The Agriculturists 19(1&2):47-62(2021) **ISSN 2304-7321 (Online), ISSN 1729-5211 (Print)**
A Scientific Journal of Krishi Foundation *Indexed Journal*

Effect of Fertilizer and Manure on Nutrient Availability, Accumulation and Yields of Boro Rice under Madhupur Tract and Young Brahmaputra-Jamuna Floodplain

Md. Asaduzzaman Khan* and Syeda Sumaya Sultana

Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh

**Corresponding author and Email: makhan@sau.edu.bd*

Received: 16 August 2021 Accepted: 20 December 2021

Abstract

The experiment was conducted in a net house of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of soils and fertilizer application on soil nutrient availability, accumulation and rice yield. The experiment consists of 2 factors i.e. soils and fertilizer plus manure. Two soils (S_1= SAU Soil, S_2= Singair Soil) and 5 levels of fertilizer (T_0: Control, T_1: 100% NPKSZn @ 120-25-60-20-2 kg/ha (Recommended dose of chemical fertilizer, RDCF), T_2: 50% RDCF + 5 ton cowdung ha^{-1}, T_3: 50% RDCF + 5 ton compost ha^{-1}, T_4: 50% RDCF + 3.5 ton poultry manure ha^{-1}) were used for Boro rice cultivation. SAU soil showed better performance than Singair soil. The highest grain and straw yield of (94.22 g pot^{-1}) and (85.2 g pot^{-1}) were obtained from T_1 treatment. The S_1T_4 showed the highest yield (97.4 g pot^{-1}) which was statistically similar to S_1T_2 and S_1T_3 treatment combinations. Pore-water N, P, K and S concentrations were varied significantly with soils and fertilizer treatments. The pore-water P and K concentration decreased with increasing days after transplantation of rice. A positive correlation was found among yield, grain nutrient concentrations and pore-water nutrient concentrations. The higher pore-water N concentrations were found in SAU soil compared to Singair soil. Higher pore water P and K concentrations were found in Singair soil compared to SAU soil. Higher grain and straw N, K and S concentrations were found in the S_1T_4 or S_2T_4 treatment combinations where higher pore-water N, K concentrations and yields were found.

Keywords: Fertilizer; manure; nutrient availability; rice nutrient accumulation; rice yield soils

1. Introduction

Rice (*Oryza sativa* L.) is the staple food for the people of Bangladesh and will continue to remain so in future. Rice production systems make a vital contribution to the reduction of hunger and poverty in Bangladesh. The country needs substantial increase in rice production to provide her teeming millions with food and other basic needs of life. There are not many options but to raise level of rice production from the limited land resources and diverse climatic conditions for improving the living standard of her common people. The depleted soil fertility is a major constraint to intensive crop production in Bangladesh. The increasing land use intensity has resulted in a great exhaustion of nutrients in soils. In Bangladesh, most of the cultivated soils have less than 1.5% organic matter while a good agricultural soil should contain at least 2%

organic matter. Moreover, this important component of soil is declining with time due to intensive cropping and use of imbalance chemical fertilizers with little or no addition of organic manure in the farmer's field. Rice-rice system is the most dominant cropping system in Bangladesh. Continuous cultivation of this highly exhaustive cropping sequence in most of the irrigated fertile lands has resulted in the decline of soil physico-chemical properties in general and particularly soil organic matter (SOM) content. This has led to a reduction in the total factor productivity and raised questions on the sustainability of this cropping system.

It will, therefore, be necessary to place greater emphasis on strategic research to increase the efficiency of applied nutrients through integration with organic manures, which will help in accomplishing twin objectives of sustaining soil health and ensuring food security and environmental protection. Application of manure and fertilizer affects the nutrient availability in soil. The bioavailability and uptake of nutrients in soil are dependent on a number of factors including the source and concentration of the nutrient, soil properties such as clay content, pH, ions and type and amount of organic matter. The availability of N, P, K and S in soil as well as its uptake by plants is governed by the difference of soil and the variation of added fertilizer. Yang *et al*. (2004) reported that application of chemical fertilizers with farmyard manure increased N, P and K uptake by rice plants and increased 1000 grain weight and grain yield of rice. The application of manure or chemical fertilizer alone in paddy soil may affect the availability of nutrient in pore-water and accumulation of nutrient in rice plant. Availability of nutrient in soil pore-water is still imperfectly understood. The pore-water nutrient concentrations were studied in this experiment with different fertilizer and manure application.

