Genetic Enhancement and Breeding

Response to Recurrent Selection for Stover Feeding Value in Pearl Millet Variety ICMV 221

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Introduction

In the more arid regions in which it is grown, pearl millet [*Pennisetum glaucum* (L.) R. Br.] commonly serves as a source of both foodgrain for humans and dry fodder for their ruminant livestock. Unfortunately, the feeding value of crop residues (stover and chaff) from pearl millet that has been harvested for grain is not high. Widely-adapted pearl millet variety ICMV 221 (Witcombe et al. 1997) was chosen as a base population for two cycles of recurrent selection among full-sib progeny to assess opportunities for improving the stover nutritional quality of farmer-accepted open-pollinated cultivars. We report here initial results from the first cycle of selection.

The objectives of the present work were threefold: first, to determine the ranges of grain and stover yields and stover quality traits in full-sib progenies of pearl millet cultivar ICMV 221; second, to assess changes in grain and stover characteristics in trait-specific experimental varieties generated by random-mating selected subsets of these full-sib progenies; and third, to compare laboratory estimates of stover quality traits used for selection among progenies in the full-sib population with direct measurements of stover quality traits obtained through animal feeding trials, using stover samples from replicated field trials of the experimental varieties.

Materials and Methods

Stover quality analysis. Stover fodder quality was analyzed by a combination of conventional laboratory analysis and Near Infrared Spectroscopy. Near Infrared Spectroscopy was calibrated for stover nitrogen content as measured by auto analyzer and for stover *in vitro* digestibility as measured by incubation in rumen inoculum (Menke and Steingass 1988). Neutral detergent fiber (NDF), an estimate of the cell wall fraction, acid detergent fiber (ADF), an estimate of cellulose content, and acid detergent lignin (ADL) were determined by routine chemical analytical procedures (Goering and Van Soest 1970).

Selection of progenies for experimental varieties. Two hundred and fifty-six full-sib progenies produced by plant × plant crosses of typical plants of pearl millet variety ICMV 221 were evaluated for agronomic characters, grain yield and stover yield in an alpha-lattice design trial with 2 replications and 36 blocks within replications conducted at ICRISAT-Patancheru during the rainy season of 2004. Each plot consisted of 1 row of 4 m length, with 60 cm between rows. The crop was over-sown and thinned to a uniform stand (10–12 cm between plants in a row). It received 28 kg ha^{-1} of both N and P in the form of 28-28-0 as basal fertilizer, and a side-dressing of 50 kg ha^{-1} of urea 22 days after sowing. One hand weeding at the time of thinning, followed by 2 interculture operations controlled weeds. The crop was completely rainfed and suffered no significant disease or insect damage. Data on flowering time (50% stigma emergence on 50% of main stem panicles), panicle yield (g), fresh stover yield (g), grain yield (g) and stover dry matter content (%) were collected on an individual plot basis, and data from this were used to calculate dry stover yields (g). Plot values of grain and stover yield were transformed to units of kg ha^{-1} and analyzed with the Residual Maximum Likelihood algorithm of the GenStat statistical package (Rothamsted, UK) to obtain estimates of the agronomic performance of each full-sib progeny. Representative dry stover samples from each plot were ground to a fine powder and analyzed for quality traits as described above and the plot values subjected to similar statistical analysis. Based on the analyzed full-sib progeny data sets for agronomic and stover quality traits, full-sibs were selected as parents for four experimental varieties:

- High-grain-yield variety: 16 full-sib progenies selected based on (1) time to flowering within mean $\pm$2 SD; (2) grain yield $\geq$ mean; (3) stover yield $\geq$ mean –1 SD; (4) nitrogen content and *in vitro* digestibility $\geq$ mean +0.5 SD.
- Dual-purpose variety: 16 full-sib progenies selected based on (1) time to flowering within mean $\pm$2 SD; (2) stover yield $\geq$ mean; (3) grain yield $\geq$ mean –1 SD;

(4) nitrogen content and *in vitro* digestibility ≥ mean +0.6 SD.

- High-nitrogen variety: 15 full-sib progenies selected based on (1) time to flowering within mean ±2 SD; (2) rank for nitrogen content.
- High-digestibility variety: 15 full-sib progenies selected based on (1) time to flowering within mean ±2 SD; (2) rank for *in vitro* digestibility.

