GENETIC AND MANAGEMENTAL EFFECTS ON VARIABILITY OF STRAW QUALITY FROM FINGERMILLET (*Eleusine Coracana*)

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SUMMARY

The genetic variation in straw quality of fingermillet and the effects of location, management and NPK fertilization on quality of fingermillet straw was studied in four experiments. In experiment I, 42 cultivars of 3 genetic groups differing in days to maturity (Short, Medium and Late) were studied to assess the genetic variability. The short duration cultivars had significantly (P < 0.01) higher N content, lower NDF content, higher IVOMD and IVNDFD than the medium and late duration cultivars. The IVNDFD of leaves was significantly (P < 0.01) higher than that of stems. In experiment II, 21 cultivars grown at three locations with different soil and climatic conditions showed a wide difference in grain production, height, stem weight, OM and NDF content and IVNDFD of straw. In experiment III, three cultivars were harvested from anthesis to grain maturity or were kept as a standing crop for ten days after maturity. Straw harvested at maturity was also stored under roof over a period of 5 months. NDF content increased (P < 0.05) with plant maturity, and kept increasing during storage. The IVOMD and IVNDFD declined with age before or after harvest (P < 0.05). In Experiment IV, application of NPK (0 : 0 : 0, 50 : 25 : 25 and 100 : 50 : 50) increased the total biomass production per hectare without altering the harvest index of three genetically different cultivars (Indaf-8, PR-202, and Hullubele). The OM content and IVOMD remained unchanged, while the NDF content and IVNDFD decreased (P < 0.01) with increasing level of NPK. The traditional variety (Hullubele) known for fodder production had a bettter straw IVOMD than the improved varieties. It was concluded, that the quality of fingermillet straw in terms of IVOMD was affected by parameters such as genotype, location, moment of harvest, storage and fertilization.

INTRODUCTION

Fingermillet (*Eleusine Coracana*) straw is an important fodder for cattle in many parts of India. It is grown as a dryland crop as well as under irrigation in the southern parts of India. Depending on the onset of monsoon (June - October) early (below 90 days), medium (100 - 110 days) or late (above 110 days) maturing varieties are sown. Since 1950, there has been a breeding policy to increase grain production, resulting in the release of several high grain yielding cultivars. This has been associated with a reduction in fodder yields. For example, the

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traditional variety of Hullubele (local) has a harvest index (grain as a fraction of total above ground biomass) of about 0.21, whereas in the improved varieties (Indaf series) the harvest index is about 0.4, while the total biomass yield of traditional and improved varieties does not differ much (Gowda *et al.*, 1988).

In some farming systems the straw has a low value compared to grain, but in others the grain and fodder value can be equally important (Kelley *et al.*, 1991; De Wit *et al.*, 1993). It is therefore desirable to develop methods for improving straw quality and/or straw yield. Several methods have been suggested to improve the low nutritive value of straw, such as physical, chemical and microbial treatments. Very few of these have become popular on small farms due to technical or other constraints. One alternative is to develop dual purpose cultivars which satisfy the farmers' requirement for grain yield and straw yield, the latter in terms of quantity and quality.

Throughout the world attempts are being made to evaluate differences in straw quality arising from varietal differences or managemental practices. A wide range of variability in composition and digestibility was reported for rice straw (Doyle *et al.*, 1986) and for wheat, barley and oats (Kernan *et al.*, 1979; Capper *et al.*, 1988; Ramanzin *et al.*, 1986; Pearce *et al.*, 1988; Ceccarelli *et al.*, 1993) and for maize (Deinum, 1986-87). Similarly Baig *et al.* (1981), and McIntire *et al.* (1988), identified superior cultivars in *Sorghum bicolor* fodder. The information available with regard to variation in quality of fingermillet straw is, however, very scanty.

The objective of the studies reported in this paper is to evaluate the possibility of breeding for fingermillet straw quality and to get information about environmental and managemental factors affecting quality of fingermillet straw. The studies were undertaken in collaboration with All India Small Millets Improvement Project (ICAR), Gandhi Krishi Vigyan Kendra, Bangalore.

