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A note on variation in grain and straw fodder quality traits in 437 cultivars of rice from the varietal groups of aromatic, hybrids, *Indica*, new planting types and released varieties in the Philippines

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Abstract

Four hundred and thirty-seven different cultivars (59 Aromatics, 53 Hybrids, 172 Indica, 92 New Planting Types and 61 Varieties) were analyzed for grain yield (GY), straw nitrogen (N) content, neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), silica, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) and for relationships between GY and these straw fodder quality traits. Highly significant ($P < 0.0001$) differences between the groups were observed for all traits with hybrid having the highest GY and also the highest mean straw N, IVOMD and ME. With the exception of NDF and ADL in Aromatics highly significant ($P = 0.002$ to 0.0001) differences were found for all traits among the cultivars in the different groups. Variations in GY and straw fodder quality traits were greater within cultivar groups than among cultivar types. The variations in straw quality traits between cultivars were of livestock nutritional significance. For example, key straw quality traits such as IVOMD varied between cultivars by at least 6.9% units in New Planting Types and up to 12.0% units in Varieties. Cultivar differences in straw quality can be exploited without detriment to GY since inverse relationships were largely absent. Weak overall inverse associations between GY and straw fodder quality traits, that is inverse relationships between straw N, IVOMD and ME and positive relationship between NDF, AD, ADL and silica and GY, were due to two obvious outliers with very low GY.

Key Words: Rice, Rice straw, Rice fodder quality

1. Introduction

Rice cultivation is the major activity and source of income for more than 100 millions of households in Asia and Africa, and 80% of those are small-scale farmers in low-income countries (FAO, 2004). The straw of rice is an important fodder resource for livestock, providing for example more than 30% of all the fodder from crop residues in India and constituting the bulk of livestock fodder in the rainfed parts of the Indo-Gangetic-Plain and in Southern India (NIANP, 2003). The fodder quality of rice straw is often low but technologies for improving the fodder quality by physical, chemical or biological treatments have not been widely adopted (Van Soest, 2006). The more recent research paradigm holds that improvement of the fodder quality of crop residues through plant breeding and selection is more promising (Blümmel et al., 2006). Here, the fodder value (quantity and quality) of the crop residue becomes an integral part of plant breeding and selection. However, some conditions need to be met. The genetic variation in fodder value of the crop residue needs to be significant from a livestock nutritional point of view. Second, fodder value of the crop residue should not, or at least not seriously, conflict with primary traits, notably grain yield. The work presented is a preliminary investigation of these conditions in a wide range of rice cultivars from the International Rice Research Institute (IRRI).

2. Materials and methods

2.1 Rice cultivars and origin of straws

The cultivars were field-evaluated at the IRRI Experimental Station in Los Banos during the 2005 dry season. A straw sample was collected from 5 randomly chosen hills from each of the harvested plots from either replicated or observational yield trials. For the replicated yield trials, a randomized complete block design with 3 replications and 6m^2 plots were used while the observational trial consisted of 6 rows of 5m long plots. Standard cultural practices were followed. Fertilizer application of 90-30-30 NPK per hectare was practiced. Each sample was placed in #25 double-ply paper bags and dried in an oven at 70 °C for at least 5 days. Representative straw samples (about 25 g) were randomly taken, cut into small pieces and ground to pass through a 1 mm mesh using Foss Cyclotec ™ 1093. A total of 437 rice cultivars were collected and shipped to the laboratory of the International Livestock Research Institute in India for straw fodder quality analysis. A large majority of rice cultivars were of *Indica* origin (172 inbreds and 53 hybrids and 69 varieties released in the Philippines). A set of 61 aromatic were bred from *Indica* x *Basmati* crosses. On the other hand, 92 New Plant Type (NPT) cultivars were derived from *Indica* x *Tropical-Japonica* crosses.

2.2 Straw quality analyses

All samples were scanned with Near Infrared Reflectance Spectroscopy (NIRS) instrument FOSS Forage Analyzer 5000 installed with software package WinISI II. Predicted were straw nitrogen content (N), neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), silica, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME). Relationships between blind-predicted and measured variables were tested by R^2 and standard error of prediction (SEP) and standard error of calibration (SEC) and good-of-fitness parameters were reported by Blümmel et al. (2007).

2.3 Statistical analysis

SAS (2012) was used to analyze effects of cultivar types by the linear model: Yi=μ+αi+ei where μ is the grand mean, α_i is the main effect of the i^{th} cultivar type and ei is the random error, assumed to be a normal distribution (with mean zero and variance σ^2_e). The general linear model (GLM) analysis was carried out by SAS (PROC GLM) procedure. The comparison of means between cultivar types were carried out using Fisher's least significance difference (LSD) test at 5% level of significance. All graphical representations were carried out by using GraphPad Prism.

