EFFECT OF VARIETY ON YIELD AND NUTRITIVE VALUE OF RICE STRAW

S. A. Chowdhury[1], M. A. Majid, K. S. Huque, M. Islam and M. M. Rahman

Animal Production Research Division, Bangladesh Livestock Research Institute, Savar, Dhaka-1341, Bnangladesh

Summary

Seven varieties of rice were cultivated in the field of BLRI of which three were native (Maloti, Nizershail and Chandrashail) and four were improved (BR_3, BR_{11}, Pasam and Mala). Yields of straw and grain were recorded and the chemical composition of straw was determined. Both the grain ($p < 0.05$) and straw ($p > 0.05$) yields were higher in the improved than the native varities. Relationships of straw dry matter yield with the hights of rice plants, tiller numbers, levels of N fertilizer and lengths of stover were found to be statistically insignificant. No significant differences were observed among the varieties in respect of NDF, cell soluble, cellulose and hemicellulose contents. However, modified acid detergent fibre and insoluble ash content were significantly ($p < 0.05$) higher in the local varieties. Except BR_3, the estimated ME content of straw was higher in the improved than the native varieties. In respect of yield, chemical composition and energy content improved straws were better and Pasam was the best.
(**Key Words** : Rice Straw, Variety, Yield, Nutritive Value)

Introduction

Bangladesh consists mostly of low-lying flat alluvial plain extensively flooded during the monsoon. The flooding together with a high human population density and the sub-tropical climate are the main reasons why rice is the principal crop in the country, accounting for almost 77% of the cultivated area (Neilson and Preston, 1981). Residues and by-products from the crop farmings provide feeds for keeping livestock. Rice straw comprises 70-80% of the total dry matter available to large ruminants (Tareque and Saadullah, 1988). The quality and quantity of rice straw varies with variety, cutting height, fertilizer level and soil type (Theander and Aman, 1984) and in Bangladesh possibly the extent of flooding. While crop breeders are mostly interested in increasing grain yield, very little attention has been given on the impact of improved variety rice on the quality and quantity of straw produced. The studies reported here have therefore been conducted to determine :

1. straw and grain yield as affected by varieties, cutting heights, fertilizer levels;
2. fractions of straw, in terms of node, internode, rachis leaf blade and leaf sheath;
3. chemical composition of straws in terms of N, NDF, ADF, cellulose, hemicellulose, lignin and insoluble ash.

Materials and Methods

Experimental plots

The experimental plots were located on a red-brown terrace soil in the low lying areas of the Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka, Bangladesh. After a preliminary survey, 20 of the 65 plots leased out to contact farmers (marginal or landless) were selected for the experiment. The plots varied in size from 0.1 to 0.2 ha, with the average of 0.15 ha.

Season

The experiment was conducted from August to November; commonly referred as 'Aman' season, which is characterized by high temperature (30℃), rain fall (337 mm) and humidity (86%) (Islam et al., 1980)

Rice variety

Seven varieties of rice were cultivated, of which, four (BR_3, BR_{11}, Pasam and Mala) were high yielding (called here improved) and three (Maloti, Nizershail and Chandrashail) were native. Among these, BR_3 and BR_{11} were of semi-dwarf (< 10 cm) and the rest were of medium (100-125 cm) height. All of them generally grows in irrigated and/or rainfed shallow land at high

[1]Address reprint requests to Dr. S. A. Chowdhury, Scientific Officer, Bangladesh Livestock Research Institute, Savar, Dhaka-1341, Bangladesh.

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temperature (25-40℃). They are usually harvested between 90-135 d, of which, Nizershail is the early (90-100 d) and Pasam is the late (120-130 d) variety.

Rice cultivation

Agronomical practices were conducted by the contact farmers at their will. However, data were recorded on each plot on varieties of rice cultivated, level of N fertilizer used, and number of hills (90-100) and tiller (350-450) per square meter. No fertilizer was applied during the land preparation. Most of the farmers did not used any fertilizer at all. Some of those farmers, that cultivated BR_3, BR_{11} and Pasam, applied urea at the rate of 190-235 kg per ha as top dressed. All the varieties were cultivated under rainfed condition and weeding was practiced in almost all plots.

Yield

The length of rice plants was measured before their harvest. In each plot straw and grain yield were recorded after harvesting the crop from five different areas of a plot, each of one square meter. The mean straw and grain yield per hectare were recorded on a dry matter (DM) basis by oven drying the samples at 104℃ for 48 hours. The amount of stover (the portion of straw left in the field after harvest) was recorded in the same way.