GENETIC VARIABILITY

Genetic variability in fingermillet straw was studied on 42 varieties belonging to 3 genetic groups viz., early (13), medium (16) and late (13) maturing. These varieties were grown in triplicate under protective irrigation at GKVK, Bangalore. In all trials grain harvesting was done by removal of ear heads and straw was harvested about 3 cms. above the ground level on the same day as the grain. For details about analysis of heritability and other genetic parameters derived from this experiment is referred to Seetharam *et al.* (1993).

Grain and fodder yield and consequently total biomass yield per hectare and height increased ($P < 0.01$) with duration till maturity (see Table 1). Genotypic effects within duration classes were observed for all parameters given in Table 1 for early maturing varieties, for height in medium and for height and harvest index in late maturing varieties.

In Table 2 the composition and *in vitro* digestibility of straw of the various duration classes of fingermillet are given as well as the significance of the genotypic effects within duration class.

No significant differences were found between duration classes in OM content, but the NDF content increased with duration. The N content was significantly higher in early maturing varieties than in the other duration groups. Digestibility decreased significantly with duration. Genotypes differed significantly with regard to OM content and OMD within all duration classes, while NDFD and N content did not differ within duration classes between varieties. The NDF content differed between genotypes within the early and medium maturing varieties.

Table 1 Grain and fodder yield, harvest index and height of fingermillet varieties

Characters	Duration			Significance of genotype effect		
	Early	Medium	Late	Early	Medium	Late
Grain yield (t/ha)	3.8^a	4.9^b	5.5^c	**	ns	ns
Fodder yield (t/ha)	6.1^a	6.4^a	7.3^b	**	ns	ns
Harvest index	0.39^a	0.44^b	0.44^b	**	ns	*
Height (cm)	88.6^a	101.2^b	115.0^c	**	**	**

Notes: Means with different superscripts per row differ significantly ($P < 0.05$)
Genotypic effects: * $P < 0.05$
** $P < 0.01$

Table 2 Chemical composition and in-vitro digestibilities of the whole straw

Characters	Duration			Significance of genotype effect		
	Early	Medium	Late	Early	Medium	Late
Composition (% DM)						
Organic matter	90.3	90.6	90.8	**	**	*
Nitrogen	0.71^b	0.54^a	0.55^a	ns	ns	ns
NDF	59.7^a	62.8^b	65.2^c	**	**	ns
Digestibility (%)						
Organic matter	62.1^c	59.3^b	57.5^a	**	**	**
NDF	42.7^b	41.2^{ab}	40.8^a	ns	ns	ns

Note: means with different superscripts per row differ significantly ($P < 0.05$)
Genotypic effects: * $P < 0.05$
** $P < 0.01$

It can be postulated that cell contents are the main determinant of variation in OMD between varieties, since the NDFD did not differ much between duration classes. The relatively larger differences in OMD could consequently be explained by the decreased NDS content with duration. It was further found, that the correlation between cell contents and IVOMD was around 0.8 within each of the three duration classes.

Thus, the lower NDS content and consequently higher NDF content in late maturing varieties of fingermillet resulted in lower digestibility. This is in agreement with findings for rice straw varieties (Roxas *et al.*, 1984; Sannasgala and Jayasuria, 1984).

MORPHOLOGICAL FRACTIONS OF STRAWS

It has been suggested that variability in straw composition and digestibility is associated with the proportion of morphological fractions for barley straw (Ramanzin *et al.*, 1986), for oat and wheat straw (Shaud *et al.*, 1987), for rice straw (Devendra *et al.*, 1986) and for barley and wheat straw (Capper *et al.*, 1988). The stem and leaves were separated from six varieties belonging to three duration groups and examined for NDF content and digestibility. NDF of leaf (66.3%) was significantly ($P < 0.01$) lower compared to stem (70.6%). The IVNDFD was significantly ($P < 0.01$) higher in leaves (50.6%) compared to stem (33.4%). This was also true for digestible NDF in leaf (39.5%) as against in stem (25.3%) despite the lower NDF in leaf. Whether these differences in digestibility of leaves and stems is also reflected in differences in DMI should be the subject of further studies.

