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APPLICATION OF DIFFERENT ORGANIC AND MINERAL FERTILIZERS ON THE GROWTH, YIELD AND NUTRIENT ACCUMULATION OF RICE IN A JAPANESE ORDINARY PADDY FIELD

*MYINT, A. K.[1], YAMAKAWA, T.[2], KAJIHARA, Y.[3] & ZENMYO, T.[1]

[1]Laboratory of Plant Nutrition, Division of Bioresource and Bioenvironmental Sciences, Graduate School, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan.

[2]Plant Nutrition Laboratory, Division of Soil Science and Plant Production, Department of Plant Resources, Faculty of Agriculture, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan.

[3]University Farm, School of Agriculture, Kyushu University, 111 Harumachi, Kasuya-machi, Kasuya-gun, Fukuoka 811-2037, Japan.
*niwincho@gmail.com

ABSTRACT

A rice cultivation study was conducted at Kyushu University farm. Cow manure (CM), poultry manure (PM), rice straw + urea mix-application (SU), urea (UF) and M-coat, a slow released compound fertilizer (M-coat) were used as the N sources by comparing with no application (Control). Treatments were made with two levels application of each N source at 40 (level I) and 80 kg N ha^{-1}(level II) excluding M-coat. In all urea treatments, three split applications were made. A study of soil incubation was conducted for 2 weeks to investigate the mineralized N of applied mineral and organic fertilizer. Plant growth characters, dry matter, yield and plant nutrient accumulations were higher in mineral fertilization than organic. Mineral fertilization was observed in correlation with the larger crop removal. PM-II as an organic matter provided comparatively higher nutrient accumulations which in turn enhanced the growth and yield of rice. CM and SU gave the lower plant growth, yield and nutrient accumulation. Mineralized N was higher in sole mineral N applications. Organic matter with high C/N ratio provided very low mineralized N and its net N mineralization percentage. Negative values of net N mineralization percentage were observed in SU due to N immobilization.

Keywords: Cow Manure, Mineralized N, Paddy Soil, Poultry Manure, Rice (*Oryza sativa* L.), Rice Straw

INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important staple food for more than two billion people in Asia and hundreds of millions in Africa and Latin America (Ladha *et al*., 1997). Within Southeast Asia, rice provides about 60% of the human food consumption. About 55% of the Asian rice is produced in irrigated areas, which accounts for about 75% of Asia's total rice production with an estimated 2.2 billion Asian rice farmers and consumers depending upon the sustainable productivity of the irrigated lowland rice ecosystem for their food supply (Buresh *et al*., 2005).

Paddy soil system favors fertility maintenance and build-up of organic matter in soils, and is the backbone of long-term sustainability of the wetland rice systems (Sahrawat, 2004). Nitrogen (N) status of soils was sustained by maintaining equilibrium between N loss of crop harvest and N gain from biological N fixation in primary rice farming of the pre-chemical period (Ladha & Peoples, 1995). However, in current intensive rice monocropping systems, this equilibrium has been disturbed with inputs of mineral fertilizers now playing a significant role (Ladha *et al*., 2000). The application of chemical fertilizers is costly and gradually lead to the environmental problems. Organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Now-a-days, agriculture production based on organic applications is growing in interest and the demands for the resulting products are increasing. Therefore, the effective use of organic materials in rice farming is also likely to be promoted.

The application of organic materials is fundamentally important in that they supply various kinds of plant nutrients including micronutrients, improve soil physical and chemical properties and hence nutrient holding and buffering capacity, and consequently enhance microbial activities (Suzuki, 1997). In addition, organic matter continuously releases N as plant need it. N is the most limiting nutrient in irrigated rice systems, but P and K deficiencies are also the constraints increasing yield for consecutive planting of rice. Therefore, use of livestock wastes in agricultural soils has been an increasing interest due to the possibility of recycling valuable components such as organic matter, N, P and K. An advantage of farm application of organic wastes is that they usually provide a number of nutritive elements to crops with little added cost.

Many researchers including Ohyama *et al*., (1998), Uenosono & Nagatomo (1998) reported that the effects of organic matter application can be observed after 3 to 5 years. Though long-term studies are confidential and could tell a story, alternative use of organic matter in short term can provide information for the farmers who are willing to start making right choice and to refer to this as a management procedure and application amount.