Anaerobic conditions in paddy soil lead to mobilization of some nutrients and thus affect nutrients bio availability to rice plants. To increase the efficiency of manure and fertilizer in rice cultivation, it is necessary to identify the suitable level and type of manure and fertilizer. The determination of nutrient availability in the pore-water is a new idea of research. Soil is a heterogeneous system, it is important to carry out studies to understand the soil nutrient availability and plant accumulation of applied fertilizers in soil-water-plant system.

Considering the present situation the present study was undertaken with the following objectives:

i. To investigate the availability of N, P, K and S in pore water with different fertilizer management systems;
ii. To evaluate the effect of soil, fertilizer and manure on the yield of Boro rice; and
iii. To investigate the correlation of pore-water nutrient, yield and rice plant nutrient accumulation.

2. Materials and Methods

The experiment was conducted at a net house, Sher-e-Bangla Agricultural University during November 2012 to May 2013 to study the effects of soils, fertilizer and manure on nutrients availability, nutrient accumulation and rice yield. The climate of the experimental area is characterized by a scanty rainfall associated with moderately low temperature in the *rabi* season (October-March). Two different soils were collected from different AEZ by considering the difference of soil texture, pH and organic matter. A total of 30 earthen pots were used (2 soils x 5 fertilizer levels x 3 replications) altogether and 14 kg soil was taken in each earthen pot. Some physicochemical properties of initial soils (0-15 cm) of SAU and Singair were shown in Table 1.

2.1 Experimental design and treatments

The experiment consists of 2 factors i.e., soil and fertilizer, manure. Two soil treatments (S_1= SAU soil, S_2 = Singair soil and five fertilizer treatments (T_0: Control, T_1: $N_{120kg/ha}$ $P_{25kg/ha}K_{60kg/ha}S_{20kg/ha}Zn_{2kg/ha}$ (Recommended dose of chemical fertilizer, RDCF), T_2: 50% RDCF + 5 ton cowdung ha^{-1}, T_3: 50% RDCF + 5 ton compost ha^{-1}, T_4: 50% RDCF + 3.5 ton poultry manure ha^{-1}. The experimental design was a Randomized complete block design and three replications. The distance maintained between pot to pot and row to row were 40 cm and 1 m, respectively. The fertilizer and manure treatments were applied in the soils of the earthen pots based on Bangladesh Agricultural Research Council (BARC) fertilizer recommendation guide, 2012. The treatment-wise required amounts of manures and N, P, K, S and Zn fertilizers per pot were applied by considering the soil weight.

There were 1.46% N, 0.29% P, 0.74% K, 0.24% S in cowdung; 2.2% N, 1.99% P, 0.82% K in poultry manure and 1.49% N, 0.28% P, 1.60% K in water hyacinth compost. The whole triple super phosphate, muriate of potash, gypsum, zinc sulphate and one third of urea were applied during final pot soil preparation as a source of P, K, S, Zn and N, respectively. The remaining one third urea was applied at 30 days after transplanting (DAT) and last one third was applied at 55 DAT. The fertilizer and manures were mixed in the pot soils. Forty days old BRRI dhan29 seedlings were carefully uprooted from the seedling nursery and transplanted on 2nd week of December, 2012. Two seedlings for one hill (BRRI dhan29) were transplanted in each earthen pot. After one week of transplanting all earthen pots were checked for any missing seedlings, which were filled up with extra seedlings whenever required. Traditional irrigation (2-3 cm continuous flooding) was applied on the soils of the pot as and when required during the growing period of Boro rice crop. Pore-water was collected by using rhizon sampler (Rhizon MOM 10 cm length, 2.5 mm OD, Rhizosphere Research Products, Wageningen, and The Netherlands). It was buried diagonally in the middle of the soil of each pot and soil pore-water samples were collected during Boro rice growing period at 30, 40 and 60 DAT of rice seedlings and analyzed for N, P, K and S concentrations following standard methods. After harvest of boro rice, the plant height, panicle length, tillers hill^{-1}, number of filled grains panicle^{-1}, 1000 grain weight, grain and straw yields were recorded.

