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The Effects of Nitrogen Fertilization Levels on the Straw Nutritive Quality of Malaysian Rice Varieties

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Abstract: Samples of straw from two varieties of rice, namely MR 211 and MR 219 which were grown at five levels of nitrogen fertilization (0, 120, 160, 200 and 240 kg N ha^{-1}) were collected at harvesting time (MR 211 at 105 DAS; MR 219 at 115 DAS). The straws were separated into leaf (including blade and sheath) and stem fractions and were analyzed for chemical composition and *in vitro* digestibility. Increases in the level of nitrogen fertilization were found to increase the Crude Protein (CP) in whole straw ($p<0.01$) from 45.6 g kg^{-1} to a maximum level of 84.5 g kg^{-1} dry matter. It also decreased ($p<0.05$) the *in vitro* true organic matter digestibility (IVTOMD) from 0.59 to 0.55, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF). The straw hemicellulose, cellulose, Acid Detergent Lignin (ADL), silica, ash and *in vitro* true dry matter digestibility (IVTDMD) were not significantly affected ($p>0.05$) by the nitrogen fertilization level. There were varietal differences in the straw chemical composition, where variety MR 219 had higher NDF, hemicellulose and cellulose ($p<0.05$) concentration where as variety MR 211 had higher amount of ADL ($p<0.01$) and silica ($p<0.05$) in the straw. There were no differences between the varieties in the straw CP, ADF, ash and digestibility. Between the two varieties, MR 219 variety is superior to MR 211 in view of the higher grain production and grain: straw ratio. The result from correlation between agronomic characteristics and straw nutritive quality implies that rice varieties with good agronomic characteristics have potential in yielding straws with better nutritive quality. The result showed that increasing nitrogen fertilization rate could overcome the problem of low protein in rice straw for animal feed.

Key words: Rice straw, nitrogen, variety, nutritive value

INTRODUCTION

Rice is the staple food for Malaysians. As population increases, there is need to increase the rice grain yield to enhance food security. Farmers are currently applying nitrogen fertilizer at rates above the recommendation by the Malaysian Agriculture Research and Development Institute (MARDI), in efforts to maximize grain yield (Alias and Manaf, 1993). In Malaysia, the rice breeding research has been focusing on improving the agronomic characteristics of rice crop such as grain yield and quality. Research has generally concentrated on the importance of nitrogen in increasing the grain yield and the effects of nitrogen on the straw yield and quality have not been investigated. Rice straw has been used as ruminant feed in many Asean countries although it is regarded as poor quality feed due to its low protein concentration (average 40 g kg^{-1} of dry matter) and digestibility. It has been reported that the nutritive composition and digestibility of rice straw varies widely among different varieties (Vadiveloo, 1992, 1995; Abou-El-Enin *et al*., 1999) and environmental conditions (fertilizer application, season, location etc.) under which the crops are grown (Bainton *et al*., 1991; Vadiveloo and Phang, 1996; Shen *et al*., 1998; Summers *et al*., 2001). The current practice of applying high rates of nitrogen fertilizer by the Malaysian rice farmers in targeting high grain production have prompted further study on the impact of this fertilizer practice on the straw quality and production. Previous studies done in Philippines (Roxas *et al*., 1985) and California (Drake *et al*., 2002) reported that the straw crude protein tended to increase as more nitrogen fertilizer was applied to the rice plant. However, the rate of nitrogen applied to the crop did not exceed 120 kg N ha^{-1} in those previous studies. In Malaysia, previous studies using the older varieties of rice straw have investigated the effects

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of storage (Devendra, 1982), botanical fractions (Vadiveloo, 1995), season, location (Vadiveloo and Phang, 1996) and chemical treatments (Vadiveloo, 1996, 2003) but the effects of nitrogen fertilizer practice have not been discovered and new varieties currently used have not been studied. In Malaysia, rice straw which is the crop by-product is regarded as a waste and has not been used as ruminant feed; therefore most of the straws are burned following grain harvest. If it is proven that the current nitrogen fertilizer practice can improve the straw nutritive quality, then it would be worthwhile using the straw for ruminant feed rather than being disposed by burning.

This present study was designed to evaluate the nutritive quality of straws from high yielding rice varieties with increasing application of nitrogen fertilizer.

MATERIALS AND METHODS

Treatments: The treatments comprised of factorial combination of five nitrogen levels (0, 120, 160, 200 and 240 kg N ha^{-1}) with two rice varieties (MR 211 and MR 219), giving a total of 10 treatment combinations. The 10 treatment combinations were replicated 4 times in a Completely Randomized Design (CRD).