Current fertilizer recommendations in Asia typically consist of blanket recommendations with fixed rates and timings for large rice-growing areas. However, considerable progress has been made in recent years in developing field and season-specific nutrient management approaches (Witt *et al*., 2002; Dobermann *et al*., 2003; Buresh & Witt, 2008). The increase in yield per unit of applied N decreases with increasing N. Recently, farmers profit maximization with proper management practices to improve indigenous soil N supply, reduce amount of applied fertilizer without yield loss and use of organic manures in conjunction with mineral fertilizer is in consideration (Khan *et al*., 2004; Antil & Singh, 2007; Buresh & Witt, 2008).

Mineralized N or ammonium released under anaerobic incubation is significantly correlated with soil organic matter; however, both quality and quantity of organic matter clearly affect N mineralization in wetland rice soils (Sahrawat, 2006). The greater part of N in paddy soil exists in soil organic matter. This tends to be conserved more in paddy soils than in upland soils, because of the anaerobic conditions. Microbial decomposition of the organic matter gradually releases ammonium N (NH_4-N). As NH_4-N is stable under anaerobic conditions, it is retained as a cation on negatively charged soil mineral and organic particles, until the time when rice roots take it up. And the rice plant acquires half to two-thirds of its N requirement from the soil mineralizable N pool even in a well-fertilized paddy (IAEA 1978). Lian (1994) suggested that the estimation of N mineralization from the manure during a cropping season is important for the adjustment of the requirement of chemical fertilizer to be applied in combination with the manure.

The rice (*Oryza sativa* L.) used in this study was the Manawthuka variety, which is very popular among Myanmar farmers for its high yield potential and wide adaptability. However, there is little available research and information related to Manawthuka. Therefore, one of the objectives of this work was to provide useful information to Myanmar farmers, at least on crop response to manure and fertilizer application. Extended research is needed at different locations in Myanmar. The rice seeds for this study were produced in a pot experiment in Kyushu University, Fukuoka, Japan (Myint *et al*., 2009) after examining their suitability and optimal growth in Japanese environment. This study was carried out to investigate the dry matter, yield and nutrient accumulations of Manawthuka rice, and to study soil N mineralization and availability as applied to the soil for different N sources.

MATERIALS AND METHODS

Site description: The field experiment was conducted in 2008 at Kyushu University Farm in Fukuoka Prefecture, Japan (33°37'N, 130°25'E). The soil (clay loam) is under yearly rice cultivation and its physicochemical properties are shown in Table 1. Nutrient content of the soil was determined by H_2SO_4-salicylic acid-H_2O_2 digestion (Ohyama *et al*., 1991) followed by the indophenol method (Cataldo *et al*., 1974) for total N; ascorbic acid method (Murphy & Riley, 1962) for total phosphorus (P); and atomic absorption spectrophotometry (Z-5300, Hitachi, Tokyo, Japan) for total potassium (K). Total carbon (C) and hydrogen (H) content were determined using a CHN corder analyzer (MT-5, Yanaco, Kyoto, Japan). Cation exchangeable capacity (CEC) was determined by the ammonium acetate shaking extraction method (Muramoto *et al*., 1992). For yearly rice production, mineral fertilizer application is generally carried out using M-coat, an S100H-polymer-coated slow-release compound fertilizer (10-7-7% of N-P_2O_5-K_2O) (JA Kasuya Co., Fukuoka, Japan) at the rate of 730 kg ha^{-1}.

Treatments and experimental design: In June 2008, 1.2×5-m plots were made by inserting the plastic frames into the subsoil layer (about 15 cm underground) in a large paddy field. Cow manure (CM), poultry manure (PM), rice straw + urea mix-application at a total N ratio of 1:1 (SU), urea (UF) and M-coat fertilizer (M-coat) were used as the organic and mineral nitrogen fertilizers by comparing with no application (Control). The selected chemical properties of organic matter (total N, P, K, C and H content) were determined using the methods described above (Table 1). Treatments were conducted at two levels at the rate of 40 kg N ha^{-1} (level I) and 80 kg N ha^{-1} (level II) excluding for M-coat. M-coat was applied at the rate of 730 kg ha^{-1} (73 kg N ha^{-1}) as basal. In SU, raw material of rice straw was used after cutting into pieces 3-5 cm. In all plots using urea fertilizer, split-application was made three times as the basal application, at active tillering (40 days after transplantation; DAT) and at panicle initiation (77 DAT). Rice straws were incorporated at 18 days before transplantation followed by irrigation. The other fertilizers and manures (including urea for SU) were applied 3 days before transplantation followed by hand mixing using a fork hoe.

