly deteriorates with increasing stage of grain maturity at harvest. The observed variations between the varieties in the measured feed related parameters but with no significant variation in grain yield indicate the possibility of manipulating some traits in the effort to improving the yield and quality of maize stover through breeding and/or selection without significantly affecting grain yield. Therefore, there is a need to work with animal nutritionists in the process of maize technology generation when targeting the mixed crop-livestock system of agricultural production. On the other hand, as the yield and quality of maize stover deteriorates as the stage of grain maturity increases, employing applicable system of feeding livestock on stover before the last stage of maturity is advisable.

Key words: Maize, stage of harvest, stover quality, stover yield, variety

INTRODUCTION

Maize is the second dominant crop next to teff (Eragrostis teff) among the cereals that are grown in Ethiopia contributing about one third of the caloric intake of the population (EARO, 2001). Most of the maize production comes from the mixed crop-livestock system (CSA, 2008) produced by smallholder farmers using inputs like draught power, cash and manure from the livestock sub-sector. Maize contributes a significant amount of fodder in the form of green or dry stover for livestock feeding particularly in the major maize growing areas. However, the contribution of livestock to maize production has been constrained by low production and productivity of livestock due to feed shortage. The degree of dependence of livestock on maize byproducts will inevitably increase because of the increasing population pressure on arable land and shrinking size of grazing lands. Thus, improving the yield and quality of maize stover and its efficient utilization is a commendable strategy to alleviate feed shortage and thus improve livestock performance and that will ultimately benefit maize production. However, the maize breeding programs in the agricultural research system focus only on grain yield neglecting fodder value (quantity and quality) of maize.

The demand for food-feed maize cultivars that provide good stover quantity and quality besides grain yield has been strongly voiced by researchers (Adugna, 2002; Devendra and Pezo., 2004; Singh et al 2004). The possibility of breeding maize genotypes that provide desirable fodder characteristics in addition to grain yield has been reported elsewhere (Reddy et al., 2003). Adugna et al (1999) studied the effect of variety on the yield and quality of maize stover using eight maize varieties grown at Awassa and indicated the possibility of combining food and feed traits in maize. However, they cautioned about the interpretation of the results as the results were of a single season and one location. Therefore, it is important to re-investigate issues of varietal difference on the yield and quality of maize stover by incorporating larger number of varieties and/or more locations. Thus, this paper reports the results of a study on effect of variety and stage of grain maturity at harvest on the yield and quality of maize stover obtained from 15 varieties planted at three different locations in Ethiopia.

MATERIALS AND METHODS

Maize varieties and sampling

Stover sampling was done at two stages of grain maturity: green (dough) and mature (dry) stages with the objective of determining the effect of stage of maturity at harvest and variety on the yield and quality of maize stover.

The mature stage sampling was done at the time of grain harvest. A total of 16 varieties were considered where the actual number of varieties at each of the stages was 15 omitting one variety (Pioneer) at the green (dough) and another (Sidancho) at the mature (dry) stage due to some inconveniences during the process of sampling. Sampling Pioneer at the green stage was not possible because the available plots were under another observation at that stage and the household where the green stage of the Sidancho variety was sampled finished it at the green (dough) stage. The list of varieties and the sites and stage of maturity at sampling are shown in Table 1. For those varieties common to Awassa and Bako, site means were considered as replicates. Except for the landraces, sampling was done from on-farm demonstration plots at Awassa, Bako and Kulumsa by cutting on average 10 randomly selected maize plants from a plot and the conversion of yield per ha was according to the planting density.

Samples from the landraces were collected from farmers' fields in Awassa and Bako where they were grown under different management conditions as compared to the other varieties. The landraces were broadcast on fields around the homesteads where they usually receive manure. Though this was the situation, landraces were included in the analysis to serve as references. The dry stage sampling included partitioning of the total biomass into grain, stover and cob. Sub-samples of 200g – 400g were taken in two replicates after mixing (homogenization) of the bulked fresh samples for further analysis.