Cultivation and fertilizer application: The field experiment was conducted in Universiti Putra Malaysia. Two rice varieties, MR 211 and MR 219 were grown under five levels of nitrogen application at 0, 120, 160, 200 and 240 kg N ha^{-1}. The rice was established by direct seeding in polyethylene (PE) tanks (0.95 m^2, 450.5 L) filled with Bakau soil series (*Typic Hidrajelbars*) obtained from MARDI station in Tanjung Karang, Selangor. The pre-germinated seeds were sown by broadcasting seeds at rate of 500 seeds per square meter (MARDI, 2002). At 5-7 Days After Sowing (DAS), water was supplied gradually and maintained at ± 5 cm during early vegetative and reproductive stage. Split urea ($CO(NH_2)_2$) fertilizer were applied at 15, 35, 55 and 75 DAS. The water was drained out at 90 DAS. Weed control was done manually, when necessary.

Rice straw: The rice plants were harvested (MR 211 at 105 DAS; MR 219 at 115 DAS) manually using sickles at 12 cm above ground. The grains were separated from the straw following harvest. Approximately 1 kg of the straws was separated into leaf (including blade and sheath) and stem fractions. The straw samples were oven-dried at 60°C for 48 h and ground to pass through a 1 mm sieve in a hammer-mill for chemical analysis. The agronomic characteristics and yield components of each rice variety were recorded.

Chemical analysis and *in vitro* digestibility: The ground samples (leaf and stem fractions) were analyzed in the laboratory for crude protein, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), ash, silica and digestibility. The crude protein and ash were determined by Association of Official Analytical Chemist (AOAC, 1984). Chemical composition for NDF, ADF and ADL were analyzed according to the procedures of Goering and Van Soest (1970) and silica was determined according to the method as described by Smith *et al.* (1971). The *in vitro* digestibility was analyzed using *in vitro* gas production technique as described by Menke and Steingass (1988). The organic matter, cellulose and hemicellulose content were obtained by calculation.

Statistical analysis: The data were analyzed using analysis of variance, regression and correlation procedure of SAS Institute Inc., USA. Factorial experiment was carried out to determine the existence of interaction between the sources of variation. F-test and Duncan Multiple Range Test (DMRT) were carried out for means and comparison between the treatments. Regression analysis was carried out to determine the relationship between the nitrogen levels and straw chemical composition and between the nitrogen levels and plant agronomic characteristics. Correlation analysis was carried out to determine the relationship between the plant agronomic characteristics and chemical composition.

RESULTS

Chemical composition

Crude protein: The crude protein concentration in the whole straw, leaf and stem fraction was found to increase ($p<0.01$) with nitrogen fertilization level (Fig. 1). The maximum crude protein obtained was 84.5 g kg^{-1} (whole straw), 98.8 g kg^{-1} (leaf) and 67.7 g kg^{-1} (stem)

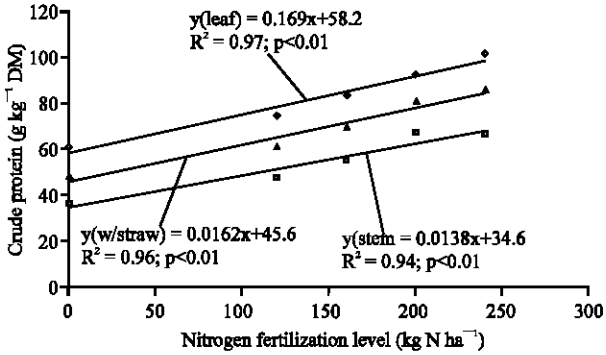

Fig. 1: Effects of nitrogen fertilization levels on the crude protein

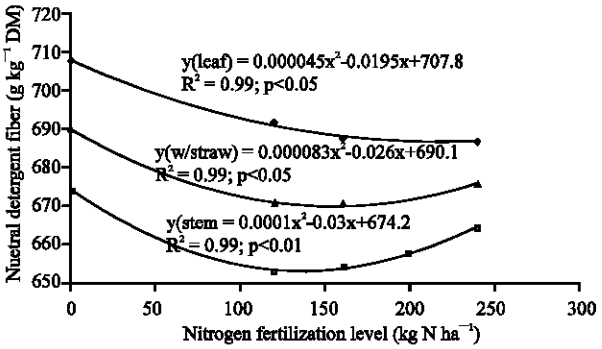

Fig. 2: Effects of nitrogen fertilization levels on the NDF

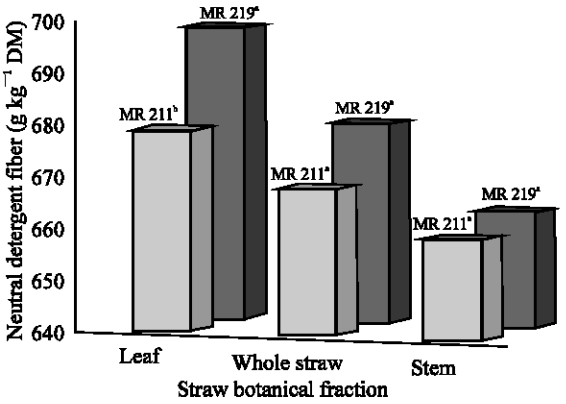

Fig. 3: Varietal differences in the NDF. Within each fraction, means with the same superscripts are not significantly different (p<0.05) according to DMRT