TABLE 1. SELECTED PHYSICOCHEMICAL PROPERTIES OF SOIL AND ORGANIC MATERIALS.

	N(%)	P(%)	K(%)	H(%)	C(%)	C/N ratio	pH $_{H2O}$	BD (g cm^{-3})	CEC (cmol kg^{-1})
Soil	0.15	0.12	1.11	0.86	2.0	-	5.73	1.16	12.11
CM	1.04	0.78	3.78	4.02	31.87	31	-	-	-
PM	2.76	4.80	10.14	3.32	22.92	8	-	-	-
RS	0.61	0.12	3.56	5.48	36.56	60	-	-	-

Note: CM = cow manure; PM = poultry manure; RS = rice straw; BD = bulk density; CEC = cation exchangeable capacity.

Randomized complete block design was used with three replications. Rice seedlings (Manawthuka variety) were prepared using commercial seedbed soil (Kokuryu Baido, Seisin Sangyo Co., Kitakyushu, Japan). Irrigation was conducted as a common management together with surrounding area. Intermittent drainage was conducted from the middle of July to the first week of August.

Plant growth characteristics: Plant growth characteristics (soil and plant analysis development (SPAD) value, tiller number and plant height) were recorded weekly in fast-growing stage and at 2 weeks interval afterwards. SPAD value was measured using a chlorophyll meter (SPAD-502, Konica Minolta Sensing Inc., Osaka, Japan). The uppermost fully expanded leaf was used to measure the SPAD value before the panicle initiation stage and the flag leaf after that.

Dry matter weight, yield investigation and nutrient accumulation in plant: At crop maturity (126 DAT), aboveground portions (cut 2-3 cm aboveground) of 10 hills from each treatment plot were harvested, oven-dried at 70°C for 48 hr and investigation were carried out on the dry matter weight, seed yield and yield parameters. Harvest index was calculated as the ratio of economic yield (seed weight) to biological yield (total dry matter weight) (Yoshida, 1981). Major nutrient content in each portion of rice plant was determined by H_2O_2-H_2SO_4 digestion (Ohyama *et al*., 1991) followed by indophenol method (Cataldo *et al*., 1974) for N, ascorbic acid method (Murphy and Riley, 1962) for P and atomic absorption spectrophotometer for K, Ca and Mg.

Soil incubation experiment: Mineralized N in soil applied with manures and fertilizers was investigated using a soil incubation study (Sahrawat, 1983b). Twenty gram of air-dried soil was placed in a 500-mL incubation bottle and treated with manures and fertilizers at the same application rate with field experiment. Fifty milliliter of deionized water was added to give a standing water layer of 2-3 cm above soil surface. Trapped air in the soil was carefully removed using a suction pump on the mouth of the bottle. Subsequently, the bottle was closed tightly with rubber stopper and incubated at 30°C for 2 weeks. Ammonium N (NH_4-N) in incubated soil was extracted by shaking with 100 mL of 2 M KCl and filtered through No. 5B filter paper (Advantec, Toyo Ltd., Japan). The NH_4-N in extract was determined by using indophenol method (Cataldo *et al*., 1974). Net N mineralization percentage was calculated as a proportion of difference in released NH_4-N between application and Control to total applied N.

Statistical analysis: Analysis of variance (ANOVA) was used to test significance and Tukey-Kramer HSD (honestly significant difference) test used to calculate the least significant difference (LSD) at 5% probability level using JMP software (JMP IN, Version 5.0.1 a, SAS Institute Inc., Cary, NC, USA).

RESULTS

Plant Growth Characters: Plant growth characters were higher in organic and mineral fertilizer application throughout the growing season than control except SU. Higher SPAD values were obtained in M-coat, UF and PM-II compared to other treatments (Fig. 1). Generally, SPAD value was highest at the beginning of cultivation season (25 DAT) in every treatment including Control but decrease afterwards. Severe decrease was observed in SU at about 40 DAT. During the vegetative growth stage form about 40 to 75 DAT, SPAD value was moderately stable at about 30 to 35. Temporary increase of SPAD values were observed at about 90 DAT in every treatment.