Data collection and analysis

The fresh stover samples were oven dried at 60^0C for 48 hours and ground to 2 mm size. The chemical composition - ash, nitrogen, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) and nutritive values – invitro organic matter digestibility (IVOMD) and metabolizable energy (ME) values of the stover samples were estimated using the near infrared reflectance spectroscopy (NIRS) technique according to Windham et al.(1989). The crude protein (CP) contents were determined multiplying the nitrogen contents by 6.25. The hemicelullose and cellulose contents were also computed from NDF, ADF and ADL values as hemicellulose = NDF – ADF and cellulose = ADF – ADL. Analysis of variance (one way using SPSS version 15.0 software) was carried out to see variety effects on the measured variables and mean separation was done according to the Duncan's multiple range test procedure. Correlation coefficients were computed to see the relationship between stage of maturity at harvest and grain yield with measured stover yield and quality parameters.

The analysis of the stover samples using the NIRS technique was conducted at ILRI-Ethiopia as a subset of a large number of maize stover samples collected from Tanzania and Ethiopia. The samples were scanned in spinning sample cells (ISI, Part number IH-0307) at 2 nm intervals for their measurements, such as inverse of the reflectance (log 1/R) over the NIR spectral range from 1100 to 2498 nm in reflectance mode by using a spectrophotometer model Foss 5000 (Foss NIR Systems, Silver Spring, MD, USA) and the chemometrics software WinISI II (Infrasoft International, LLC, 109 Sellers lane, PA 16870,

Table 1: List of varieties and the sites and stage of maturity at sampling.

Variety	Site			Stage of maturity	
	Awassa	Bako	Kulumsa	Green/dough	Mature/Dry
BH543[a]	*x*	*x*		*x*	*x*
BH542[a]	x	x		x	x
BH545[a]	x	x		x	x
BH540[a]	x	x		x	x
BH670[a]	x	x		x	x
BH660[a]	x	x		x	x
Sidancho[c]	x			x	
Kuleni[b]		x		x	x
Gibe 1[b]		x		x	x
Gutto LMS5[b]		x		x	x
BH140[a]		x		x	x
Burre[c]		x		x	x
Arganne[a]			x	x	x
Wenchi[a]			x	x	x
Jibata[a]			x	x	x
Pioneer[a]	x				x

[a] Hybrid variety (a maize variety produced from a cross between two or more inbred lines with different genetic constituents under controlled pollination).
[b] Open pollinated variety - OPV (a variety that has been grown and selected for its desirable traits under natural pollination).
[c] Local variety (Landrace).

Table 2: Maize global calibration equation statistics for chemistry and NIRS variables

Maize (n = 690)	**Calibration samples statistics**				**Calibration equation statistics**		
Variable (% DM)	**Min**	**Max**	**Mean**	**Std. Dev**	**SEC**	**R^2**	**SECV**
DM	88.891	95.755	92.797	1.078	0.304	0.908	0.344
Ash	4.023	19.600	7.695	2.346	0.469	0.951	0.514
N	0.270	1.669	0.796	0.266	0.042	0.975	0.049
NDF	51.580	84.331	69.191	6.406	1.127	0.969	1.227
ADF	25.798	52.981	38.554	5.642	0.906	0.974	1.020
ADL	0.922	6.653	3.317	0.964	0.338	0.872	0.357
ME	5.417	10.643	8.311	0.917	0.230	0.933	0.259
IOMD	38.307	70.296	55.960	5.699	1.447	0.932	1.626

n = number of samples

USA) version 1.50 was used. In order to highlight the chemical entities, the noise from spectral distortions was reduced by the use of standard normal variance (SNV) and de-trending (DT) transformation (Barnes et al., 1989).

The NIRS global calibration equation for maize samples was selected (NIRS models) to predict the unknown samples set and taken the blind predicted results in to considerations. The calibration samples were selected by the spectral selection procedures for crop and experiment specific product calibration equations. All the samples were pooled for arriving at an expanded global calibration equation (Table 2) for the

Table 3: Chemical composition of maize stover from the 15 varieties harvested at the green/dough stage (g kg^{-1} DM) (n = 2)

Variety	Ash	CP	NDF	ADF	Lignin	Cellu lose	Hemi cellulose
BH543	55	74	$693a^{bcd}$	369	39^{bc}	330	324
BH542	50	70	698^{abc}	372	42^{b}	330	327
BH545	52	76	687^{bcd}	345	41^{b}	303	342
BH540	46	59	746^{a}	294	50^{a}	243	402
BH670	60	76	671^{bcdef}	317	42^{b}	275	355
BH660	46	73	678^{bcde}	368	41^{b}	327	311
Sidancho	77	84	622^{fg}	354	38^{bc}	315	318
Kuleni	41	69	680^{bcde}	355	38^{bc}	316	325
Gibe1	44	70	697^{abc}	307	40^{b}	267	394
Gutto LMS5	41	62	710^{ab}	382	42^{b}	340	328
BH140	55	77	666^{cdef}	353	35^{bcd}	318	313
Burre	31	59	692^{abcd}	353	38^{bc}	315	339
Arganne	62	64	637^{defg}	355	30^{de}	324	282
Wenchi	73	70	626^{fg}	344	32^{cd}	311	283
Jibat	75	74	609^{g}	329	27^{e}	301	280
Mean	54	70	674	346	39	308	328
SE	9.12	4.92	16.52	31.14	2.32	31.33	31.43