2.2 Soil and pore-water analysis

Soil pH was measured by glass electrode pH meter using soil-water ratio 1:2.5 (McLean, 1982). Organic matter content was estimated by wet oxidation method (Walkley and Black, 1975). The total N concentrations in soil and pore-water samples were determined by micro-Kjeldahl method (Bremner and Mulvaney, 1982). The P (Olsen and Sommers, 1982) and K (Page *et al*. 1982) of soil, pore-water were determined by using spectrophotometer and flame photometer, respectively. S concentrations in pore water samples were determined by turbidimetrically at 420 nm wavelength described by (Page *et al*. 1982).

Table 1. Some physicochemical properties of initial soils (0-15 cm) of SAU and Singair

Characteristics	**SAU Soil**	**Singair Soil**
Agroecological Zones	Madhupur Tract (AEZ 28)	Young Brahmaputra and Jamuna Floodplain(AEZ 8)
Textural class	Silt loam	Clay loam
pH	6.4	6.5
Organic matter (%)	1.12	2.12
Total N (%)	0.08	0.12
Available P (mg kg^{-1})	8.6	5.72
Exchangeable K (meq. 100g^{-1})	0.05	0.08
Available S (mg kg^{-1})	10.5	15.2

2.3 Chemical analysis of plant samples

2.3.1 Grain and straw N analysis

An amount of 0.5 g oven dry, ground sample was taken in a micro Kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 8 ml conc. H_2SO_4 were added. The flasks were heated at 160^0C and added 2 ml 30% H_2O_2, then heating was continued at 360 ^{0}C until the digests become clear and colorless. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

2.3.2 Grain and straw P, K and S analysis

A sub sample weighing 0.5 g was digested by di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture. The flasks were heated at a temperature 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred and the content became clean and colorless. P, K and S concentrations were determined from this digest by using different standard methods (Page *et al*. 1982).

2.4 Statistical analysis

The data obtained for different parameters were statistically analyzed by Mstat-C. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3. Results and Discussion

3.1 Effect of soil and fertilizer on the yield attributes and yield of Boro rice

3.1.1 Effect of soils on the growth and yield of Boro rice

The effects of soils on the growth and yield of rice were presented in Table 2. The plant height, panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, thousand grain weight and grain yield were significantly influenced with the variation of soils. Insignificant straw yield variation was observed in two different soils. The SAU soil showed the highest plant height (79.8 cm), panicle length (25.95 cm), number of filled grains per panicle (174.5), 1000 grain weight (23.73 g), grain (86.67 g pot^{-1}) and straw yield (71.65 g pot^{-1}) than Singair soil. The number of unfilled grains per panicle was significantly influenced with the variation of two soils and Singair soil showed the higher (21.46) number of unfilled grains panicle^{-1} than SAU soil.

3.1.2 Effects of fertilizer and manure on yield attributes and yield of Boro rice

Rice plants showed significant variation in respect of plant height, panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, thousand grain weight, straw and grain yield among the fertilizer treatments (Table 3). Among the treatments, T_4 (50% RDCF + 3.5 ton poultry manure ha^{-1}) gave highest plant height (79.43 cm), panicle length (25.95 cm), and thousand grain weight (23.76 g) those were statistically similar to all other treatments except control. The lowest values of all the parameters were found in control treatment (T_0). Plant height was significantly influenced by the manure and chemical fertilizers reported by Nayak *et al.* (2007). Yang *et al.* (2004) recorded that 1000-grain weight increased by the application of chemical fertilizer with organic manure. Reddy *et al.* (2005) reported similar results for increasing plant height, panicle length and thousand grain weight.

The T_4 treatment gave highest number of filled grains per panicle (166.7) which was statistically similar to T_2 (50% NPKS + 5 ton cow dung ha^{-1}) treatment and the lowest (119.1) number was observed in T_0 treatment. Similar result was found by Rahman *et al.* (2009).