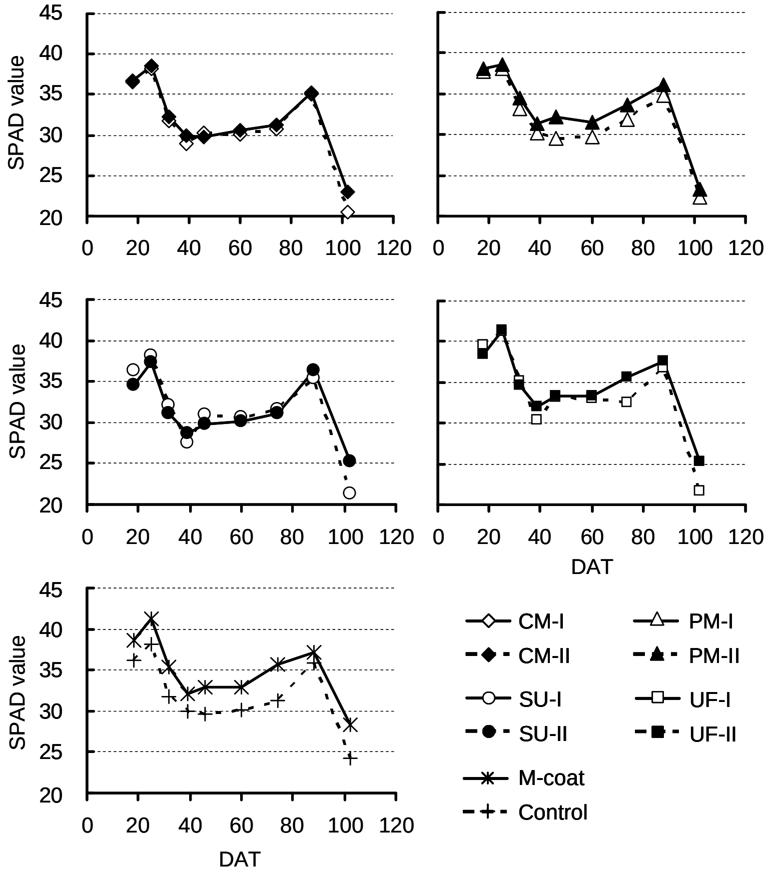


FIG. 1. EFFECTS OF DIFFERENT ORGANIC AND MINERAL FERTILIZATION ON SPAD VALUE OF RICE IN FIELD CULTIVATION

Tiller numbers drastically increased in all treatments at the beginning of the cultivation season with higher value, but lower in SU compared to Control (Fig. 2). Afterwards, tiller numbers in all treatments decreased due to tiller death. In the reproductive stage, high tiller numbers were obtained in M-coat, UF and PM while lowest was in the Control. Moreover, plant height (data not shown) corresponded to treatment's effect as same with SPAD value and tiller number especially higher in M-coat, UF and PM.

Dry matter weight and yield parameters: Higher dry matter weights (both for straw and panicle) and grain yield were obtained in all organic and mineral fertilization compared to Control excluding CM-I (Table 2, Fig. 3). Dry matter and grain yield in M-coat was the highest in amount (about 34% higher than Control), but did not statistically differ from UF-II, UF-I and PM-II ($P<0.05$). In organic manure applications, PM gave higher dry matter weights than CM application. Highest level application for each treatment gave the highest dry matter accumulation except in SU where SU-II is 3.8% lower than SU-I (Table 2). Both levels of SU provided the lower grain yield compared to other treatments. UF-II, UF-I and PM-II gave the highest grain yield and those were 28, 22 and 22% higher than Control, respectively (Fig. 3). Among yield parameters, panicle number per hill was directly related to effective tiller number and significantly higher in M-coat ($P<0.05$), whereas the lowest in CM-I.

Nutrient accumulation in plant: Macronutrient accumulations were significantly higher in M-coat among the treatments especially for N, P and Mg ($P<0.05$) (Table 3). There was no significant difference among the treatment in plant Ca accumulation. The amounts of macronutrient accumulation were high in higher levels of application except SU, in which lower accumulation was observed in SU-II. N accumulation was the highest in M-coat application (79% higher than control). In UF-II, N accumulation was only 55% higher than control, however the applied N was larger than M-coat. Macronutrient accumulations were comparatively higher in PM-II and CM-II than other organic matter application.