Means followed by different superscripts in a column are significantly different (p<0.05).

samples. The expanded maize global calibration samples were split in to two equal sets of 50% each and the first set was termed as calibration set and was used for calibration and the remaining set was used for validating samples testing the calibration equations' robustness and precision. The problems with strong dependence between spectral signals in different wavelength bands were avoided by the reduction to a few latent orthogonal variables (terms) using the modified partial least squares regression by Shenk and Westerhaus (1991). The optimal number of terms to be included in the NIRS models was determined as having the lowest standard error of cross validation (SECV) (Windham et al 1989).

RESULTS AND DISCUSSION

Table 3 shows the chemical composition of stovers obtained from the maize varieties harvested at the green (dough) stage. Significant (p<0.05) differences only in NDF and lignin fractions were observed between varieties. The BH540 variety was the most fibrous and most lignified with NDF and lignin contents of 746 g kg^{-1} and 50 g kg^{-1} of stover dry matter, respectively. The CP content of the same variety was the least (59 g kg^{-1}) at the green stage. The variety with the name Jibat showed the least NDF and lignin contents with reasonably good CP (74 g kg^{-1}). This implies that green stover from Jibat is of the best quality.

As shown in Table 4, significant varietal differences (p<0.05) were observed in the ash, ADF, lignin and cellulose contents of stover at the mature (dry) stage whereas the differences in CP, NDF and hemicellulose fractions were not significant (p>0.05).

As shown in Table 5, varietal differences in in vitro organic matter digestibility (IVOMD) and metabolizable energy (ME) values of maize stover were significant (p<0.05). The variety with the name Jibat showed significantly higher IVOMD and ME values than the other varieties while the respective values for Burre were the least.

There were no significant variations (p>0.05) between varieties in their gain and total biomass yield (Table 6). BH660 was found to be the highest grain yielder and Kuleni the least. The absence of significant varietal difference ingrain yield observed in the current study disagrees with that of Adugna et al. (1999). This may be attributed to differences in the set of varieties used. However, varieties exhibited significant

Table 4: Chemical composition of maize stover from the 15 varieties harvested at mature (dry) stage (g kg^{-1} DM)

Variety	Ash	CP	NDF	ADF	Lignin	Cellulose	Hemi cellulose
BH543	62^{abc}	52	807	483^{abc}	55^{b}	428^{ab}	324
BH542	47^{c}	50	820	459^{cd}	60^{ab}	429^{ab}	361
BH545	49^{c}	45	817	478^{abc}	60^{ab}	418^{ab}	339
BH540	47^{c}	41	816	456^{cd}	62^{ab}	395^{abc}	360
BH670	58^{bc}	51	787	473^{bcd}	59^{ab}	414^{ab}	314
BH660	56^{bc}	47	788	488^{abc}	61^{ab}	427^{ab}	300
Kuleni	43^{c}	52	822	473^{bcd}	55^{b}	420^{ab}	348
Gibe1	45^{c}	51	831	440^{cd}	57^{b}	384^{bc}	391
Gutto LMS5	42^{c}	42	749	488^{abc}	62^{ab}	426^{ab}	263
BH140	52^{bc}	51	826	475^{abcd}	55^{b}	421^{ab}	351
Burre	57^{bc}	44	814	528^{a}	65^{a}	463^{a}	386
Arganne	62^{abc}	55	783	459^{cd}	46^{c}	413^{ab}	325
Wenchi	51^{bc}	38	776	476^{abcd}	46^{c}	430^{ab}	300
Jibat	72^{ab}	57	692	382^{e}	30^{d}	352^{c}	310
Pioneer	82^{a}	44	793	523^{ab}	62^{ab}	462^{a}	270
Mean	55	48	795	472	56	419	322
SE	6.44	5.07	30.84	15.61	2.25	17.22	26.07

