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Stover Quality Traits for Improvement of Dual-Purpose Sorghum

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ABSTRACT

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Twenty four sorghum stovers were investigated with sheep for organic matter digestibility (OMD) and intake (OMI), and for digestible organic matter intake (DOMI) and for relations between laboratory fodder quality traits and these *in vivo* measurements. Statistically highly significant and nutritionally important differences were found between the stover with OMD differing by 15 percentage units and OMI and DOMI varying 1.6 and 2 times, respectively. For each of the *in vivo* measurements, chemical (NDF, ADF, ADL) and *in vitro* (*in vitro* digestibility, metabolisable energy content) traits were identified which accounted for at least 50% of the variation in the respective traits. Using multiple regression procedures and stringent cross-validation (“*blind-predictions”*) procedures OMD, OMI and DOMI could be predicted with R^2 for comparing observed and predicted values of 0.36, 0.65 and 0.75, respectively. The reported research showed selection for dual purpose sorghum cultivars is promising, and identified and validated simple laboratory traits that can be used for such phenotyping.

Key words: Stover quality, Dual-purpose sorghum, Metabolisable energy.

INTRODUCTION

Sorghum stover plays an important part in the feed budget of Indian farmer’ who often prefer dual-purpose type sorghums. This has resulted in sorghum improvement exploring ways of including stover fodder quantity and quality traits in breeding and selection (Reddy *et al.*, 1995; Kelley and Rao, 1996). Such crop improvement requires simple yet meaningful laboratory fodder quality traits to rank cultivars reliably for stover quality. Many laboratory traits have been proposed by livestock nutritionist for fodder

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quality assessments, but validation of these indicators through actual livestock productivity trials were limited, and often generally applied to the higher quality feedstuffs used in industrialized livestock feeding. Basing dual-purpose crop improvement work on untested laboratory traits could clearly present a major set back to the breeding objective. The present work therefore investigates the relationship between a wide range of chemical traits (nitrogen, NDF, ADF, ADL) and measurements of *in vitro* digestibility, metabolisable energy content and extent and rate of *in vitro* gas production with the organic matter digestibility, organic matter intake and digestible organic matter intake of 24 sorghum stovers fed *ad libitum* to sheep.

MATERIALS AND METHODS

Sorghum stovers used

A total of 24 sorghum stovers obtained from 13 cultivars were evaluated. The total treatment numbers of 24 was arrived since some cultivars were grown in consecutive years and compared when grown sole and when intercropped. In addition, stover from three cultivars was purchased from different fodder traders at different times.

Feeding trials

Male growing Deccani sheep of mean live weight of about 20 kg were used for the *in vivo* experiments. The sheep were housed in metabolic cages with provision for measurement of feed intake and faecal collection for feed digestibility measurements. Each stover was fed to six sheep randomly allocated according to body weight (sheep groups were balanced according to live weight). The sheep were accustomed to a stover for a minimum of two weeks, followed by a 10-days faecal collection period for estimation of digestibility. All chopped stovers were offered as sole feed about 15% above the appetite. In other words sheep were allowed to refuse about 15% of the stover offered, which is the most common norm when investigating voluntary (*ad libitum*) feed intake.

Laboratory stover quality analysis

Stovers were analyzed for nitrogen (N x 6.25 equals crude protein), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) by routine chemical analytical procedures (Goering and Van Soest, 1970). As biological laboratory fodder quality traits, stovers were analyzed for apparent *in vitro* digestibility using *in vitro* gas production procedures according to Menke and Steingass (1988) and for true *in vitro* digestibility using the gravimetric procedure of Goering and Van Soest (1970). Extent, rate and lag phase of *in vitro* fermentation kinetics was determined using *in vitro* gas production test as described by Blümmel and Ørskov (1993).

Statistical analysis

The statistical package of SAS (1988) was used for analysis of variance (SAS GLM Procedure), for simple correlations between laboratory traits and *in vivo* measurements and for stepwise multiple regressions between laboratory traits and *in vivo* measurements using an entry level of $P \leq 0.05$. SAS cross validation procedures were used for predictions of *in vivo* variables where observations from the treatment to be predicted are not used in the development of the regression equation.