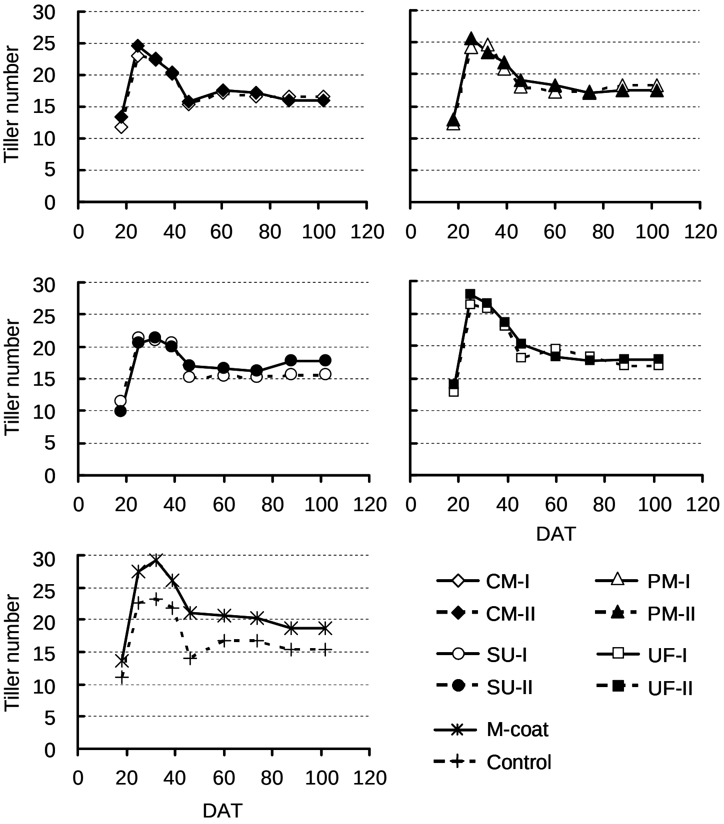
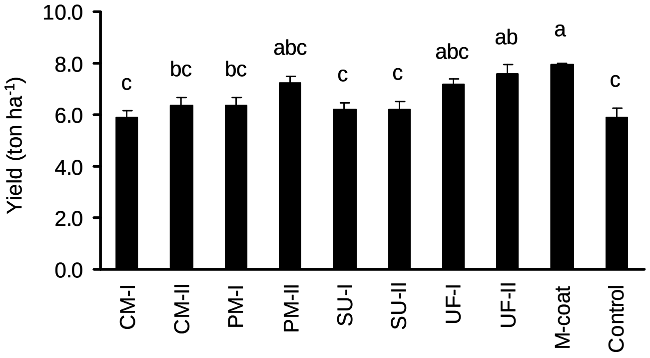


FIG. 2. EFFECTS OF DIFFERENT ORGANIC AND MINERAL FERTILIZATION ON TILLER NUMBER OF RICE IN FIELD CULTIVATION

TABLE 2. YIELD PARAMETERS IN RICE PRODUCTION BY DIFFERENT ORGANIC AND MINERAL FERTILIZATION.

	Dry matter (ton ha^{-1})		Harvest index	Filled grain percentage	TGW (g)	Panicle number hill^{-1}	Seed number panicle^{-1}
	Panicle	Straw					
CM-I	5.19c	5.04cd	0.51ab	71.7	16.2	15.5b	124
CM-II	5.59bc	5.72bcd	0.49ab	77.6	16.0	16.3ab	119
PM-I	5.59bc	5.56bcd	0.50ab	77.1	15.8	16.6ab	125
PM-II	6.33abc	6.39abc	0.50ab	78.2	16.5	16.6ab	124
SU-I	5.44c	5.28bcd	0.51ab	73.1	16.3	16.0ab	124
SU-II	5.45c	5.08cd	0.52a	75.9	16.5	16.2ab	114
UF-I	6.32abc	6.43abc	0.50ab	73.0	16.3	17.6ab	127
UF-II	6.65ab	6.63ab	0.50ab	74.5	15.9	18.1ab	135
M-coat	6.96a	7.34a	0.49b	77.0	15.8	18.9a	131
Control	5.19c	4.79d	0.52a	74.2	16.2	15.9ab	117

Note: TGW = thousand grain weight
Means followed by same letter in each column are not significantly different ($p < 0.05$).