Means followed by different superscripts in a column are significantly different ($p<0.05$)

Table 5: In vitro organic matter digestibility (IVOMD), digestible DM yield (DSY) and energy (ME) values of the stovers of the 15 varieties of maize harvested at mature (dry) stage

Variety	IVOMD (g kg-1 DM)	DSY (t DM ha-1)*	ME (MJ kg-1)
BH543	60.21bc	4.81cd	8.95bc
BH542	56.31cde	4.89cd	8.35cde
BH545	56.78cde	4.24d	8.48cde
BH540	54.04de	3.87d	8.08de
BH670	58.45bcd	6.83bc	8.71bcd
BH660	57.02cde	5.85cd	8.51cd
Kuleni	59.77bc	5.28cd	8.91bc
Gibe1	59.77bc	5.67cd	8.92bc
Gutto LMS5	55.60cde	4.17d	8.29cde
BH140	59.53bc	4.51cd	8.86bc
Burre	53.25e	5.71cd	7.91e
Arganne	61.29b	5.91cd	9.21b
Wenchi	62.25b	9.08a	9.29b
Jibat	67.24a	8.50ab	10.02a
Pioneer	58.49bcd	5.05cd	8.67bcd
Mean	58.70	5.62	8.74
SE	1.38	0.71	0.19

Means followed by different superscripts in a column are significantly different ($p<0.05$).
*DSY was a calculated value based on stover yield and IVOMD.

Table 6: Grain, stover, cob and total biomass yield of the 15 maize varieties

	Yield (t DM ha^{-1})			
Variety	Grain	Stover	Cob	Total biomass
BH543	8.17	7.99^{bc}	1.30	17.46

BH542	7.21	8.71[bc]	1.83	17.75
BH545	8.90	7.43[c]	1.85	18.17
BH540	7.58	7.16[c]	1.47	16.21
BH670	8.93	11.69[b]	1.90	22.52
BH660	9.20	10.01[bc]	1.34	20.55
Kuleni	4.80	8.83[bc]	0.99	14.62
Gibe1	6,72	9.02[bc]	1.17	16.91
Gutto LMS5	6.26	7.60[bc]	1.21	15.07
BH140	5.71	7.62[bc]	1.13	14.45
Burre	6.35	10.78[bc]	1.27	18.40
Arganne	5.88	9.57[bc]	1.18	16.62
Wenchi	5.53	14.59[a]	1.09	21.20
Jibat	5.18	8.64[bc]	0.97	18.76
Pioneer	8.63	9.48[bc]	1.72	18.99
Mean	7.00	9.48	1.36	17.84
SE	1.50	1.20	0.27	2.57

Means followed by different superscripts in a column are significantly different (p<0.05)

Table 7: Correlation coefficients (r) of the measured variables with stage of harvest on maize stover (n=56)

	Measured variables						
	Ash	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**	**SY**
r	0.049	-0.812**	0.804**	0.851**	0.734**	-0.602**	-0.671**

** Correlation is significant at the 0.01 level

Table 8: Correlation coefficients (r) of grain yield and stover yield and stover quality (n=30)

	Grain yield	**CP**	**NDF**	**ADF**	**ADL**	**ME**	**IVOMD**	**Stover DM yield**
Grain yield								
CP	-0.295							
NDF	0.126	-0.230						
ADF	0.252	-0.538**	0.468**					
ADL	0.461*	-0.468**	0.564**	0.690**				
ME	-0.415*	0.579**	-0.506**	-0.646**	-0.926**			
IVOMD	-0.410*	0.599**	-0.508**	-0.639**	-0.920**	0.999**		
Stover DM yield	0.019	-0.019	-0.201	-0.158	-0.448*	0.348	0.342	
Digestible stover DM yield	-0.092	0.130	-0.314	-0.321	-0.635**	0.563**	0.556**	0.967**

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
n = number of observations

variations in stover yield. Significantly higher stover yield was recorded for Wenchi than the rest of the varieties.

All feed related parameters had highly significant (p<0.01) correlations with stage of harvest except the ash contents (Table 7). Stage of harvest had negative and significant correlations with CP, ME, stover yield (SY) and IVOMD whereas its correlations with NDF, ADF and ADL were positive and significant.