Fractioning straw

The different varieties of straw were fractioned into leaf blade, leaf sheath, node, internode and rachis. After oven drying at 104℃ for 48 hours, the DM of the different fractions were recorded.

Chemical analysis

Organic matter and crude protein content were determined according to AOAC (1984). Straw samples were analyzed for neutral detergent fibre (NDF), modified acid detergent fibre (MADF), cellulose and hemicellulose according to van Soest (1963). Lignin content was estimated from the difference between MADF and cellulose, while the insoluble ash (silica) content was estimated from the difference between total ash and soluble ash.

Digestibility and ME estimation

The coefficient of digestibility of organic matter (OMD), digestible organic matter (D) and metabolizable energy (ME) were estimated from the equations of Clincy & Wilson (1966).

The coefficient of organic matter digestibility (OMD%) = 110.13 − 1.32 MADF (%).

Digestible organic matter (D g per 100 g) = 99.43 − 1.77 MADF (g per 100 g).

Metabolizable energy (MJ/kg DM) = 16.37 − 0.0205 MADF (g/kg DM).

Statistical analysis

Comparison between the improved and native varieties was made using the student's t-test, while the F-test was used for comparing different varieties. Simple linear regression of the form $Y = a + bx$ was used for determining the relationship between two independent variables where appropriate.

Results

The yields of grain and straw, and their ratios are given in table 1. Grain Yield was significantly ($p < 0.05$) higher in the improved than the native varities. Improved varieties produced more straw than the native, but the difference was not significant. The grain : straw ratios were 1:1.11 and 1:1.29 in the improved and native varieties, respectively. Improved varieties had significantly more leaf blade, and less leaf sheath and internode than the native varieties. Of the total rice plant, leaf components accounts for about 67% for the improved and 63% for the native varities.

TABLE 1. GRAIN YIELDS AND STRAW (TONE / HA) AND RATIO OF GRAIN TO STRAW OF DIFFERENT VARIETIES OF RICE (DM BASIS)

Varieties of rice	Yield of grain	Yield of straw	Ratio grain: straw
Improved varieties:			
BR_3	3.533	3.023	1:0.86
BR_{11}	2.950	3.489	1:1.18
Pasam	3.032	3.935	1:1.30
Mala	2.979	3.243	1:1.09
Mean of improved varieties	$3.12^a \pm 0.28$	$3.42^a \pm 0.39$	$1:1.11^a \pm 0.19$
Native varieties:			
Maloti	2.245	3.400	1:1.34
Nizershail	2.097	3.176	1:1.52
Chandrashail	2.544	2.539	1:1.00
Mean of native varieties	$2.30^b \pm 0.23$	$3.04^a \pm 0.45$	$1:1.29^a \pm 0.26$
Mean of all varieties	2.77 ± 0.501	3.26 ± 0.430	1:1.19 ± 0.222

[a, b] Means in the same column having different superscripts differ significantly ($p < 0.05$).

TABLE 2. DIFFERENT FRACTIONS OF RICE STRAW IN DIFFERENT VARIETIES (PER CENT DM BASIS)

Varieties of rice	Leaf blade	Leaf sheath	Node	Internode	Rachis
Improved: BR_3	39.78	38.63	1.78	11.45	8.36
BR_{11}	33.87	33.23	3.17	19.10	11.089
Pasam	32.33	33.22	3.54	24.26	6.47
Mala	33.30	24.72	2.51	22.78	8.04
Mean of improved varieties	$34.8^a \pm 3.4$	$32.5^b \pm 5.7$	$2.8^a \pm 0.8$	$19.4^b \pm 5.73$	$8.6^a \pm 1.8$
Native: Maloti	26.66	32.16	3.24	25.33	11.58
Nizershail	27.78	35.97	3.68	22.48	9.85
Chandrashail	28.23	36.73	2.90	24.5	8.09
Mean of native varieties	$27.6^b \pm 0.8$	$34.9^a \pm 2.4$	$3.3^a \pm 0.4$	$24.0^a \pm 1.4$	$9.8^a \pm 1.7$
Mean of all varieties	31.7 ± 4.6	33.5 ± 4.5	2.97 ± 0.6	21.4 ± 4.8	9.1 ± 1.8

[a, b] Means having different superscripts in the same column differ significantly ($p < 0.01$).