EFFECT OF LOCATION

In a trial conducted during 1988 - 1989, 21 cultivars were grown on three locations having distinct soil and climatic difference viz., Tamil Nadu (Coimbatore: red soils, rainfall 423 mm), Andhra Pradesh (Vizayanagaram: sandy soils, rainfall 1141 mm) and Karnataka (Bangalore: red lateritic soils, rainfall 576 mm). The straw varieties were analysed for yield, composition and quality (see Table 3).

This is probably also true for straw yield, which was not recorded, but which is related to plant height and stem weight grain yield which was highest in Bangalore. Genotypic differences existed with regard to the yield parameters. Small, but significant differences in composition existed between locations, but no genotypic differences were observed in composition. The IVOMD did not differ between locations, but small differences in NDFD were observed. More NDF seemed to be compensated by a higher NDFD. Genotypes did not differ significantly in digestibility of OM or NDF. The information about growth conditions was insufficient to explain the differences in yield, composition and IVNDFD between locations.

Table 3 Yield, chemical composition and *in vitro* digestibility

Character	Significance of genotypic effect	Location		
		Coimbatore	Vizayanagaram	Bangalore
Grain yield (T/ha)	***	1.3^{b}	1.8^{b}	5.0^{a}
Plant height (cm)	***	73^{c}	81^{b}	94^{a}
Stem weight (g/plant)	***	2.3^{b}	2.5^{b}	3.8^{a}
Composition (%DM)				
Organic matter	ns	87.5^{b}	87.9^{b}	88.2^{a}
Nitrogen	ns	1.5^{a}	0.6^{c}	1.1^{b}
NDF	ns	64.1^{c}	67.8^{a}	65.9^{b}
In vitro Digestibility (%)				
Organic matter	ns	51.4	51.6	51.2
NDF	ns	33.8^{b}	37.1^{a}	34.5^{b}

Note: means with different superscripts per row differ significantly ($P < 0.05$)

EFFECT OF MANAGEMENT

The effect of different stages of harvesting on the composition of fingermillet as a forage crop was studied. The three tested varieties were a local traditional variety called by farmers as Hullubele with an average HI - 0.21, a variety PR-202 improved from the local variety (average HI 0.40) and an Indo-African hybrid variety - Indaf-8 (HI - 0.41). These varieties were grown in three replicates in randomized block design during monsoon season (July - October). Samples of the crop were analysed at the following stages of growth:

M-1 - Anthesis stage: (50% flowering - 70 days after sowing for Hullubele and PR-202 and 75 days after sowing for Indaf-8).

M-2 - Dough stage (88 days after sowing for Hullubele and PR-202 and 90 days after sowing for Indaf-8).

M-3 - Grain maturity stage (120 days after sowing for Hullubele and PR-202, 138 days after sowing for Indaf-8)

M-4 - Ten days after grain maturity (after removal of ear heads as in M-3, straw left standing in the field).

To study losses during storage a part of the straw harvested at grain maturity (M-3) was sun dried (for 1-2 days) and stored under roof condition to assess storing effects for 60 (M-5) and 150 days (M-6). The results are presented in Tables 4 and 5.

There was a drastic decline of IVOMD as the plant neared harvest period for all three varieties (Table 4). A similar observation was made by Roxas *et al.* (1988) with rice straws. The decrease of OMD for improved varieties (Indaf-8 and PR-202) was greater than for Hullubele from anthesis to grain maturity. The decrease in OMD from grain maturity during storage upto five months was high for all straws with at least 10% units loss in digestibility.

The OM content did not vary much between treatments. NDF increased with maturity before grain maturity and during the first 60 days of storage (M-5 compared to M-3), but the NDF content did not change much from 60 (M-5) to 150 days (M-6) of storage. This indicates that losses of cell solubles happened during the first part of storage. IVOMD and IVNDFD decreased with the stage of maturity. The reduction of IVOMD may be attributed to loss of cell solubles and decrease of the IVNDFD. The reduction of NDFD during storage may be due to losses of leaf. Losses of cell solubles may be attributed to grain filling before grain maturity and to respiration during drying after harvest.