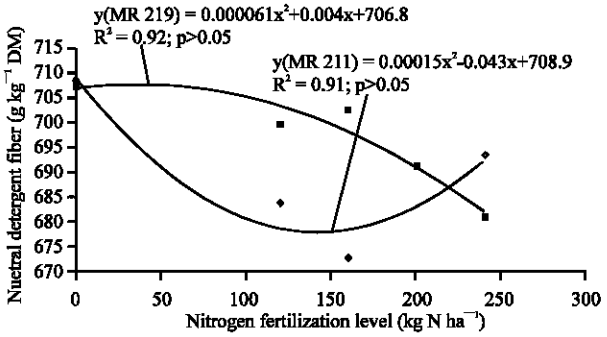

Fig. 4: Interaction between the nitrogen level and variety in leaf NDF

under optimum nitrogen application at 240 kg N ha^{-1}. The increase in nitrogen level (from 0 kg N ha^{-1} to 240 kg N ha^{-1}) had increased the crude protein by 85.31% (whole straw), 69.76% (leaf) and 95.66% (stem). The leaf fraction was found to contain higher crude protein concentration compared to the stem. There were no significant differences (p>0.05) between the varieties on

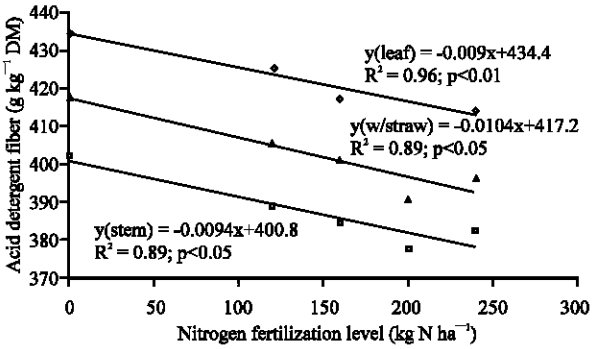

Fig. 5: Effects of nitrogen fertilization levels on the ADF

the crude protein concentration. No interaction existed (p>0.05) between the nitrogen level and variety (N×V).

Neutral Detergent Fiber (NDF): A quadratic decline in the NDF concentration was observed with increasing nitrogen fertilization level (Fig. 2). The result suggests that nitrogen level up to 160 kg N ha^{-1} reduces the cell wall concentration in straw but further increases in nitrogen level raised the cell wall concentration especially in the stem fraction. The leaf had higher NDF concentration compared to stem. There were significant varietal differences in the NDF concentration in the leaf fraction (p<0.05). The amount of NDF in the whole straw and stem fraction did not differ significantly (p>0.05) between the varieties. Variety MR 219 had higher NDF concentration compared to MR 211 (Fig. 3). Interaction between nitrogen and variety (N×V) in the leaf fraction was significant (p<0.05), where both varieties responded differently to the nitrogen level (Fig. 4). In MR 211, a quadratic decline in NDF concentration was observed with increasing nitrogen level where as in MR 219, the NDF concentration was found to decrease with nitrogen level. Interaction between the nitrogen and variety (N×V) in the whole straw and stem fraction was not significant (p>0.05).

Acid Detergent Fiber (ADF): Increasing nitrogen fertilization level resulted in a linear decline in the ADF concentration in whole straw (p<0.05), leaf (p<0.01) and stem (p<0.05) fraction (Fig. 5). The increase in nitrogen level (from 0 kg N ha^{-1} to 240 kg N ha^{-1}) was found to reduce the ADF concentration by 5.97% (whole straw), 4.97% (leaf) and 5.64% (stem). The leaf fraction contained higher amount of ADF compared to stem. No varietal differences (p>0.05) was observed in the ADF concentration. Interaction between the nitrogen and variety (N×V) was not significant (p>0.05).