3. Results and discussion

3.1 Differences in GY and rice straw fodder quality traits

Ranges in grain yield (GY), straw nitrogen content (N), neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), silica, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) in different cultivars types are reported in Table 1. With the exception of NDF and ADL in

Aromatics, highly significant (P = 0.002 to 0.0001) cultivar differences were found for all traits among the cultivars in the different groups.

Table 1 about here

The cultivar-dependent ranges in straw quality traits were substantial. For example, lack of N is common in cereal straws with rumen microbes requiring at minimum of 1 to 1.2% of N in the feed for efficient feed digestions (Van Soest, 1994). While all rice straws fell short of providing minimum N some came close to it (Table 1) and some moderate N supplementation from other feedstuffs would close the N gap. However, there is substantial evidence from ex-ante assessments (Kristjanson and Zerbini, 1990), on station (Sharma et al., 2010) and fodder market work (Blümmel and Rao,2006; Teufel et al., 2010) that straw fodder quality traits relating to the available energy in the straw, notably IVOMD and ME, provide the most meaningful about straw quality. Kristjanson and Zerbini (1999) calculated that a one-percentage unit increase in digestibility in sorghum and pearl millet stover would increase milk, meat and draught power outputs ranging from 6 to 8%. Blümmel and Rao (2006) surveyed six major sorghum stover traders in Hyderabad in India monthly from 2004 to 2005 and observed that a difference in IVOMD of 5% units was associated with price premiums of 25%. Protein content was not related to stover prices but IVOMD accounted for 75% of the price variation. In rice straw trading differences in IVOMD as low as 2 to 3% units could be associated with similar price premiums (Teufel et al., 2010). The variations in straw IVOMD observed in the present work, for example at least 6.9 % units in New Planting Types but up to 12.0% units in Varieties, must therefore considered to be highly relevant for livestock nutrition. Choice of cultivar, rather than choice of cultivar type, will be of higher importance for livestock productivity, since difference in rice straw quality between cultivar types, though statistically highly significant, were comparatively small (Table 2).

Table 2 about here

3.3 Relationships between GY and rice straw quality traits

Livestock contribute significantly to livelihoods of rural and urban poor in developing countries, and the forecasted increase in demand for livestock products will further strengthen the role of livestock as a pathway out of poverty (Delgado et al., 1999). However, fodder shortages already present a serious constraint to benefits from livestock, and shrinking common property resources and the increasing scarcity of arable land and water will further restrict fodder production. The breeding and selection of rice cultivars with good straw fodder traits is therefore of strategic importance. Better quality rice straw will benefit the mixed crop-livestock farmer who uses rice straw for feeding his animals. Farmers without animals can trade better quality rice straw on the fodder market while landless livestock keepers can buy this rice straw as fodder. Improved rice straw fodder traits will also increase the likelihood of adoption of new varieties and hybrids with better grain yields (see also below). The potential impact of improved dual-purpose rice cultivars is therefore considerable. However, genotypic variation in straw quality should not be exploited at the expense of grain yield. It is therefore encouraging to note that rice straw fodder quality traits and GY were largely unrelated (Figures 1 to 7). Where inverse relationship existed between GY and straw quality two outliers with very low GY were responsible, see Figures 6 and 7. Thus Hybrids had highest average GY (with the *Indic*a group see Table 2) but also highest IVOMD (Table 2). Interestingly average Silica content was also highest in Hybrids, rejecting the assumption of a close consistent inverse relationship between Silica content and IVOMD.

Figures 1 to 7 about here

4. Conclusions

Rice cultivars differ substantially in straw fodder quality traits. Fodder quality traits seem to be largely independent from grain yields, which suggest that high grain yield and high straw fodder quality traits are essentially compatible traits. Crop improvement and new rice cultivars releasing agents should include information about straw fodder quality traits when promoting new cultivars in areas where rice straw contributes significantly to livestock feeding.