Remnant seed of the selected full-sib progenies were sown in an off-season nursery and the progenies in each group random-mated manually to produce Syn0 generation seed of the four experimental varieties. A nonselected sample of the base population, ICMV 221, was also random-mated manually to provide an appropriate control entry.

Agronomic assessment of experimental varieties. The four experimental varieties and the nonselected control ICMV 221 were grown in two field replications of large plots (10 rows of 80 m length), arranged in a randomized complete block design, at ICRISAT-Patancheru during the rainy season of 2005. The trial was conducted on an Alfisol, was oversown and thinned to a uniform stand, and otherwise managed similarly to the full-sib progeny trial of the previous rainy season. Grain and stover from each plot were harvested separately. Stover was sun-dried prior to transportation and storage for quality assessment.

Feeding experiment. Growing male Deccani sheep of mean live weight of about 20 kg were used for the *in vivo* feeding experiments. The sheep were housed in metabolic cages enabling the measurement of feed intake, feed digestibility and nitrogen balances. Each stover was fed to 12 sheep randomly allocated according to body weight since sheep groups were balanced according to live weight. The sheep were accustomed to a stover diet for a minimum of two weeks, which was then followed by a 10-day fecal and urine collection period for estimation of digestibility and nitrogen balance respectively. All stovers were offered chopped and as sole feed about 115% of 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.

Results and Discussion

Variation in grain and stover traits in 256 full-sib progenies of ICMV 221. Variation in grain and stover productivity and variation in stover quality traits among the 256 full-sib progenies of ICMV 221 are reported in Table 1. Substantial ranges were observed for grain (1.5-fold difference) and stover (1.8-fold difference) yields. Stover protein content varied twofold, ranging from 4.3%, which presents a highly deficient protein status, to 8.6%, which is more than the minimum (about 7%) feed protein requirement of rumen microbes. Similarly, yield of digestible stover, which is the product of stover yield and stover *in vitro* digestibility, ranged from 1132 kg ha^{-1} to 2388 kg ha^{-1} — more than a twofold difference (Table 1). Stover *in vitro* digestibilitiy varied by 5.4 percentage units. This magnitude in stover quality difference is considerable. In sorghum stover trading for example, such a difference would be associated with a 25% higher unit price of stover at Rs 4 kg^{-1} instead of Rs 3 kg^{-1} (Blümmel and Rao 2006). Clearly, considerable scope exists within an open-pollinated variety such as ICMV 221 for selection of experimental varieties having contrasting grain and stover characteristics.

Variation in grain and stover traits among four experimental varieties selected from ICMV 221. Total biomass yield was highest in the dual-purpose experimental variety followed by the control and the high-grain-yield type. The differences among varieties approached the significance level (P = 0.06; Table 2). No significant differences were observed for grain yields (P = 0.26) but stover yields differed significantly between the varieties (P = 0.007), being the highest for the dual-purpose variety. No significant differences were found for harvest indices.

The dual-purpose cultivar performed best from both grain and stover yield perspectives. The fact that no significant difference was found for grain yield between the five varieties suggests that genetic enhancement of stover quality would not adversely affect grain yield. However, grain yield was numerically lowest in the high-digestibility variety. In terms of grain and stover yield, the dual-purpose variety appears preferable.

Two stover quality traits were directly targeted by the selection process: high nitrogen content and high digestibility. The results reported in Table 3 are consistent with the intentional design of the experimental varieties. Stover of the high-nitrogen variety did have the highest nitrogen content while the high-digestibility variety had

Table 1. Summary of variation in food-feed crop traits within 256 full-sib progenies of pearl millet cultivar ICMV 221, ICRISAT-Patancheru, India, rainy season 2004.

Variable	Mean	Range
Grain yield (kg ha^{-1})	3561	2719–4154**
Stover yield (kg ha^{-1})	3617	2783–5005**
Stover protein (%)	6.2	4.3–8.6**
Stover *in vitro* digestibility (%)	43.6	40.7–46.1**
Digestible stover yield (kg ha^{-1})	1577	1132–2388**

**Maximum and minimum values are significantly different at P <0.01.

the highest *in vitro* digestibility and the lowest cell wall (NDF), cellulose (ADF) and lignin contents of all varieties tested.