Table 4 Chemical composition and *in vitro* digestibility

Constituents (%)	M-1	M-2	M-3	M-4	M-5	M-6
			Indaf-8			
Organic Matter	88.2	88.2	87.5	89.7	87.6	87.2
NDF	59.1	57.1	65.0	67.5	69.2	68.1
IVOMD	75.0	72.2	61.5	58.4	51.6	51.4
IVNDFD	62.6	57.1	48.1	44.7	38.7	37.8
			PR - 202			
Organic Matter	90.2	90.2	89.1	90.3	88.5	88.0
NDF	58.6	60.8	67.5	69.3	72.0	71.5
IVOMD	73.5	66.7	58.4	55.5	48.3	46.8
IVNDFD	59.1	50.5	45.7	42.0	36.4	34.5
			Hullubele			
Organic Matter	89.1	90.7	90.5	90.6	90.0	88.8
NDF	59.3	59.5	67.0	68.6	73.1	72.0
IVOMD	73.6	69.2	62.8	56.0	49.6	48.0
IVNDFD	60.4	53.1	49.6	41.7	38.0	35.7

Table 5 Means per treatment and statistical significance

Stage	Organic matter (% of DM)	NDF (% of DM)	IVOMD (%)	IVNDFD (%)
M-1	89.2^{bc}	59.0^{c}	74.0^{a}	60.7^{a}
M-2	89.7^{ab}	59.1^{c}	69.4^{b}	53.6^{b}
M-3	89.0^{bcd}	66.5^{b}	60.9^{c}	47.8^{c}
M-4	90.2^{a}	68.5^{b}	56.6^{d}	42.8^{d}
M-5	88.7^{cde}	71.4^{a}	49.8^{e}	37.7^{e}
M-6	88.0^{e}	70.5^{a}	48.7^{e}	36.0^{e}

Note: different superscripts a, b, c, d, e means significant ($P < 0.05$) when varieties pooled for age group

EFFECT OF NPK APPLICATION

Previous studies conducted by Erikson (1981), Biswas and Choudhury (1981), Roxas *et al.* (1985), and Sannasgala *et al.* (1985), have shown that application of N to soils tends to increase the N content of straws, but has variable effects on NDF and IVOMD. However, it is thought that the increase in N content of the straw might positively affect the dry matter intake and in-vivo digestibility. The effect of other fertilizers on straw quality is not yet clear. An earlier study carried out at NDRI, Bangalore on fingermillet cultivars on three levels of nitrogen (50, 75 and 100 kg/ha) revealed no effect on the IVOMD of straw (Subba Rao *et al.*, 1988).

In the present experiment the effect of three levels of NPK on composition and digestibility of fingermillet straw was studied. The three varieties (Indaf-8, PR-202, and Hullubele) belonging to distinct genetic characters were grown in a RBD with three replicates on red soils.
Three levels of NPK were applied under irrigated conditions (kg/ha):
- (T1): 0, 0, 0,
- (T2): 50, 25, 25,
- (T3): 100, 50, 50.

Grain, fodder yield and straw qualities as revealed on three levels of fertilizer application are summarized in Tables 6 and 7. See also Seetharam *et al.* (1993) for information about this experiment.