Table 8 shows the correlation of grain yield with stover yield and its quality. Grain yield showed positive but insignificant (p<0.05) correlations with stover yield and NDF contents. However, its correlation with stover ADL content was positive and significant. Grain yield was not significantly

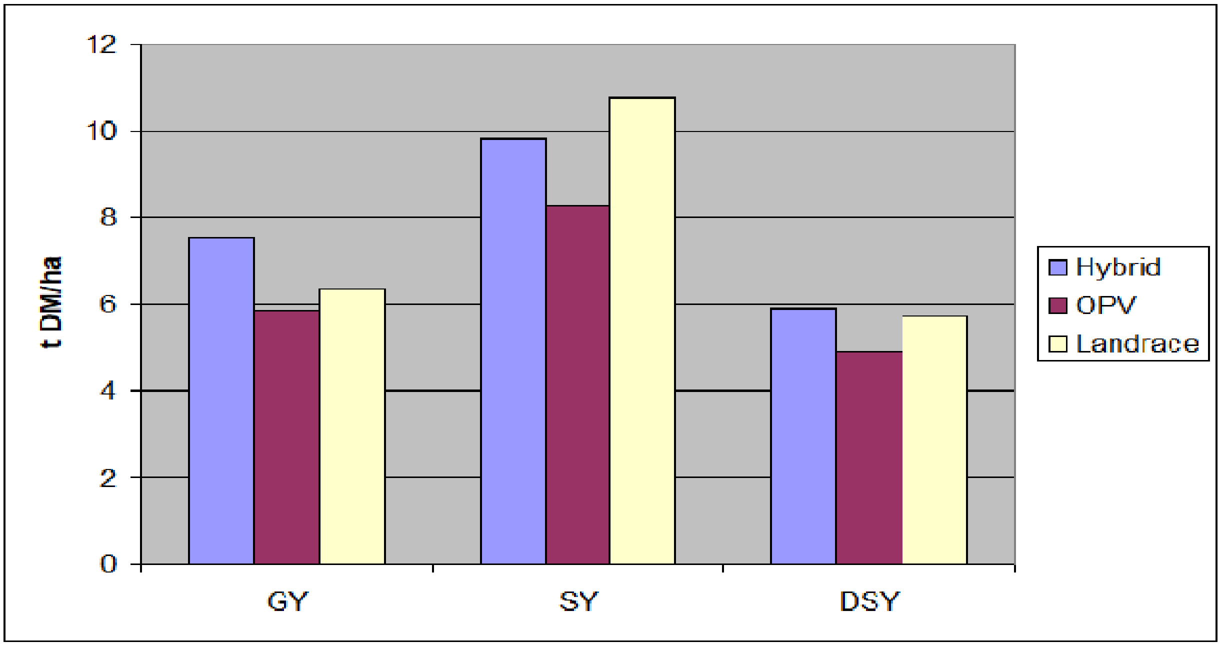

Figure1.: Observed yields of grain (GY), stover (SY) and digestible stover (DSY) in the studied maize varieties categorized into hybrid, OPV(open pollinated variety) and landrace

correlated to CP content of stover, but significantly and negatively correlated to IVOMD and ME values of the stover.

Figure 1 presents the observed yields of grain, stover and digestible stover between variety categories. There were no significant ($p>0.05$) variations between variety categories (hybrid, OPV and landrace) in grain yield and both yield and quality of their stovers. However, hybrids exhibited the highest grain production and digestible stover yield.

An important indicator of stover quality could be the protein content since it is the most limiting nutrient for efficient utilization of feed resources like maize stover for dry season feeding. The reported CP values were below 55 g kg^{-1} stover DM which indicates the magnitude of protein deficiency of maize stover to meet livestock requirements. However, the stover CP values varied considerably from 38 - 57 g kg^{-1} DM (50%) in variety Wenchi and Jibat, respectively. The existence of this variation and the insignificant, though negative, correlation between grain yield and CP contents of the stovrers indicate that there is a potential to breed maize for better stover CP contents embedded in the general focus of improving stover yield and quality.

The findings of the current study on the effect of stage of harvest on the yield and quality of maize stover agree with that of Adugna et al. (1998) where decreases in stover yield and its nutritive value with increasing stage of maize grain maturity at harvest were reported. These are strong and valid confirmations that total feed and its quality from maize seriously decline from the green/dough or dough stage to full maturity. This implies that conservation of the stover harvested at the dough stage helps ensure availability of maize stover with better quality for dry season feeding. It could be exercised in areas like Awassa where a considerably large volume of green stover is harvested due to the practice of selling maize for dough. Moreover, systematic defoliation and conservation could be practiced up to the level where the physiological processes for grain filling are not significantly affected. However, the extent to which this can be practiced requires investigations.