Among the fertilizer treatments, T_0 treatment gave the highest number of unfilled grains per panicle (24.52) while other treatments showed the statistically similar number of unfilled grains per panicle. The T_1 (RDCF) showed the highest grain (94.22 g pot^{-1}) and straw yields (85.2 g pot^{-1}) and the lowest grain (62.53 g pot^{-1}) and straw (54.53 g pot^{-1}) yields were observed in T_0 treatment.

Table 2. Effects of soils on growth parameters, yield attributes and yield of Boro rice

Soil	Plant height (cm)	Panicle length (cm)	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
S_1	79.8 a	25.95 a	174.5 a	17.87 a	23.73 a	86.67 a	71.65
S_2	74.57 b	24.45 b	121.2 b	21.46 b	22.90 b	76.15 b	69.19
SE(±)	0.617	0.13	2.649	0.792	0.077	1.572	NS

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 3. Effect of fertilizer and manure on yield attributes and yield of Boro rice

Treatments	Plant height (cm)	Panicle length (cm)	Filled grains no. panicle^{-1}	Unfilled grains no. panicle^{-1}	1000 grain weight (g)	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
T_0	72.52b	23.95b	119.1c	24.52a	22.42 b	62.53 c	54.53c
T_1	78.81a	25.31a	146.0b	19.75ab	23.42 a	94.22 a	85.2a
T_2	77.18a	25.16a	160.0ab	17.73b	23.33 a	83.32b	71.72b
T_3	77.99a	25.63a	147.4b	17.07b	23.67 a	82.9 b	67.0b
T_4	79.43a	25.95a	166.7a	19.25b	23.76 a	84.08b	73.63b
SE(±)	0.975	0.206	4.19	1.25	0.122	2.49	2.89

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 4. Interaction effects of soils and fertilizer on growth parameters, yield attributes and yield of Boro rice

Soil and Fertilizer	Plant height (cm)	Panicle length (cm)	Filled grains no. panicle^{-1}	Unfilled grains no.panicle^{-1}	1000 grain weight (g)	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
S_1T_0	74.80 cd	23.71e	128.5c	20.82	22.67de	60.0 d	49.93
S_1T_1	77.47 bc	25.79 bc	166.4 b	18.68	24.17a	94.87a	87.67
S_1T_2	83.14 a	26.61ab	202.6a	17.55	23.83ab	91.47a	77.17
S_1T_3	80.50 ab	26.63ab	170.2b	15.47	24.0ab	89.6 ab	69.37
S_1T_4	83.08a	26.98a	204.8a	16.81	24.0 ab	97.4 a	74.10
S_2T_0	70.23d	24.17de	109.7c	28.22	22.17e	65.07cd	59.13
S_2T_1	80.15abc	24.82cde	125.7c	20.81	22.67de	93.57a	82.73
S_2T_2	71.21 d	23.72e	117.3c	17.92	22.83cde	75.17c	66.27
S_2T_3	75.47bcd	24.64cde	124.6c	18.66	23.33 bcd	76.2 bc	64.63
S_2T_4	75.79bcd	24.92cd	128.5c	21.69	23.52abc	70.77cd	73.17
SE(±)	1.38	0.291	5.925	NS	0.173	3.516	NS

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 5. Effect of soil on the pore-water N, P, K and S concentration

Soil	N (mg L^{-1})			P (mg L^{-1})			K (mg L^{-1})			S (mg L^{-1})		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
S_1	7.88 a	7.56	6.55a	0.288b	0.343	0.157b	3.444	2.072	2.431b	2.176	2.202	2.555
S_2	4.69 b	6.77	5.34b	1.4 a	0.407	0.269 a	3.693	1.773	3.123 a	2.046	2.389	2.347
SE (±)	0.27	NS	0.12	0.02	NS	0.009	NS	NS	0.132	NS	NS	NS

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 6. Effect of fertilizer and manure on the pore-water nutrient concentration