RESULTS AND DISCUSSION

Responses of sheep to different sorghum stover

As shown in Table 1, stover differed significantly in organic matter digestibility (OMD), and intake (OMI), nitrogen balance and digestible organic matter intake (DOMI). (When these *in vivo* measurements were calculated for only one stover per cultivar– the one first fed - the statistical differences were of the same order (results not shown). The ranges in the measurements reported in (Table 1) are substantial. For example in breeding program with forage grasses a difference in 4 to 5 percentage units in *in vivo* digestibility resulted in 17 to 24% difference in livestock productivity (Vogel and Sleper, 1994). When surveying price: quality relationships in sorghum stover trading Blümmel and Rao (2006) observed that a 5% difference in *in vitro* digestibility (47 to 52%) was associated with a price difference of about INR 1 per kg dry sorghum stover (INR 4 *vs* INR 3). For comparison the difference in *in vivo* digestibility observed in the sorghum stovers was about 15 percentage units (Table 1). Similarly, DOMI which is closely related to livestock performance in cereal crop residue fed livestock (Blümmel *et al.,* 2003), varied by more than 1.6-fold. Stover quality differences of this magnitude will have substantial implication for livestock productivity. From nitrogen balances in sheep (Anandan *et al*. 2009) it can be extrapolated that on sorghum stover a DOMI of 10.7 g/kg LW /d suffices for maintenance requirement of the animal. Applied to the data in Table 1 (which are reported relative to metabolic weight) a DOMI of about 22 to 23 g / kg $LW^{0.75}$/d would provide maintenance requirements to livestock. This figure is close to the mean DOMI observed in the current work, suggesting that sorghum stovers could also provide some energy for milk and meat production in addition to maintenance requirements. In fact sorghum, stover are the most highly priced cereal crop residues traded in India (Teufel personal communication).

Laboratory traits for estimating sorghum stover fodder quality

Correlations between laboratory fodder quality traits and OMD, OMI and DOMI are presented in Table 2. In general laboratory traits were significantly related to OMD,

Table 1. Mean values and ranges in organic matter digestibility (OMD) and intake (OMI) and digestible organic matter intake (DOMI) in 24 sorghum stovers fed *ad libitum* to sheep

Parameter	Mean	Range	Probability	LSD[1]
OMD (%)	56.5	46.0 to 65.1	<0.0001	3.3
OMI (g/kg $W^{0.75}$/d)	44.6	35.1 to 56.8	<0.0001	5.55
DOMI (g/kg $W^{0.75}$/d)	25.4	16.3 to 33.0	<0.0001	3.2

[1] LSD: Least significant difference.

Table 2. Correlation matrix between laboratory stover quality traits and organic matter digestibility (OMD) and intake (OMI) and digestible organic matter intake (DOMI)

Parameters	OMD	OMI	DOMI
Simple linear correlations			
Nitrogen	0.23 (0.29)	0.61 (0.002)	0.58 (0.003)
NDF	-0.60 (0.002)	-0.48 (0.018)	-0.61 (0.001)
ADF	-0.69 (0.0002)	-0.77 (<0.0001)	-0.84 (<0.0001)
ADL	-0.67 (0.0003)	-0.66 (0.0004)	-0.80 (<0.0001)
ME	0.71 (<0.0001)	0.66 (0.0005)	0.78 (<0.0001)
In vitro digestibility	0.69 (0.0002)	0.54 (0.007)	0.70 (0.0002)
Extent of fermentation	0.55 (0.005)	0.72 (<0.0001)	0.70 (0.0001)
Rate of fermentation	0.59 (0.002)	0.22 (0.29)	0.33 (0.11)
Lag time of fermentation	-0.46 (0.02)	-0.46 (0.02)	-0.49 (0.01)
Cross validation procedures			
Nitrogen	-0.02 (0.93)	0.52 (0.009)	0.51 (0.01)
NDF	0.49 (0.015)	0.36 (0.08)	0.53 (0.008)
ADF	0.58 (0.003)	0.73 (<0.0001)	0.81 (<0.0001)
ADL	0.57 (0.003)	0.58 (0.002)	0.75 (<0.0001))
ME	0.60 (0.002)	0.59 (0.002)	0.74 (<0.0001)
In vitro digestibility	0.57 (0.0035)	0.42 (0.04)	0.61 (0.001)
Extent of fermentation	0.27 (0.21)	0.67 (0.0003)	0.61 (0.001)
Rate of fermentation	0.39 (0.06)	-0.32 (0.13)	-0.13 (0.53)
Lag time of fermentation	0.25 (0.23)	0.31 (0.14)	0.35 (0.09)

OMI and DOMI. Mostly relations between laboratory traits and *in vivo* measurements were as expected in that nitrogen content and *in vitro* digestibility measurements were positively associated with OMD, OMI and DOMI while fiber constituents (NDF, ADF and ADL) were significantly negatively associated with OMD, OMI and DOMI. Time and analytical inputs required for the various traits listed in (Table 2) are quite different. For example nitrogen, NDF and ADF are quite convenient for analyses while ADL (lignin) analysis demands first the ADF preparation which then has to be treated with 72% sulphuric acid, washed, filtered, dried and ashed (Goering and Van Soest, 1970). Similarly, measurements of *in vitro* digestibility are easily obtained than *in vitro* fermentation kinetics (extent, rate and lag time measurements). In other word, ease of measurement and predictive power of a laboratory traits need to be balanced. From this point of view, nitrogen, ADF and *in vitro* digestibility measurements seem to be recommendable laboratory traits for sorghum stover analysis (Table 2). These laboratory