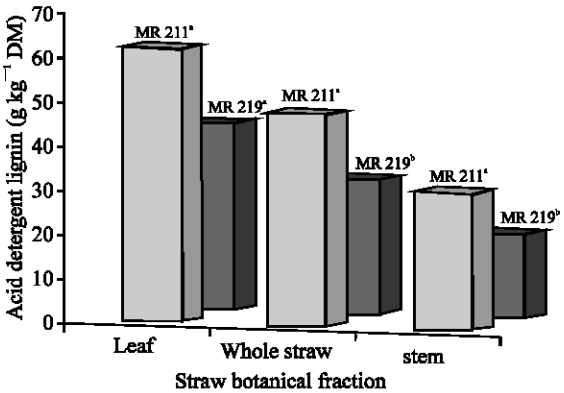

Fig. 6: Varietal differences in the acid detergent lignin (ADL). Within each fraction, means with the same superscripts are not significantly different (p<0.05) according to DMRT

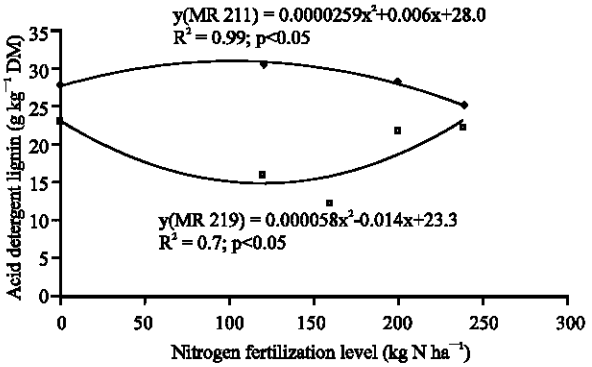

Fig. 7: Interaction between the nitrogen level and variety in the stem ADL

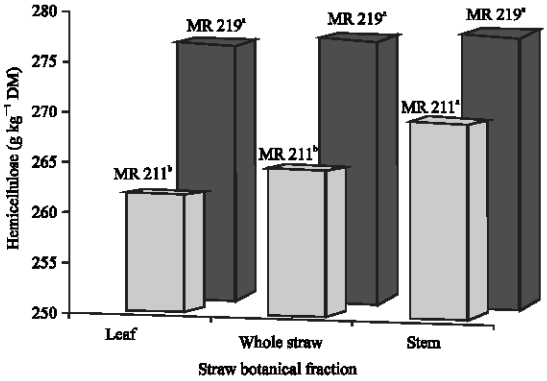

Fig. 8: Varietal differences in the hemicellulose. Within each fraction, means with the same superscripts are not significantly different (p<0.05) according to DMRT

Acid Detergent Lignin (ADL): The ADL concentration was not affected (p>0.05) by nitrogen fertilization level.

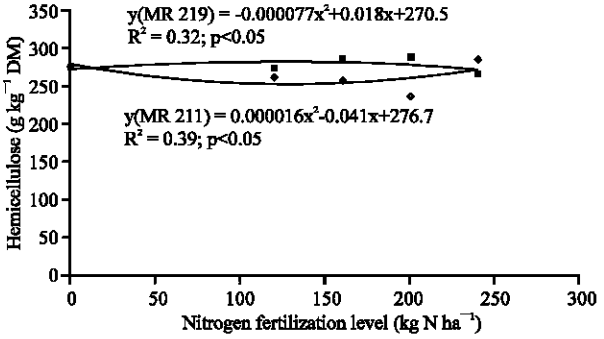

Fig. 9: Interaction between the nitrogen level and variety in the leaf hemicellulose

Varietal differences were significant in the whole straw (p<0.01) and stem but not in the leaf (p>0.05) fraction (Fig. 6). Variety MR 211 had higher ADL concentration compared to variety MR 219. The leaf fraction had higher concentration of ADL compared to the stem fraction. Interaction between the nitrogen and variety (N×V) were significant (p<0.001) in the stem fraction (Fig. 7). In MR 211, a quadratic increase in ADL concentration was observed with increasing nitrogen level where as in MR 219, a quadratic decline in ADL concentration was observed with nitrogen application. The interaction between nitrogen and variety (N×V) in the leaf fraction and whole straw was not significant (p>0.05).

Hemicellulose: There were significant varietal differences in the hemicellulose concentration in the whole straw (p<0.05) and leaf (p<0.05) fraction. Variety MR 219 had higher hemicellulose concentration compared to variety MR 211. The concentration of hemicellulose in the stem fraction did not differ significantly (p>0.05) between the varieties (Fig. 8). The stem fraction had higher concentration of hemicellulose compared to the leaf fraction. The nitrogen fertilization level was not shown to affect (p>0.05) the hemicellulose in rice straw. There were significant interaction between the nitrogen and variety (N×V) in the leaf (p<0.01) fraction, where both varieties responded differently to the nitrogen level (Fig. 9). In MR 211, increase in nitrogen level up to 100 kg N ha^{-1} reduced the hemicellulose concentration in the leaf fraction, but further increases in nitrogen level raised the concentration of hemicellulose. In MR 219, increase in nitrogen level up to 120 kg N ha^{-1} raised the hemicellulose concentration, but further increases in nitrogen level reduced the hemicellulose concentration. The interaction between the nitrogen and variety (N×V) in the stem and whole straw fraction was not significant (p>0.05).