Histograms with the same letter are not significantly different (p<0.05).
Bar on each symbol indicates standard error

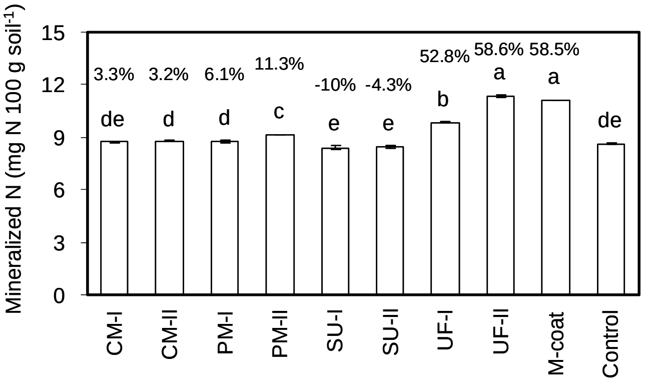
FIG. 3. EFFECTS OF DIFFERENT ORGANIC AND MINERAL FERTILIZERS ON RICE YIELD

TABLE 3. MAJOR NUTRIENT ACCUMULATION IN RICE BY DIFFERENT ORGANIC AND MINERAL FERTILIZATION.

	Nutrient accumulation in rice (kg ha^{-1})				
	N	P	K	Ca	Mg
CM-I	61.7c	6.75c	100b	3.22	7.76b
CM-II	70.3bc	8.28bc	130ab	2.48	9.46b
PM-I	66.9c	7.87bc	121ab	2.24	8.32b
PM-II	79.3bc	8.26bc	140ab	2.72	9.40b
SU-I	67.1c	7.83bc	122ab	2.33	7.89b
SU-II	63.0c	7.35c	115ab	2.71	7.83b
UF-I	83.1bc	8.61bc	124ab	3.42	9.68b
UF-II	97.9ab	10.42ab	136ab	3.69	11.99a
M-coat	113.3a	11.62a	150a	4.11	13.54a
Control	63.2c	6.83c	102b	2.81	7.69b

Means followed by same letter in each column are not significantly ($p < 0.05$).

Mineralized N: Mineralized N was significantly higher in soil with mineral fertilizer than organic applications (P<0.05) (Fig. 4). Except for CM and SU, higher level application gave higher mineralized N. In SU, mineralized N were lower than Control, however large amount of N with both organic and mineral source were applied. PM-II provided significantly high mineralized N among organic fertilization treatments. The net N mineralization percentages of applied mineral and organic fertilizer corresponded in line with mineralized N. The net N mineralization percentage was the highest in UF-II (58.6%) followed by M-coat (58.5%) while negative values were observed in SU (-10 to -4.3%).



Values on each histogram represent the net N mineralization % of respective treatments.
Histograms with same letter are not significantly different (p<0.05).
Bar on each symbol indicate standard error

FIG. 4. EFFECTS OF DIFFERENT ORGANIC AND MINERAL FERTILIZERS ON MINERALIZED N CONTENT IN ANAEROBIC SOIL INCUBATION

DISCUSSION

Plant growth and yield: Growth characters of the plant represent the real-time nutritional status of soil and the results may provide the information on future crop nutrient management. SPAD value and tiller number were different characters, however, they showed similar expression response to soil nutritional status (Figs. 1-2). The SPAD value, the most important plant growth character, was highly correlated with leaf N and chlorophyll content of the paddy rice. Takebe & Yoneyama (1989) reported that paddy rice plants do not contain any significant amount of nitrate (differ from upland crops) and therefore, their N status can be easily determined by SPAD value.

In Manawthuka variety, very high SPAD values were observed at tillering period in all treatments including control. At active tillering stage (30 DAT), a decrease of SPAD value was observed. The decrease was severe in control, SU, CM and PM-I and might be due to the shortage of available nutrients (especially N) in soil since the nutrients in inorganic forms and decomposable organic matters had been decreased by plant uptake. In contrast, higher SPAD value was observed in PM-II due to higher decomposable nutrient content. Increase in SPAD was observed in SU and UF treatments after 40 DAT which could be the effect of urea split applications. Peng *et al*., (1996) focused on determination of SPAD value that farmers could refer to in the field and suggested the use of 35 as a critical SPAD value for an International Rice Research Institute's high yielding cultivar (IR72) and recommended a top-dressing of 30 kg N ha^{-1} whenever SPAD value fall below this number. In the present study, the SPAD values in all treatments were lower than 35 during mid-growing season. In that period, rice plant might need further N application especially in CM, SU and PM-I. However more systematic investigations will be necessary to determine the threshold value for Manawthuka rice.