Ferti-lizer	N (mg L^{-1})			P (mg L^{-1})			K (mg L^{-1})			S (mg L^{-1})		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
T_0	3.30d	4.33c	4.77c	0.69c	0.24b	0.15b	2.63c	1.27b	2.09b	1.27b	1.63b	1.42b
T_1	7.20ab	6.87b	6.18ab	0.80bc	0.36 ab	0.22a	3.82ab	1.897ab	2.91ab	2.70a	2.35a	2.57a
T_2	5.33c	7.30ab	5.80b	1.03a	0.47a	0.24a	3.02bc	1.959a	2.83ab	2.21a	2.43a	2.42ab
T_3	6.93bc	8.40ab	6.27ab	0.89ab	0.47a	0.22a	3.74ab	1.987a	2.72ab	2.09a	2.53a	2.43ab
T_4	8.67a	8.93a	6.70a	0.92ab	0.33 ab	0.24a	4.64a	2.5a	3.34a	2.28a	2.54a	3.42a
SE(±)	0.42	0.46	0.18	0.04	0.04	0.014	0.25	0.17	0.21	0.18	0.12	0.26

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 7. Interaction effect of soil and fertilizer on the pore-water nutrient concentration

Soil and Ferti-lizer	N (mg L^{-1})			P (mg L^{-1})			K (m gL^{-1})			S (mg L^{-1})		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
S_1T_0	4.00 cd	3.73e	4.53e	0.14e	0.22c	0.21bcd	2.38 c	1.39	2.05	1.21	1.42	1.30
S_1T_1	8.40 b	6.27cde	5.50de	0.18 de	0.31bc	0.32a	3.77bc	2.05	2.48	3.21	2.19	2.65
S_1T_2	5.73 c	7.93bc	5.67d	0.53c	0.31bc	0.30a	2.96bc	2.18	2.48	2.30	2.44	2.37
S_1T_3	9.13 b	9.33ab	5.53de	0.37 cd	0.52ab	0.27ab	3.95b	2.31	2.38	2.00	2.36	2.34
S_1T_4	12.13a	10.53a	5.47de	0.23 de	0.34bc	0.26abc	3.76bc	2.44	2.77	2.15	2.60	4.11
S_2T_0	2.60d	4.93de	5.00de	1.25 b	0.25c	0.09f	2.47c	1.16	2.14	1.34	1.83	1.54
S_2T_1	6.00c	7.47bcd	6.87bc	1.43 ab	0.42abc	0.19cde	3.87bc	1.74	3.33	2.20	2.52	2.48
S_2T_2	4.93cd	6.67cd	5.93cd	1.52a	0.63a	0.19cde	3.09bc	1.74	3.19	2.11	2.42	2.48
S_2T_3	4.73cd	7.47bcd	7.00ab	1.41 ab	0.42 abc	0.17de	3.52bc	1.67	3.05	2.18	2.70	2.52
S_2T_4	5.20c	7.33bcd	7.93a	1.61a	0.33bc	0.21bcd	4.52a	2.56	3.90	2.41	2.48	2.72
SE(±)	0.60	0.64	0.26	0.05	0.06	0.02	0.35	NS	NS	NS	NS	NS

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT

3.1.3 Interaction effects of soils and fertilizer on yield attributes and yield of Boro rice

Combined application of fertilizer and soils had significant variation on the plant height, panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, thousand grain weight and grain yield of rice (Table 4).The higher plant height, panicle length, filled grains panicle^{-1}, thousand grain weight, straw and grain yield were found in SAU soil with different fertilizer treatments. The highest plant height (83.14 cm), panicle length (26.98 cm) and filled grains panicle^{-1} (204.81) were found in S_1T_4 (SAU Soil + 50% RDCF + 3.5 ton poultry manure ha^{-1}) which was statistically similar to S_1T_2, S_1T_3 treatment combinations and lowest in S_2T_0 (Singair Soil + control treatment). The number of unfilled grains per panicle was not significantly influenced by combined application of soil and fertilizer. The highest number of unfilled grains per panicle (28.22) was obtained from S_2T_0 treatment combination and the lowest (15.47) was obtained from S_1T_3. The highest (24.17 g) 1000 grain weight was recorded with S_1T_1 (SAU Soil + Recommended dose of fertilizer) treatment which was statistically similar to S_1T_4 and S_2T_4 treatment combinations and the lowest (22.17 g) was observed in the treatment combination S_2T_0 treatment combination.