Cellulose: There were significant varietal differences in the cellulose concentration in the whole straw (p<0.01)

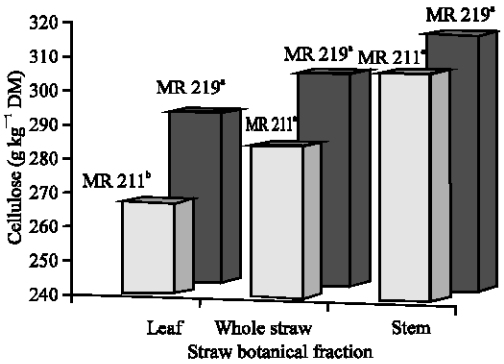

Fig. 10: Varietal differences in the cellulose. Within each fraction, means with the same superscripts are not significantly different (p<0.05) according to DMRT

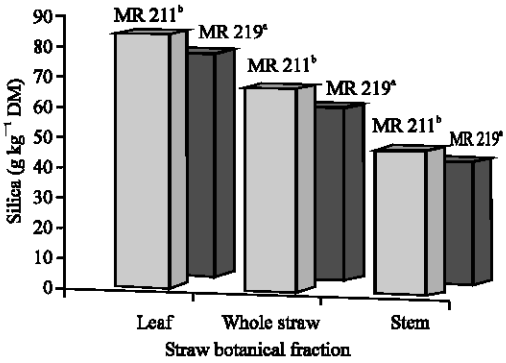

Fig. 11: Varietal differences in the silica. Within each fraction, means with the same superscripts are not significantly different (p<0.05) according to DMRT

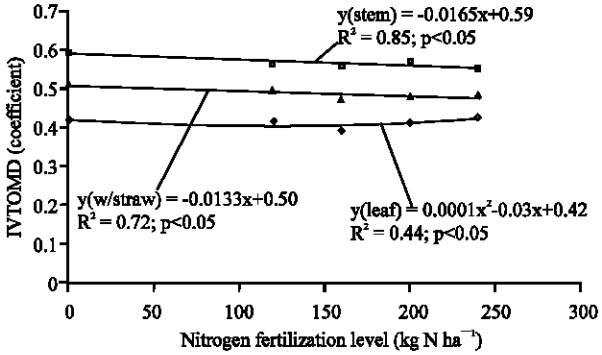

Fig. 12: Effects of nitrogen fertilization level on the *in vitro* true organic matter digestibility (IVTOMD)

and leaf (p<0.05) but not in the stem (p>0.05) fraction (Fig. 10). Variety MR 219 had higher cellulose concentration compared to variety MR 211. The stem had higher cellulose concentration compared to leaf. The nitrogen fertilization level was not shown to affect (p>0.05) the cellulose in rice straw. No interaction existed (p>0.05) between the nitrogen and variety (N×V).

Table 1: Agronomic characteristics and yield components of two rice varieties

Variety	Stem height (cm)	Maturity (DAS)	Leaf stem	Grain yield (t ha⁻)	Grain straw
MR 211	53.07	102	1.2	5.51	0.62
MR 219	57.36	108	0.93	8.00	0.88
Means	55.22	105	1.07	6.76	0.75
SD	5.45	1.74	0.18	1.85	0.22
Significant level	*	***	***	***	**

*** p<0.001. ** p<0.05, SD Standard Deviation

Ash: The nitrogen fertilization level did not affect (p>0.05) the ash in rice straw. The leaf had higher ash concentration compared to stem. There were no varietal differences (p>0.05) in the ash concentration.

Silica: There were significant varietal differences in the silica concentration in the whole straw (p<0.01), leaf (p<0.01) and stem (p<0.05) fraction (Fig. 11). Variety MR 211 had higher silica concentration compared to variety MR 219. The leaf had higher concentration of silica compared to stem. The nitrogen fertilization level did not affect (p>0.05) the silica in rice straw. No interaction existed (p>0.05) between the nitrogen and variety (N×V).