Table 6 Grain, fodder yield, chemical composition and IVOMD

Character	Indaf-8	PR-202	Hullubele
		Treatment - T1	
Grain yield (T/h)	1.96	2.41	1.85
Fodder yield (T/h)	4.13	6.02	5.41
Harvest index	0.32	0.29	0.25
Organic Matter (%)	87.7	88.7	90.1
NDF (%)	67.8	68.8	69.4
IVOMD (%)	60.7	60.2	63.7
IVNDFD (%)	49.2	48.7	52.8
		Treatment - T2	
Grain yield (T/h)	3.74	4.10	2.47
Fodder yield (T/h)	8.0	9.11	10.63
Harvest index	0.32	0.32	0.20
Organic Matter (%)	88.2	89.2	90.5
NDF (%)	66.1	67.0	67.0
IVOMD (%)	59.5	58.7	61.0
IVNDFD (%)	45.9	46.2	47.4
		Treatment - T3	
Grain yield (T/h)	4.47	4.88	3.10
Fodder yield (T/h)	9.64	10.80	11.76
Harvest index	0.32	0.32	0.21
Organic Matter (%)	88.2	89.3	90.2
NDF (%)	63.7	64.3	63.3
IVOMD (%)	61.6	59.8	61.7
IVNDFD (%)	46.8	44.2	45.4

Table 7 Effect of fertilization (means of three varieties)

Parameters	Levels of fertilizers		
	(T1)	(T2)	(T3)
Grain yield (kg/ha)	2100[c]	3400[b]	4200[a]
Fodder yield (kg/ha)	5200[c]	9200[b]	10080[a]
Harvest Index	0.29	0.28	0.28
Composition (% DM)			
Organic matter	88.8	89.3	87.3
NDF	68.6[a]	66.8[b]	63.8[c]
In-vitro digestibility (%)			
Organic matter	61.5	60.0	61.0
NDF	50.2[a]	46.5[b]	45.4[b]

Note: different superscripts a, b, c means significant (P < 0.05)

Grain yield significantly (P < 0.05) responded to NPK fertilization, but more in case of Indaf-8 and PR-202 than in case of the local variety Hullubele. A reverse trend was noticed for straw yield, i.e. straw yield increased more in the local variety than in the new varieties after fertilization. The OM content and OMD was higher (P < 0.05) in the local variety which had lower harvest index (0.23) compared to hybrids (0.32). The NDF content was not very different between varieties indicating the small improvement in OMD of the traditional straw was due to more digestible NDF.

The grain and fodder production (biomass) per hectare increased with the level of application of NPK (P < 0.05). The improved varieties Indaf-8 and PR-202 produced more grain and the local (traditional) variety yielded more fodder. The different levels of NPK application did not alter the harvest index.

The OM content and OMD remained unchanged (see Table 7), while NDF content and NDFD decreased (P < 0.05) with increasing level of NPK application. This study indicates that higher dosages of fertilizer (NPK) tend to enhance total biomass per unit area, without affecting straw quality as is seen by IVOMD. The total amount of energy available as animal feed, namely fodder yield * IVOMD, was significantly increased when more fertilizer was applied. Although there were more NDS in higher fertilized varieties this was counterbalanced by a lower digestibility of NDF components.

The quality of straw studied in the two different experiments is compared in Table 8.

The three cultivars tested in two experiments (Table 8) indicate that the traditional (Hullubele) variety contains higher OM and OMD compared to hybrids. This was consistent in both trials which were conducted in the same year at different areas of the research station.

Table 8 Straw quality of three cultivars in 2 experiments

Constituents	Indaf-8		PR-202		Hullubele	
	Exp-I	Exp-II	Exp-I	Exp-II	Exp-I	Exp-II
Composition (% DM)						
Organic matter	87.5	88.2	89.1	89.2	90.5	90.5
NDF	65.0	66.1	67.5	67.0	67.0	67.0
In-vitro digestibility (%)						
Organic matter	61.5	59.7	58.4	58.7	62.8	61.0
NDF	48.1	45.9	45.7	46.2	49.6	47.4

Notes: Exp I Varieties harvested at different stages of maturity, (M-3 level) under effect of management
Exp II Effect of different levels of NPK on straw quality, (T-2 level)

CONCLUSIONS

The studies showed that variability of fingermillet straw quality and straw yield could be due to genotype, duration of growth, leaf content and level of fertilization. It seems possible that this variability could be used in plant breeding and in crop management to increase the quality and quantity of the straw harvested. Further research is, however, required to quantify the improvements in quality and quantity.

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