TABLE 3. RELATIONSHIP BETWEEN STRAW YIELD (DM BASIS) FACTORS WHICH AFFECT STRAW PRODUCTION

Sample	Attribute	No. of observation	correlation coefficient	Regression equation	Values of t
Considering all observations	Straw yield (Y) $g.M^2$ with length or rice plant (X) cm	20	$r=0.21$	$Y=0.254.7+0.95X$	$t=0.98$
Considering all observation	Straw yield (Y) $g.M^2$ with tiller number (X_1) and no. of hills (X_2)	20	$r=0.04$	$Y=226.62+0.032X_1 + 0.75X2$	$t=0.01$
BR_{11}	Straw yield (Y) $g.M_2$ with tiller number (X)	11	$r=0.31$	$Y=496.39+0.64X$	$t=1.36$
Pasam	Straw yield (Y) $g.M^2$ with tiller number (X)	3	$r=0.42$	$Y=460.28+0.15X$	$t=0.41$
BR_3	Straw yield (Y) $g.M^2$ with length of stover (X) cm	3	$r=0.04$	$Y=354.06-0.002X$	$t=0.001$
BR_3	Straw yield (Y) g/M^2 with N level g/M^2 (X)	3	$r=0.96$	$Y=459.11-68.299X$	$t=3.23$
BR_{11}	Straw yield (Y) $g.M^2$ with N level g/M^2 (X)	4	$r=0.44$	$Y=298.35+13.06X$	$t=0.59$
Pasam	Straw yield (Y) $g.M^2$ with N level g/M^2 (X)	4	$r=0.44$	$Y=342.446+1.85X$	$t=0.48$
BR_3, BR_{11} and Pasam	Straw CP% (Y) with N level g/M^2	11	$r=0.42$	$Y=3.85+131X$	$t=1.40$

Table 3 presents the correlation and regression coefficients for straw yield and other related parameters. The length of rice plant (X) was found to be positively correlated with straw yield (Y), having the equation $Y = 154.7 + 0.95X$, but the relationship was weak ($r = 0.21$ and $t = 0.99$). Similar equations were also derived from the relation of straw yield with the number of tillers and hills. Length of stover was negatively correlated with straw yield, with the equation $Y = 354.6 - 0.002X$, where X = length of stover (cm) and Y = yield (g) of straw DM per square meter.

For BR_{11} and Pasam, straw yield was positively correlated ($p > 0.05$) with the level of N fertilizer applied, but inversely correlated ($p > 0.05$) in case of BR_3. Crude protein contents of straw increased ($p > 0.05$) linearly ($Y = 3.85 + 131X$; where, Y = % CP and X = N level g/M^2; $r^2 = 0.18$) with the increase of N fertilizer.

The organic matter and crude protein contents of different varieties of straw are given in table 4. No significant differences were observed among the varieties in organic matter (OM) or crude protein (CP) content. The average CP contents were 4.4% and 4.5% for improved and native varieties, respectively. Rachis had the highest OM content (91.3%), followed by leaf sheath (85.9%), node (85.7%) and leaf blade (83.8%). No significant differences were observed between improved (86.8%) and native (87.1%) varieties in OM content (table 4), but the overall differences in OM content were significant ($p < 0.01$) in different fractions of rice plant (table 6).

The cell wall constituents (NDF, MADF, hemicellulose, cellulose and lignin), cell contents and insoluble ash of different varieties of straw are presented in table 5. Modified ADF content was significantly higher ($p < 0.01$) in native (46.3%) than improved (43.6%) varieties. Insoluble ash content was also significantly ($p < 0.01$) higher in native (8.6%) than the improved (6.9%) varieties. No significant differences were observed in the NDF, cell content, hemicellulose, cellulose and lignin of the different varieties of straw.

TABLE 4. DRY MATTER (DM), ORGANIC MATTER (M), AND CRUDE PROTEIN (C) CONTENTS OF DIFFERENT VARIETIES OF RICE STRAW

Variety of rice	DM content	g nutrient / 100 g DM of sample		
		Ash content	OM content	CP content
Improved varieties :				
BR_3	80.7	14.5	85.5	4.8
BR_{11}	91.2	12.6	87.4	4.6
Pasam	89.9	10.6	98.7	3.4
Mala	95.9	15.5	84.6	4.9
Mean of improved varieties	91.9 ±27NS	13.3 ±2.7NS	86.8 ±2.23NS	4.4 ±0.7NS
Native : Maloti	87.1	9.0	90.0	4.3
Nizershail	90.7	15.9	87.1	4.8
Chandrashail	91.1	15.9	84.1	4.3
Mean of native varieties	89.8 ±1.9NS	13.9 ±3.4NS	87.1 ±2.9NS	4.5 ±0.26NS
Over all mean	89.6 ±4.67	13.4 ±2.77		

NS : No significant difference between the means in the same column.