During the flowering stage, temporary increase of SPAD value was observed in all treatments which could assumed to be a varietal characteristic rather than soil fertility. Moreover, increase in SPAD value of flag leaf during the flowering period was reported in pot experiments with different levels and kinds of manure and fertilizer application using Manawthuka variety (Myint *et al*., 2009) and in field studies using several indica varieties (Turner & Jund, 1994; Peng *et al*., 1998; Hussain *et al*., 2000).

Myint *et al*. (2009) reported that rice yield and N availability of low fertility soil increased within three years of continuous organic manure application. However, it may depend on the kind and amount of organic matter used. Growth characteristics (SPAD value and tiller number), dry matter and yield were lower in SU, it suggesting that the limited N nutrition was due to N immobilization (Figs. 1-3 & Table 2). However, they are still larger in SU than control and that might be due to nutrient availability from urea split applications. Excellent effect of split application on plant uptake was due to supplying the nutrient to plant when the root system was well developed (Savant & DeDatta, 1982).

Plant nutrient accumulation: Understanding of nutrient removal by a crop may provide the important information for the soil fertility management by comparing the plant total accumulation to application from all sources. In low level applications (for example, application of 40 kg N ha^{-1} in CM-I, PM-I, SU-I and UF-I), plant accumulations were higher than applied amount, suggesting that the N amount from application was lower than crop needs (Table 3). Consecutively, it may lead to soil fertility declining in succeeding season due to inadequate nutrition. UF-II and M-coat revealed higher plant growth, yield and nutrient accumulation. However, use of UF-II in long term may lead to soil fertility degradation due to the very high plant removal. On the other hand, N accumulation was not higher than applied N in high level organic application, such as CM-II and PM-II. Moreover, comparatively higher yield was obtained in PM-II (Table 2). It is indicating that using of PM-II in rice production may increase soil fertility in long-term with optimal rice yield.

Organic materials supply various kinds of plant nutrients including micronutrients (Suzuki, 1997). In our study, macronutrients such as N, P, K, Ca and Mg were significantly different among the treatments except in Ca (Table 3). Dobermann *et al.* (1998) stated that the demand of the rice plant for other macronutrients mainly depends on the N supply. In the same way, higher plant macronutrient accumulation was observed in higher N level in all treatments of our study.

Plant Ca accumulation was small and not significantly different among the treatments and might be due to the soil selectivity of K which came from the manure and fertilizer application. With addition of K to soil, Yang & Skogley (1990) observed decrease in the soil selectivity coefficient for K-Ca ($K_{K/Ca}$) because K fills soil exchangeable sites and replaces Ca. They explained that the greater predominance of K^+ with increased application rate of K-rich nutrients would be expected to replace more Ca^{2+} from the soil exchange sites, leading to its movement down the soil profile.

N mineralization in soil: The mineralization of organic nitrogen or ammonium production is the key process for the N nutrition of wetland rice because N mineralization stops at ammonium production and nitrification is at low ebb in submerged soils (Sahrawat, 2006). Waring & Bremner (1964) reported that mineralizable N is the ammonium nitrogen produced in soil during the anaerobic incubation and can be used as an index of N availability. In this study, mineralized N was higher in M-coat and UF indicating that it was directly related to N application when mineral N sources were used (Fig. 4). In contrast, mineralized N in SU treatments, in which both organic and chemical N were applied, were lower than Control. Relatively higher urea-N was applied in SU-II (double of SU-I), but the mineralized N was not significantly different between levels of SU treatments. In SU mixed application, N availability was lower than Control and it indicate that the N immobilization occurred due to higher C content of rice straw. This was confirmed by the results in net N mineralization percentage with negative values in SU treatments (Fig. 4).