Absence of significant differences in grain yield and the considerable and significant variations in the yield and quality of stover observed between the studied maize varieties support the view that improving the yield and quality of maize stover through breeding and selection without significantly affecting grain yield is possible.

Berhanu (2009) reported significant positive correlations between grain yield and stover yield whereas the correlation between grain yield and the nitrogen content of sovers of the maize hybrids was negative and significant. Contrary to this report, no significant correlations between grain yield and both yield and CP content of maize stovers were found in the current study. However, absence of any significant correlations ($p>0.05$) between grain yield and both NDF and ADF contents of maize stovers agrees with that reported by Berhanu (2009). Stover ME and IVOMD exhibited positive and nearly 100% correlation indicating that a measure of digestibility of maize stover is a measure of its metabolizable energy.

In conclusion, the observed variations between the varieties in the measured feed related parameters but with no significant variation in grain yield indicate the possibility of manipulating some traits in the effort to improving the yield and quality of maize stover through breeding and/or selection without significantly affecting grain yield. Therefore, there is a need to work with animal nutritionists in the process of maize technology generation when targeting the mixed crop-livestock system of agricultural production. On the other hand, as the yield and quality of maize stover deteriorates as the stage of grain maturity increases, employing applicable system of feeding livestock on stover before the last stage of maturity is advisable.

REFERENCES

Adugna Tolera, Sundstol F and Said N A (1998). The effect of stage of maturity on yield and quality of maize grain and stover. *Animal Feed Science and Technology* 75:157-168

Adugna Tolera, Berg T and Sundstol F (1999). The effect of variety on maize grain and crop residue yield and nutritive value of the stover. *Animal Feed Science and Technology* 79:165-177

Adugna Tolera (2002). Integrated food and feed production on small-holder mixed farms: Effect of early harvesting or variety on maize grain and stover yield and nutritive value of stover. pp.187-194. Proceedings of the second National Maize Workshop of Ethiopia. Addis Ababa, Ethiopia, 12- 16 November 2001. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Barnes R J, Dhanoa M S and Lister S J (1989). Standard normal variate transformation and detrending of near infrared diffuse reflectance spectra. *Applied Spectroscopy* 43: 772-777.

Berhanu Taddese (2009). Heterosis and combing abilities for yield, yield-related parameters and stover feed quality traits for food-feed in maize adapted to the mid altitude areas of Ethiopia. M.Sc Thesis submitted to the School of Graduate Studies, Haramaya University. 189p.

CSA (Central Statistical Agency of Ethiopia) (2008). Agricultural sample survey report for 1995/1996. Addis Ababa, Ethiopia EARO 2001

Devendra C and Pezo D (2004). Crop-animal systems in Asia and Latin America: Characteristics, opportunities for productivity enhancement and emerging challenges, including comparisons with West Africa. Pp 123-159. Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa. Proceedings of an international conference held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 19-22 November 2001.

EARO (Ethiopian Agricultural Research Organization now Ethiopian Institute of Agricultural Research - EIAR) (2001). Strategies and priorities for maize research. November 14, 2001. Addis Ababa, Ethiopia

Reddy B V S, Reddy P S, Bidinger F and Blummel M (2003). Crop management factors influencing yield and quality of crop residues. *Field Crops Research* 84:57-77

Shenk J S and Westerhaus M O (1991). Population definition, sample selection and calibration procedures for near-infrared reflectance spectroscopy. *Crop Science* 31: 469-474.

Singh B B, Larbi A, Tabo R. and Dixon A G O (2004). Trends in development of crop varieties for improved crop-livestock systems in West Africa. pp 371-388. Proceedings of an international conference on ‘Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa’. 19-22 November 2001. Ibadan, Nigeria. International Livestock Research Institute.

Windham W R, Mertens, D R and Barton F E (1989). Protocol for NIRS Calibration: sample selection and equation development and validation. . pp. 96-103. In: Marten, G.C., Shenk, J.S., Barton, F.E., (Eds). Near infrared reflectance spectroscopy (NIRS): analysis of forage quality. Agriculture Handbook No. 643 (Revised), Suppl. 1, USDA. Washington, D.C.