One of the traits the experimental varieties were designed for, high digestibility, should be reflected in the results of the feeding trial. This was indeed the case and the *in vivo* digestibility of this variety was 57.5%, significantly higher than of any of the other four varieties (Table 4). If the control variety is taken as the point of departure (54.4%), one cycle of selection has resulted in an increase in digestibility of 3.1 percentage units, which seems remarkable.

The high-nitrogen experimental variety indeed had the highest nitrogen content (Table 3) but feed nitrogen does not automatically translate into nitrogen retention in the animal, as energy is required for nitrogen accretion as lean tissue, and this energy comes from the digestible matter. Stover of only two varieties promoted positive nitrogen balances in the present study. These were the high-digestibility and high-nitrogen experimental varieties (Table 4). These findings can be regarded as consistent with the design of the experimental varieties. However, the overall level of nitrogen inputs and outputs in this feeding experiment were relatively small, and the potential

Table 2. Biomass, grain and stover yields and harvest indices of control and four experimental varieties selected from ICMV 221, ICRISAT-Patancheru, India, rainy season 2005.

Cultivar type	Biomass yield ($kg\ ha^{-1}$)	Grain yield ($kg\ ha^{-1}$)	Stover yield[1] ($kg\ ha^{-1}$)	Harvest index
ICMV 221 (control)	7097	3110	3138b	0.44
High-grain-yield	6988	3110	3051b	0.45
Dual-purpose	7617	3250	3499a	0.43
High-nitrogen	6675	2990	2892b	0.45
High-digestibility	6582	2860	2945b	0.43
	NS[2]	NS	$P<0.007$	NS

1. Values for a trait that are followed by different letters are different at $P < 0.01$.
2. NS = Nonsignificant.

Table 3. Stover nitrogen, *in vitro* digestibility, neutral detergent fiber (NDF) and acid detergent fiber (ADF) and acid detergent lignin (ADL) content in stover of control and four experimental varieties of ICMV 221 produced at ICRISAT-Patancheru, India, rainy season 2005.

Cultivar type	Nitrogen (%)	*In vitro* digestibility (%)	NDF (%)	ADF (%)	Lignin (%)
ICMV 221 (control)	0.90c[1]	53.4b	69.6b	40.8a	5.9a
High-grain-yield	0.93b	50.1c	70.5a	40.2c	5.6bc
Dual-purpose	0.91bc	54.7ab	69.6b	40.2c	5.5cd
High-nitrogen	0.99a	53.5b	71.1a	41.7a	5.8ab
High-digestibility	0.90c	56.0a	67.7c	39.7d	5.2d
	$P<0.0001$	$P<0.003$	$P<0.0001$	$P<0.0001$	$P<0.005$

1. Values for a trait that are followed by different letters are different at $P<0.01$.

Table 4. Organic matter intake (OMI), organic matter digestibility (OMD), digestible organic matter intake (DOMI) and nitrogen balance in sheep fed stover of control and four experimental varieties of ICMV 221, ICRISAT-Patancheru, India, rainy season 2005.

Cultivar type	OMI ($g\ kg^{-1}$ LW)	OMD (%)	DOMI ($g\ kg^{-1}$ LW)	N balance ($g\ kg^{-1}$ LW)
ICMV 221 (control)	23.8	54.4b[1]	12.9	–0.020b
High-grain-yield	24.2	54.1b	13.1	–0.003ab
Dual-purpose	25.5	56.6a	14.4	–0.031b
High-nitrogen	24.0	54.0b	13.0	0.001ab
High-digestibility	24.9	57.5a	14.3	0.015a
	NS[2]	$P<0.001$	NS	$P<0.01$

1. Values for a trait that are followed by different letters are different at $P<0.01$.
2. NS = Nonsignificant.

for analytical errors is considerable because feed nitrogen, feed-refusal nitrogen, urinary nitrogen and fecal nitrogen are all input variables in the balance. The findings of the nitrogen balance should therefore be taken with some caution. The fact that the high-nitrogen experimental variety indeed had the highest nitrogen content (Table 3) provides a better basis for assessing the feasibility of selecting for high nitrogen than do the nitrogen balances reported in Table 4. Overall, the results from this initial assessment of response to recurrent selection for improved ruminant livestock feeding value of stover of pearl millet variety ICMV 221 are very encouraging.

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