Moderately higher correlation between mineralized N and plant N accumulation was observed (Fig. 5). Higher mineralized N in M-coat and UF treatments gave the highest dry matter. In manure applications, comparatively lower mineralized N was observed in PM treatments. However, higher dry matter accumulation was obtained in PM-II (Table 2). It suggests that PM-II in the field condition might provide the larger amount of available N and other essential nutrients. In contrast, both levels of CM application provided low mineralized N and plant N accumulation. Organic matter applications endorse the increasing of organic C in soil. Sahrawat (1983a) reported that organic C or total N significantly correlated with mineralizable N, which in turn enhanced N uptake and yield of rice crop. In our study, less direct correlation between applied total N and N uptake or crop yield was observed for CM and SU treatments due to the high content of undecomposed organic matter. Further studies will be necessary to investigate the organic matter application related to organic C content and mineralized N of the soil.

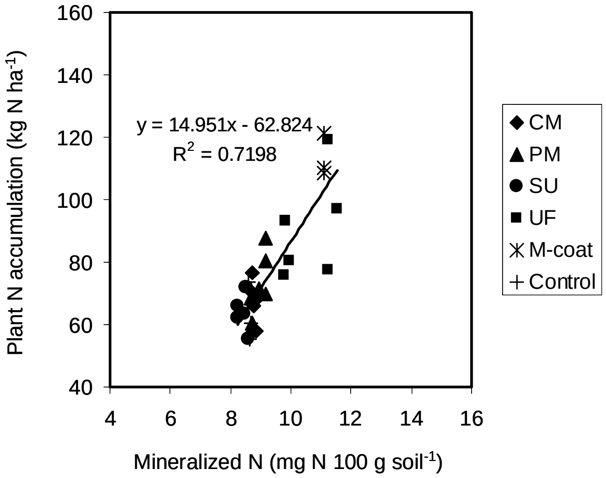


FIG. 5. LINEAR CORRELATION BETWEEN MINERALIZED N IN INCUBATION STUDY AND THE PLANT N ACCUMULATION OF RICE IN FIELD STUDY

Organic fertilization in wetland rice: Now-a-days, organic farming and agricultural production using several organic materials as the alternatives for mineral fertilizer are interests in progress. However it still associates with the low crop production. Many studies proved the superiority of different kind of organic materials in agriculture with the purposes of environmental sustainability. On the other hand, many researchers investigated to produce chemical fertilizer with environmentally least impact, such as slow-release, pelletized or coated fertilizers ensuring to reduce losses and pollution. However, such kinds of fertilizers are commonly related to high technology and high price. Therefore, they are still away from the ordinary farmers in the developing countries. Green manuring is one promising alternatives because of its very high N fixation ability and suitable for many tropical countries. However, its major problems in the tropics are lack of irrigation water and time needed for cultivation of green manure in some rice growing areas.

Application of plant waste, farmyard manure, barnyard manure, municipal wastes etc. were also advanced in interest. Among them, animal waste manures are rich in nutrients including micronutrients, readily available and commonly used by farmer around the world. Combination of organic matter with mineral N fertilizer is recently paid attention in many rice growing areas of Asia. Khan *et al*., (2004) and Antil & Singh (2007) reported that organic and mineral conjunctive application was highly beneficial for wetland rice cultivation. Therefore, rice growth and yield of CM application may be improved with partial substitution of mineral fertilizer as urea. However, SU mix-application showed N immobilization and led to the poor growth, yield and N availability although urea was used as split application in our study. Suzuki (1997) stated that organic materials with a high C/N ratio are likely to compete with crops for N, which can lead to N deficiency in extreme cases. Moreover, added or soil organic matter accumulated in submerged soils and enhanced slower, incomplete, and inefficient decomposition (Sahrawat, 2006). It is necessary to make compost or lower the C/N ratio for CM and rice straw before using. Therefore, in the case of wetland rice cultivation, using of well-decomposed or low-C/N-ratio organic matter (such as PM) is preferable.

As our results, mineral fertilization gave the highest plant growth and nutrient uptake in one-season cultivation compared to organic fertilizers. However, use of PM-II as organic fertilizer provided the optimal yield and can be adjudged to be environmentally saved. To get the superiority of the PM applications, long term practice may be necessary. Use of CM and SU provided comparatively low yield and nutrient accumulation and further systematic investigation will be necessary to determine the optimal amount and management strategies. Reliable prediction of mineralized N and net N mineralization of organic matters in wetland soils would help in an efficient and judicious use of mineral N. An understanding of the relationship between added or soil organic matter and mineralized N or soil N availability is needed. For this object, further investigation will be necessary.

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