***In vitro* true digestibility:** Increasing nitrogen fertilization level was shown to decrease the *in vitro* true organic matter digestibility (IVTOMD) significantly in the stem (p<0.05) fraction (Fig. 12). The nitrogen level did not affect the IVTOMD in the leaf and whole straw fraction. The effects of nitrogen fertilization level on the *in vitro* true dry matter digestibility (IVTDMD) were not significant (p>0.05). The stem was found to have higher digestibility compared to the leaf. There were no significant varietal differences (p>0.05) in both IVTOMD and IVTDMD.

Agronomic characteristics and yield components: Data on the agronomic characteristics and yield components for each variety are shown in Table 1. The analysis of variance showed that these were significantly different (p<0.05) between the varieties. MR 211 was found to have higher leaf: stem, lower stem height and shorter maturation period where as MR 219 had higher grain yield and grain: straw ratio.

Correlation between agronomic characteristics and straw nutritive value: Table 2 showed that the grain yield, stem height, maturity and leaf: stem ratio were positively correlated with the crude protein. This positive correlation

Table 2: Correlation between agronomic characteristics and straw nutritive value

	CP	NDF	ADF	IVTDMD	ITOMD
Grain yield	r = 0.31 *	r = -0.02 ns	r = -0.17 ns	r = 0.06 ns	r = 0.15 ns
Stem height	r = 0.57 ***	r = -0.39 *	r = -0.55 ***	r = -0.18 ns	r = -0.15 ns
Maturity	r = 0.27 ns	r = -0.05 ns	r = -0.35 *	r = -0.002 ns	r = 0.13 ns
Leaf: stem	r = 0.57 ***	r = 0.05 ns	r = 0.08 ns	r = -0.36 ns	r = -0.55 **

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, ns $p>0.05$, CP: Cmde Protein, NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, IVTDMD: *In vitro* True Dry Matter Digestibility, IVTOMD: *In vivo* True Organic Matter Digestibility

indicates that, increased grain yield, stem height, duration to maturity and leaf: stem ratio increased the straw crude protein. The grain yield, stem height and maturity were negatively correlated with NDF and ADF. This negative correlation implies that the increased in grain yield, stem height and duration to maturity decreased the straw cell wall (NDF) and fiber (ADF) fractions. The stem height, leaf: stem ratio were correlated negatively with digestibility. This negative correlation implies that the increased stem height and leaf: stem ratio, decreased the straw dry matter and organic matter true digestibility. The straw digestibility has tendency to increase with increasing grain yield, although the correlation was not significant.

DISCUSSION

The crude protein concentration was significantly increased with nitrogen fertilization level. The maximum crude protein obtained in the whole straw was 84.5 g kg^{-1}. The increased crude protein in rice straw due to nitrogen fertilization level has been reported by Roxas *et al.* (1985), Ibrahim *et al.* (1988), Bainton *et al.* (1991) and Drake *et al.* (2002). The maximum crude protein in this present study was higher than those reported by these researchers (53.0-69.6 g kg^{-1}, in the whole straw). The reason is probably due to higher level of nitrogen fertilizer (0, 120, 160, 200 and 240 kg N ha^{-1}) was applied in this present study compared to the previous study (0-120 kg N ha^{-1}) done by these researchers. The highest crude protein concentration was found in the leaf fraction and lowest crude protein in the stem fraction is in agreement with the findings reported by Sanasgala and Jayasuria (1984, 1986) and Vadiveloo and Phang (1996). Since rice straw is fed to the ruminants as a whole straw which comprises of both leaf and stem, the result shows that nitrogen fertilizer applied at rate above 160 kg N ha^{-1} is adequate to obtain the crude protein above 70 g kg^{-1} in the whole straw; which is the critical crude protein level required for voluntary feed intake in ruminants. The result recommends that it is worth while to apply higher rates of nitrogen fertilizer as it was found to improve the straw crude protein while at the same time producing high grain yield. The result of this study support earlier observation (Kernan *et al.*, 1984) that the straw feed value tended to be improved by increased nitrogen fertilizer application. The crude protein concentration in this present study was found to be higher than in chemically treated straw (26.0-62.0 g kg^{-1}) reported by Vadiveloo (1996).