TABLE 5. CELL WALL (NDF), MADF, CELLULOSE, HEMICELLULOSE, LIGNIN AND AS CONTENT OF DIFFERENT VARIETIES OF RICE STRAW (% OF DM)

Type of rice	NDF	MADF	Cell Content	Hemicellulose	Cellulose	Lignin	Insoluble ash
Improved varieties : BR_3	90.7	46.3	8.3	45.4	33.6	5.3	7.4
BR_{11}	70.1	44.7	29.9	25.4	35.4	2.3	7.0
Pasam	70.7	41.6	29.3	29.1	31.1	3.8	6.7
Mala	62.2	41.9	37.8	20.3	31.8	3.6	6.5
Mean of Improved varieties	73.4^a ±12.15	43.6^b ±2.26	26.3^a ±12.62	30.1^a ±1.92	32.9^a ±1.92	3.7^a ±1.26	6.9^b ±0.41
Native : Maloti	73.9	47.0	26.0	33.5	33.5	4.9	8.6
Nizershail	70.1	46.4	29.9	34.1	34.1	2.7	9.6
Chandrashail	60.4	45.3	30.6	33.6	33.6	3.9	7.8
Mean of Native Varieties	71.1^a ±2.44	46.3^a ±0.89	28.9^a ±2.44	33.70^a ±0.32	33.70^a ±0.32	3.9^a ±1.11	8.6^a ±0.91
Over all mean	71.2 ±9.90	44.7 ±2.18	27.4 ±9.14	31.6 ±7.92	33.3 ±1.43	3.7 ±1.08	7.66 ±1.11

[a, b] Data having differed superscripts in the same column differ significantly ($p < 0.01$).

TABLE 6. ORGANIC MATTER CONTENT OF DIFFERENT FRACTIONS OF STRAW (PERCENT DM BASIS)

Variety of rice	Leaf blade	Leaf sheath	Node	Inter-node	Rachis
Improved varieties :					
BR_3	80.7	83.5	84.5	85.5	80.1
BR_{11}	86.9	89.9	89.5	80.2	90.8
Pasam	83.6	87.5	88.6	90.9	95.8
Mala	84.3	88.1	88.6	88.3	91.7
Mean of improved varieties	83.9 ±2.5	87.2 ±2.6	85.5 ±4.0	88.8 ±2.3	92.1 ±2.6
Native :					
Maloti	84.9	85.6	85.3	86.9	87.6
Nizershail	81.8	80.6	76.1	88.2	89.1
Chandrashail	84.0	85.9	86.8	89.5	93.9
Mean of native varieties	83.4 ±1.6	84.1 ±3.00	86.1 ±0.7	88.2 ±1.3	90.2 ±3.3
Mean of all varieties	83.8^a ±2.0	85.9^c ±3.0	85.7^{bc} ±2.9	88.6^{ab} ±1.8	91.3^a ±2.8

[a, b, c] Data in the same row having dissimilar superscripts differ significantly ($p < 0.01$).

TABLE 7. ESTIMATED DIGESTIBLE ORGANIC MATTER (OM), COEFFICIENT OF DIGESTIBILITY (COD) OF OM AND CALCULATED METABOLIZABLE ENERGY VALUE OF THE DIFFERENT VARIETIES OF STRAW

Varieties of rice	MADF %	Digestibility of OM %	COD of OM %	Metabolizable energy MJ / kg DM
Improved varieties :				
BR_3	46.3	45.3	49.0	6.9
BR_{11}	44.7	47.2	57.2	7.2
Pasam	41.6	50.8	55.2	7.8
Mala	41.9	50.4	54.8	7.8
Mean of improved varieties	43.6^b ±2.26	48.4^a ±2.64	54.1^a ±3.51	7.4^a ±0.46
Native : Maloti	47.1	44.4	48.0	6.7
Nizershail	46.4	44.9	48.9	6.9
Chandrashail	45.3	46.4	50.3	7.1
Mean of native varieties	46.3^a ±0.89	45.2^b ±1.06	49.1^b ±1.16	6.9^a ±0.18
Over all mean	44.7 ±2.20	47.1 ±2.59	51.9 ±3.71	7.2 ±0.43

[a, b] Mean in the same column having different superscripts differ significantly ($p < 0.01$).

Table 7 represents the estimated OM digestibility (DOM%), digestible organic matter (D, g per 100 g) and metabolizable energy (ME, MJ per kg DM) values of different varieties of rice straw. The estimated D and DOM were significantly higher ($p < 0.01$) in improved than native varieties. Although not significant, the ME values were higher in the improved than the native (7.43 vs. 6.88 MJ/kg DM) varieties.