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Table 1: Ranges in grain yield (GY), straw nitrogen content (N), neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), silica, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) in different cultivars types of rice grown at the International Rice Research Institute

Trait	Aromatics (59)	Hybrids (53)	Indica (172)	NPT (92)	Varieties (61)
	Range				
GY	4.9 – 7.5 (<0.0001)	0.9 – 8.3 (<0.0001)	4.5 – 8.1 (<0.0001)	5.2 – 7.8 (0.002)	2.0 – 8.4
N	0.49 – 0.78 (0.0001)	0.51 – 0.90 (<0.0001)	0.47 – 0.75 (<0.0001)	0.41 - 0.75 (<0.0001)	0.34 – 0.82 (<0.0001)
NDF	61.8 – 66.9 (0.19)	61.2 – 67.2 (0.0002)	62.1 – 68.5 (<0.0001)	62.0 – 69.1 (<0.0001)	57. 4 – 69.7 (<0.0001)
ADF	51.5 – 57.2 (<0.0001)	47.9 – 57.1 (<0.0001)	51.7 – 57.2 (<0.0001)	51.2 – 56.4 (<0.0001)	47.4 – 57.7 (<0.0001)
ADL	2.8 - 3.6 (0.21)	3.0 – 3.8 (<0.0001)	2.7 – 3.9 (<0.0001)	2.6 – 3.6 (<0.0001)	2.4 – 3.6 (0.001)
Silica	13.2 – 19.2 (<0.0001)	12.2 – 18.3 (<0.0001)	13.4 - 18.7 (<0.0001)	12.6 – 17.1 (<0.0001)	13.3 – 18.0 (<0.0001)
IVOMD	34.8 – 45.2 (<0.0001)	40.2 – 49.8 (<0.0001)	36.6 – 45.8 (<0.0001)	38.6 – 45.5 (<0.0001)	37.9 – 49.9 (<0.0001)
ME	4.41 - 6.17 (<0.0001)	5.35 – 6.96 (<0.0001)	4.72 – 6.27 (<0.0001)	5.14 – 6.23 (<0.0001)	5.07 – 7.03 (<0.0001)

Table 2: Means of grain yield (GY), straw nitrogen content (N), neutral (NDF) and acid (ADF) detergent fiber, acid detergent lignin (ADL), silica, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) in across different groups of rice grown at the International Rice Research Institute

Cultivar Type	GY	N	NDF	ADF	ADL	Silica	IVOMD	ME
	(t/ha)	(%)	(%)	(%)	(%)	(%)	(%)	(MJ/Kg)
Aromatics (59)	6.2	0.61	65.1	54.3	3.2	15.4	41.4	5.6
Hybrids (53)	6.7	0.67	64.3	54.9	3.4	16.1	43.5	5.9
Indica (172)	6.7	0.60	65.3	54.7	3.3	15.6	41.3	5.6
NPT (92)	6.4	0.59	66.3	54.1	3.2	14.9	41.4	5.6
Varieties (61)	4.8	0.56	64.8	54.1	3.1	14.9	42.5	5.8
P < F	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD	0.25	0.025	0.48	0.44	0.06	0.33	0.58	0.09

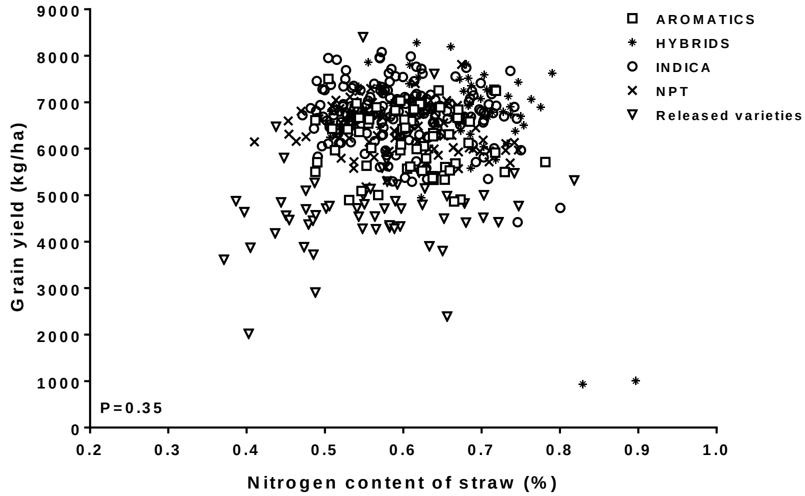

Figure 1: Relation between straw nitrogen content and grain yield in 437 cultivars of rice from IRRI