The nitrogen fertilization level was shown to decrease the Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) in rice straw. The result of this study supports previous study in Illinois, that the NDF and ADF in rye straw were negatively correlated with nitrogen concentration (Ruffo and Bollero, 2003). Similarly, a study done in Florida also found that the NDF concentration was lower on limpograss pastures receiving 150 kg N ha^{-1} compared to those receiving 50 kg N ha^{-1} (Lima *et al.*, 1999). In addition, Chesson (1997) suggested that there is an inverse relationship between nitrogen concentration and cell wall thickness, which is estimated by NDF and ADF fraction. In contrast, a study in California found that the ADF content increased with nitrogen fertilizer application (Siskiyou County Cattlemen's Meeting, 2001). Roxas *et al.* (1985) reported that the straw NDF content was not affected by nitrogen fertilization level. The higher concentration of NDF and ADF in the leaf fraction compared with stem is similar to the report by Sannasgala and Jayasuria (1986). The NDF and ADF concentration in this present study were lower compared to the traditional Malaysian rice straw varieties reported by Devendra *et al.* (unpublished, Doyle *et al.*, 1986). This result is in agreement with earlier observations (Devasia *et al.*, 1976; Devendra, 1982; Roxas *et al.*, 1984; 1985) that straws from high yielding varieties produce better nutritive value than the traditional varieties. The higher NDF concentration in MR 219 was expected due to its longer maturation period since prolonged maturity time will increase the fiber content due to the depletion of soluble carbohydrates (Juliano, 1985). This observation is similar to a report by Roxas *et al.* (1985) who found that variety H4 which has the longest maturation period produced the highest cell wall content in comparing four varieties of rice straw.

The higher concentration of ADL (lignin) in variety MR 211 may be attributed to its agronomic characteristics as having short stem height. Similarly, previous study done by Vadiveloo (1992) in comparing four varieties of rice straw, it was shown that variety MR 84 which has the shortest plant height, produced the highest lignin concentration in the straw. Variety with short stem has high lodging resistance which is closely related to high distribution of lignin that strengthens the plant structure.

The leaf fraction had higher ADL (lignin) concentration; probably because the role of lignin which serve as a protection against the loss of water due to transpiration which occur in the leaf organ. However, from the perspective of straw nutritive value, the presence of lignin is regarded as a negative index for straw digestibility due to its nature that covalently bound to the carbohydrates, inhibiting the carbohydrate degradation by rumen microbes.

Both hemicellulose and cellulose concentration were not affected by the nitrogen fertilization level. Similar result was reported by Roxas *et al.* (1985) who found that the cellulose concentration was not affected by nitrogen level but there were varietal differences in the cellulose concentration. It was found that variety MR 219 had higher hemicellulose and cellulose concentration in the leaf fraction compared with variety MR 211. The higher concentration of hemicellulose and cellulose in variety MR 219 is probably due to its longer maturation period. This is because longer maturity period extends the duration of photosynthesis in which more carbohydrates will be produced. Varietal differences in hemicellulose and cellulose concentration of rice straw were also reported by Shen *et al.* (1998). The cellulose concentration was found to be higher in the stem fraction and similar result was also reported by Aman and Nordkvist (1983) in wheat and barley straw, Winugroho (1985) and Shen *et al.* (1998) in rice straw.

The ash and silica concentration were not affected by the nitrogen fertilization level. A similar observation was reported by Eriksson (1981) and Kernan *et al.* (1984) on the ash concentration and Roxas *et al.* (1985) and Siskiyou County Cattlemen's Meeting (2001) on the silica concentration due to nitrogen fertilizer application. Both ash and silica concentration were higher in the leaf fraction. During vegetative growth, silica is absorbed as monosilicic acid by the roots and reacts with O-phenol, precursor of lignin biosynthesis (Mengel and Kirby, 1987). The silica is then deposited in the xylem cell wall of vascular tubes and serves as a structural component. During ripening, most silica is transported in opaline form to the epidermal cells of leaf blade and sheath (Theander and Aman, 1984; Juliano, 1985; Mengel and Kirby, 1987; Van Soest, 1994) and this explained why the silica accumulation was higher in the leaf fraction compared to stem. Reports from Hu and Wang (1995), Vadiveloo and Phang (1996) and Summers *et al.* (2001) also found that the leaf fraction had higher ash and silica concentration. Silica has a negative effect on straw nutritive quality because it reduces straw digestibility and palatability (Van Soest, 1981). Smith *et al.* (1971) reported that for every increase of 1% silica concentration, the straw organic matter digestibility decreased by 0.98% where as Widyastuti and Abe (1989) reported that the increase of silica concentration by 1% decreased the organic matter digestibility by 0.83%. Variety MR 211, which has shorter maturity period, produced higher silica concentration compared with variety MR 219. This result is contrary to reports by Summers *et al.* (2001) who found that the silica concentration increases with maturity. Variety MR 211 which has shorter plant height is more lodging resistant and this characteristic may contribute to their higher silica concentration, since increases of silica in plant increases the resistance to lodging by imparting strength and support to the plant (Roxas *et al.*, 1984). Varietal differences in the silica concentration had been reported by several researchers (Roxas *et al.*, 1985; Deren *et al.*, 1994; Vadiveloo, 1996; Shen *et al.*, 1998; Summers *et al.*, 2001).