Table 3. Stepwise multiple regressions between stover laboratory quality traits and *in vivo* measurements (as in Table 1)

X –Variables	Y-Variable	R^2	Probability
Model: ME	OMD	0.51	0.0001
Step 1:ME		0.51	0.0001
Model: Extent + Nitrogen	OMI	0.73	0.0001
Step 1: ADF		0.59	0.0001
Step 2: Nitrogen		0.14	0.004
Model: ADF + Nitrogen	DOMI	0.80	0.0001
Step 1: ADF		0.70	0.0001
Step 2: Nitrogen		0.10	0.0003

traits each accounted for more than 50% in the variation in DOMI, the most pertinent of the *in vivo* measurement listed in Table 2, and for example ADF accounted for 67% of the variation in DOMI. It is encouraging to see that the correlations between the key laboratory traits and OMD, OMI and DOMI remained strong when used in cross validation procedures, where the laboratory traits of the individual treatment to be predicted are excluded from establishing the correlation. In other words, OMD, OMI and DOMI of a given treatment are blind-predicted.

Prediction of *in vivo* measurements by laboratory traits of sorghum stover could be improved through combination of traits in multiple regressions. For example 73% and 80% of the variation in OMI and DOMI were accounted for by ADF in combination with nitrogen content (Table 3). The last model of the stepwise multiple regressions seems to particularly suitable for reliably ranking of sorghum stover for fodder quality for two reasons: 1) DOMI is a very pertinent *in vivo* measurement that is very closely related to milk and meat production and 2) ADF and nitrogen are simple and convenient to measure and to predict by Near Infrared Spectroscopy.

Using the stepwise multiple regression models presented in (Table 3) in cross validation procedures in comparison to measured and predicted OMD, OMI and DOMI resulted in R^2 of 0.36, 0.65 and 0.75, respectively (see figures 1a-c). The R^2 for comparing measure and predicted OMD was weaker than in the cases of OMI and DOMI. The reason for this is unclear, however when revisiting individual treatments 3 to 4 outliers could be traced back to the stover obtained from the intercropping experiments. Also the sheep experimental data were obtained from a total of six different consecutive trials and experimental conditions like season and temperature and animals varied which can have affected OMD, OMI and DOMI measurements. In this context the generally good agreement between measured and observed OMI and DOMI is encouraging considering aforementioned conditions and the stringent statistical analysis of cross validation applied.

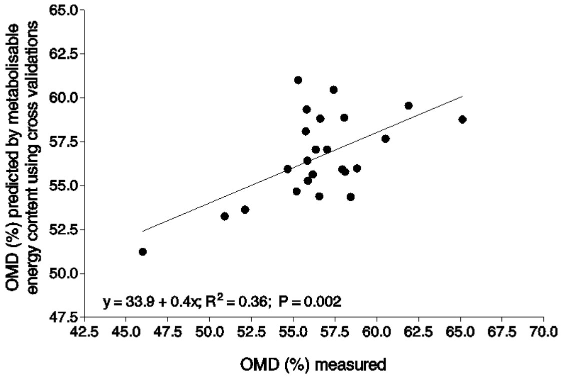

Fig. 1a. Relationship between measured and by cross validation predicted organic matter digestibilities (OMD)

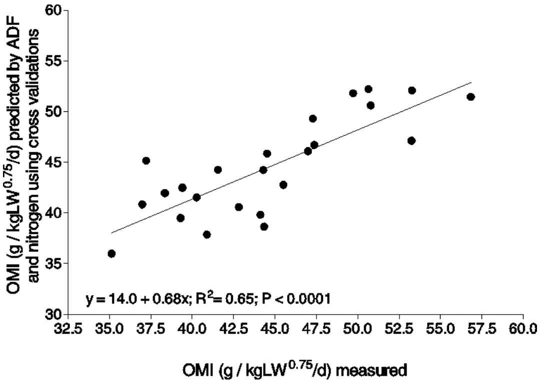

Fig. 1b. Relationship between measured and by cross validation predicted organic matter intakes (OMI)

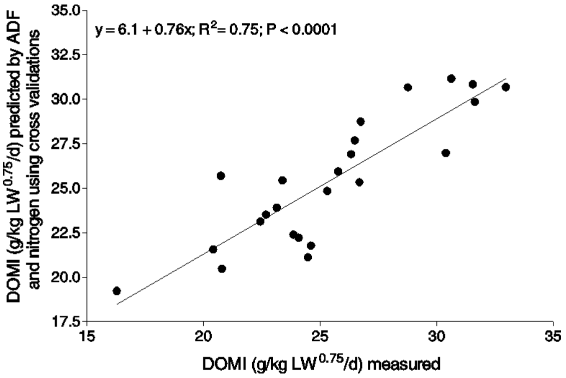

Fig. 1c. Relationship between measured and by cross validation predicted digestible organic matter intakes (DOMI)

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