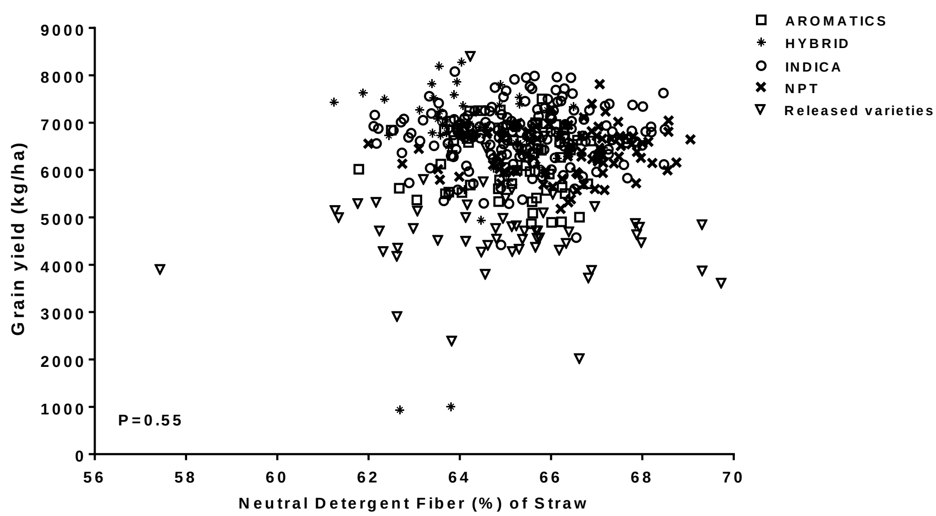

Figure 2: Relation between straw neutral detergent fiber content and grain yield in 437 cultivars of rice from IRRI

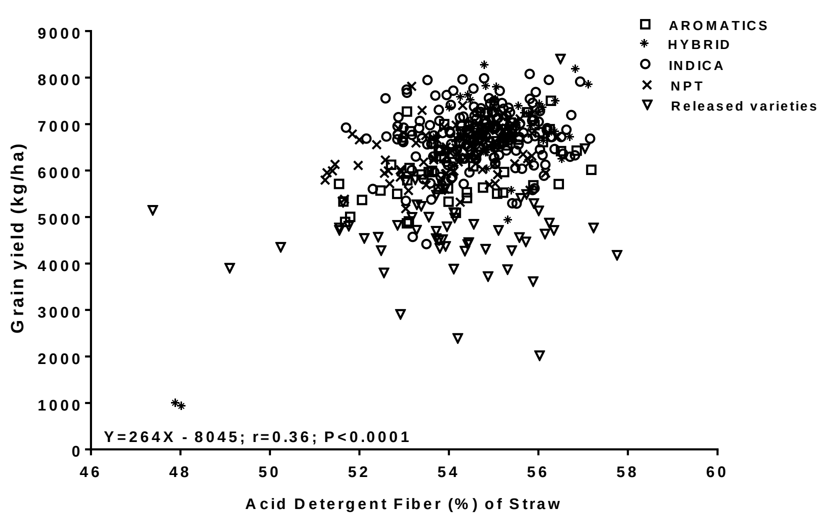

Figure 3: Relation between straw acid detergent fiber content and grain yield in 437 cultivars of rice from IRRI

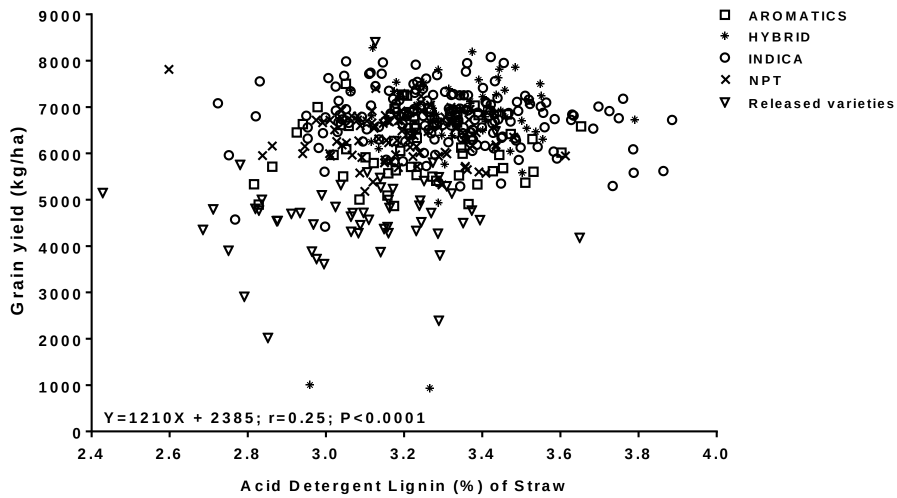

Figure 4: Relation between straw acid detergent lignin content and grain yield in 437 cultivars of rice from IRRI