The nitrogen fertilization level did not affect the straw *in vitro* true dry matter digestibility (IVTDMD). However, the *in vitro* true organic matter digestibility (IVTOMD) was slightly decreased by 6%, due to increased nitrogen application from 0 to 240 kg N ha^{-1}. Although, the *in vitro* digestibility of true organic matter (IVTOMD) decreased a little, but the change was so small that it is of no practical importance. Nitrogen fertilizer had relatively less influence on digestibility, although it was thought that this improved the straw digestibility in view of the increased crude protein and decreased cell wall (NDF) and fiber (ADF) fraction in this present study. The reason why digestibility was not improved despite the increased crude protein and decreased cell wall and fiber fraction might be due to the presence of lignin and silica fraction which depressed the structural carbohydrate digestibility. Similar result was reported by Eriksson (1981) who found that the *in vitro* organic matter digestibility (IVOMD) in wheat straw decreased from 48 to 43%, due to nitrogen fertilization levels (0 to 240 kg N ha^{-1}) where as Bainton *et al.* (1991) found that the *in vitro* dry matter digestibility (IVDMD) in both semi-dwarf and tall rice straw decreased with nitrogen level (0, 90 kg N ha^{-1}). In contrast, Coxworth *et al.* (1981) reported that nitrogen fertilizer applied at 0, 56 and 224 kg N ha^{-1} increased the *in vitro* dry matter digestibility (IVOMD) in wheat straw from 36 to 38%. However, the effect on digestibility reported by Coxworth *et al.* (1981) was small. Reports from Roxas *et al.* (1985) and Ibrahim *et al.* (1988) found that the IVOMD was not affected by the nitrogen application.

The results from correlation between the agronomic characteristics (grain yield, stem height, maturity and leaf: stem ratio) and straw nutritive value (crude protein, NDF, ADF, IVTDMD and IVTOMD) suggests that rice varieties with good agronomic characteristics produced straw with

better nutritive value. The grain yield which was positively correlated with straw crude protein and digestibility and negatively correlated with NDF and ADF implies that high yielding rice varieties has potential to produce straw with improved crude protein and digestibility and low cell wall (NDF) and fiber (ADF) concentration. This result is supported by the reports from Devasia (1976) and Mohammed and Rai (1969) who found that the high yielding, modern rice varieties had higher crude protein and lower crude fiber compared to the local varieties. Good correlation between the agronomic characteristics and nutritive value was also reported by Soebarinoto *et al.* (1992) and Vadiveloo (2003). In contrast, several researchers reported poor correlation between the agronomic characteristics and straw nutritive value (Erickson *et al.*, 1982; Capper, 1988, Bainton *et al.*, 1991).

CONCLUSIONS

The finding of this study highlights the importance of fertilization management practices in improving the straw nutritive quality. It appears that as higher nitrogen rates are being applied to the rice plant, the better nutritive quality would be produced. In the current situation, farmers are applying nitrogen fertilizer at rates above the recommendation by the Malaysian Agriculture Research and Development Institute (MARDI), in efforts to maximize grain yield. The practice of applying high rates of nitrogen fertilizer not only produce rice with high grain yield, but was shown to improve the straw nutritive quality, particularly the crude protein. The nitrogen application above 160 kg N ha^{-1} was shown to produce straw with crude protein concentration above 70 g kg^{-1} and this is the optimum nitrogen level that could yield straw of adequate protein concentration for ruminant feed. Crude protein concentration in feed is one of the most important nutritive parameter in maintaining the animal's health. The crude protein concentration obtained in this present study is above the critical level required for animal maintenance. Rice straw is often regarded as poor quality feed due to the low protein concentration (average 40 g kg^{-1}), but in this present study, it was shown that the nutritive quality of rice straw was improved and this was achieved through application of high rates of nitrogen fertilizer to rice plant. The improved nutritive quality of straw is hoped to change the general attitude so that straws are regarded as a feed resource rather than a crop residue that needs to be disposed. Both high yielding varieties MR 211 and MR 219, which has been developed through careful selection and screening process, appeared to produce straw characteristics with improved nutritive quality in response to nitrogen fertilization level. However, in comparison between these two varieties, MR 219 variety is superior to MR 211 in view of the higher grain production and grain: straw ratio (harvest index). Rice growers and animal producers are interested in possibility of selecting rice varieties with high grain yield and good straw quality to improve whole crop utilization. Hence, the varietal differences in this study provide information for both rice growers and animal producers to select variety with high grain yield and at the same time having improved straw quality. The varietal differences in both agronomic characteristics and straw nutritive quality are believed to be influenced by environmental factor (fertilization management practice) and genetic (variety).

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