Discussion

Varietal effects on grain and straw yield

As was expected, both grain and straw yield were higher in the improved than the native varieties. Pasam gave the highest yield of straw in both categories, partly because of its longer stem, as indicated by the positive relationship between stem length and yield of straw (table 3). The native varieties were relatively poor producers of both grain and straw.

Our grain : straw ratio of 1:1.11 for improved varieties is similar to that reported by Carrangal and Calub (1986). Assuming an ultimate production of 3600 kg of grain per hectare in the farmer's field, enough straw would be produced to maintain two adult cattle for about one year, even at 1:1 of grain to straw ratio (Dolberg, 1988).

Straw fractions

Both in the improved and native varieties, leaf blade, leaf sheath and internode comprised the larger portions of the straw, with rachis and node quantitatively unimportant, which agrees with other observations (Doyle et al., 1985; Ernst et al., 1960). Ernst et al. (1960) have shown that leaf components (blade & sheath) comprises about 60% of total rice plant which is slightly less (63-67%) than the present observation. Leaf sheath ($p < 0.05$) and internode ($p < 0.01$) fractions were higher in the native varieties, while, the leaf blade fraction was higher ($p < 0.01$) in the improved varieties. All the native varieties and two improved varieties, e.g., Pasam and Mala, had higher a internode content. This is important, because internode is reported to have the higher IVODM (54%, range 38 to 56%) than other fractions of straw (Winugroho 1981). Further, animals prefer leaves and young stems, as compared with other parts of the plants (Burton 1987). Wilson (1982) has referred to some situation where high rates of N fertilization or water stress have incresed leafiness, but Pearce (1985) raised the question whether the effect carries through to the senescent stage of plants.

Prediction of straw yield from regression equation

Very poor linear relationships were observed between straw yield and factors affecting it (table 3). The negative regression value ($b = -0.002$) between straw yield and length of stover, indicated straw DM loss with the increase of stover length. Burton (1987) concluded that since stems of rice straw are better utilized than stems of other species of straw, stover loss of rice straw can be important particularly when there is a scarcity of DM for feeding bovine animals in Bangladesh.

Effect of fertilizer on yield

The insignificant effect of nitrogen levels on straw yield was may be due to the presence of required level of N in the soil, thus increased level of N did not effect the plant in any way. Roxas et al. (1985) found increasing N level increased the CP content in rice straw which agrees with the present findings except that our relationship was not significant. However, Sannasgala et al. (1985) found no positive effect on N content with the increasing level of N fertilizer.

Prediction of straw quality from chemical analysis

In the present study, the CP content of straw ranged from 3.4 to 4.9 per cent in different varieties which agrees with the reported observation of Theander and Aman (1984) and Sennasgala et al. (1985). As per as the efficient microbial fermentation of straw in the rumen is concerned, the CP contents of both the native (4.5%) and the improved (4.4%) varieties were very low. Morelover, much of this CP is associated with less digestible cell wall (Theander and Aman, 1984). As a result, it is exceedingly important to provide rumen degradable N source (e.g., urea), for maintaining a high rate of fermentation and maximizing intake and digestibility. The total ash content of different varieties of straw we studied, ranged from 10 to 15.9 percent, which is typical for the rice straw (Theander and Aman. 1984). Here, the insoluble ash (mostly silica) in different varieties of straw, ranged from 6.8 to 9.6%, which is similar (7%) to the observation by Doyle et al. (1985). Native varieties straw (8.6%) had higher ($p < 0.01$) silica content than the improved varieties (6.9%). Since, silica is negatively correlated with digestibility of the polysaccharides in the rumen (van Soest and Jones, 1986 van Soest, 1970), improved varieties straw are more desirable than native varieties for feeding ruminants.

The NDF, MADF, cell content, hemicellulose and cellulose of our different varieties of rice straw agree with the observation of other authors (Doyle et al., 1985; Theander and Aman, 1984). Significant features were the high NDF and lignin contents of BR_3, and relatively lower lignin contents of all other varieties.

Prediction of estimated energy value

Among the varieties of straw, Pasam had the highest digestible OM, COD of OM, and ME values. In general the improved varieties had significantly higher ($p < 0.01$) digestible OM and COD of OM than the native varieties. However, this result must be viewed with cautions because these values were only estimated from equations based on modified ADF contents.

Conclusion and Suggestion

Under Bangladesh conditions, improved varieties cultivated during the season of Aman, showed better performance than the native varieties both in quality and quantity of straw. Quality was only estimated from laboratory analysis and need to be assessed by *in sacco* dacron bag digestibility or by similar techniques to determine the rate and extent of digestion. Further, similar experiments should be conducted on rice grown in Boro (March to May) and Aus (May to August) seasons and in different localities.

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