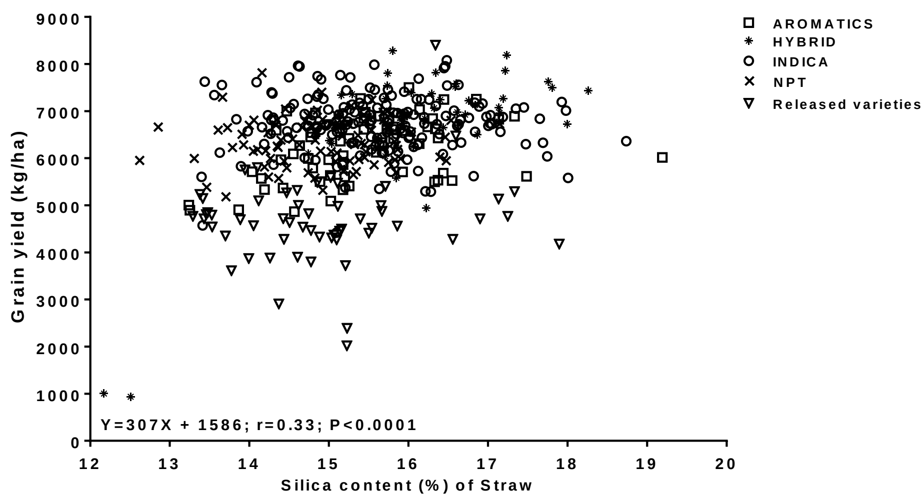

Figure 5: Relation between straw silica content and grain yield in 437 cultivars of rice from IRRI

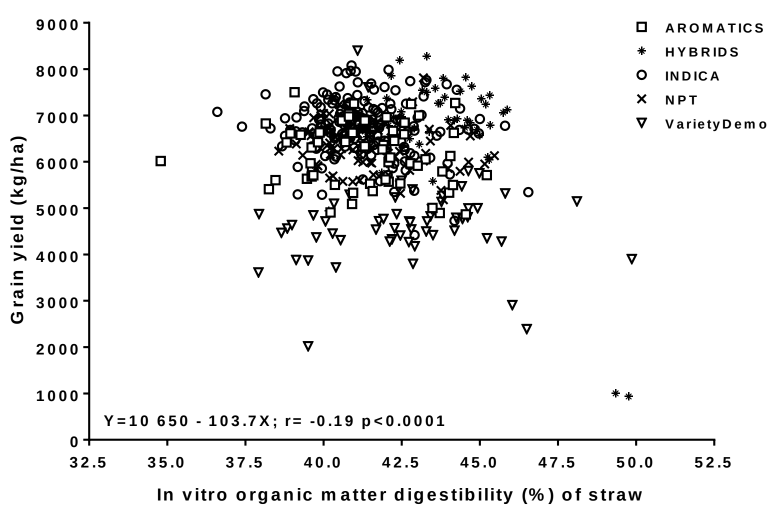

Figure 6: Relation between straw *in vitro* organic matter digestibility and grain yield in 437 cultivar of rice from IRRI

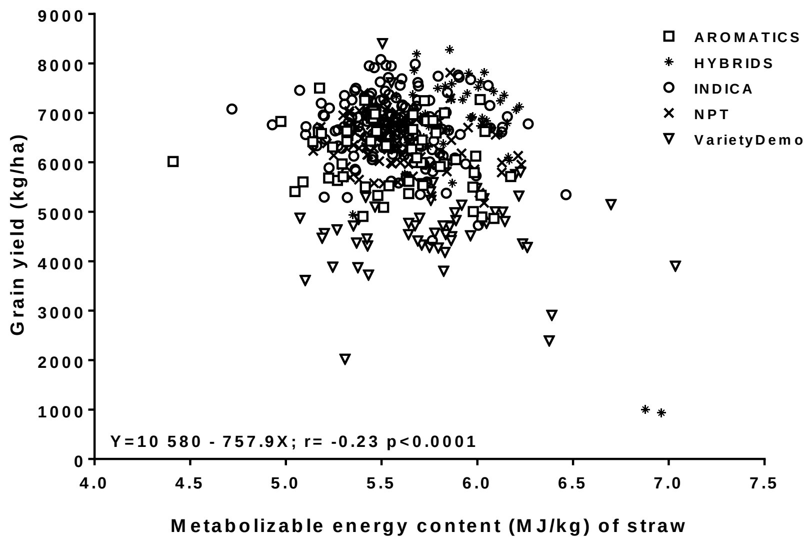

Figure 7: Relation between straw metabolizable energy content and grain yield in 437 cultivars of rice from IRRI