The combined effect of fertilizer and soils on the straw yield of rice was insignificant (Table 4). The higher straw yield (87.67 g pot^{-1}) was recorded with the treatment combination S_1T_1 and the lowest straw yield (49.93 g pot^{-1}) was found in S_1T_0 treatment combination. The highest grain yield (97.40 gpot^{-1}) was obtained from S_1T_4 (SAU Soil + 50% RDCF + 3.5 ton poultry manure ha^{-1}) which was statistically similar to S_1T_1, S_1T_2, S_1T_3 and S_2T_1 treatment combinations. Similarly, the application of inorganic fertilizer plus poultry manure in SAU soil performed better in the experimental findings of Atik *et al*. (2021) in Boro rice cultivation. The lowest grain yield (60 g pot^{-1}) was obtained in S_1T_0 treatment combination which was closely similar to the treatment combination S_2T_0.The higher level of organic matter present in the Singair soil, so combined application of fertilizer and manure was not so effective for increasing rice yield in comparison 100% inorganic fertilizer (T_1) treatment.

3.2 Pore-water nutrient concentrations

3.2.1 Effect of soils on the pore-water nutrient concentrations

The pore-water N and P concentrations of 20 and 60 DAT were significantly affected with the variations of soils (Table 5). The higher levels of pore-water N concentrations were found at 20, 40 and 60 DAT with SAU soil compared to Singair soil. At 20 DAT, the highest pore-water N concentration of 7.88 mg L^{-1} was found in SAU soil and the lowest N (4.69 mg L^{-1}) was found in Singair soil. At 60 DAT, the highest pore-water N concentration (6.55 mgL^{-1}) was found in SAU soil and the lowest (5.34 mgL^{-1}) was found in Singair soil.

The higher levels of pore-water P concentrations of 20, 40 and 60 DAT were found in the Singair soil. At 20 DAT, the highest pore-water P concentration (1.44 mg L^{-1}) was found in Singair soil and the lowest (0.288 mg L^{-1}) in SAU soil. At 60 DAT, Singair soil showed higher (0.269 mgL^{-1}) pore-water P concentration compared to SAU soil (0.157 mgL^{-1}). The effect of soils on the pore-water K concentration was significantly identical at 20 and 40 DAT but significantly different at 60 DAT (Table 5). At 60 DAT, Singair soil showed higher pore-water K concentration compared to SAU soil. The effect of soils on the pore-water S concentration was significantly identical (Table 5) and similar concentrations were found in both SAU and Singair soils.

3.2.2 Effect of fertilizer and manure on the pore-water nutrient concentration

The pore-water N, P, K and S concentrations were significantly affected with different fertilizer treatments (Table 6). N concentration was found the highest in T_4 (50% RDCF + 3.5-ton poultry manure ha^{-1}) treatment at 20, 40 and 60 DAT. However, the lowest N concentration was found in T_0 (control) treatment at 20, 40 and 60 DAT. The pore-water P concentrations decreased with increasing DAT (Figure 1A). At 20 DAT, the highest pore-water P (1.03 mg L^{-1}) concentration was found in the T_2 treatment which was statistically similar to T_3 and T_4 and the lowest P concentration of 0.69 mgL^{-1} was recorded in T_0 treatment. At 40 DAT, both T_2 and T_3 treatments showed the highest pore-water P concentration (0.47 mg L^{-1}) which was comparable to T_4 and T_1 (RDCF) and the lowest P concentration (0.24 mg L^{-1}) in T_0 (control) treatment. At 60 DAT, the highest P levels were recorded in T_2 and T_4 treatments though all the treatment combinations showed the lower level of pore-water P concentrations than 20 DAT and 40 DAT, respectively.

The pore-water K and S concentrations were found the highest where fertilizer plus manures was applied and concentrations decreased with increasing DAT. The highest pore-water K concentrations 4.64, 2.50 and 3.34 mg L^{-1} were found from T_4 treatment at 20, 40 and 60 DAT, respectively. The lowest pore-water concentration was recorded with T_0 treatment (Table 6). Among the all DAT, the highest pore-water S concentration was found in T_4 treatment which was statistically similar to other treatments except control.

3.2.3 Interaction effects of soil and fertilizer on the pore-water nutrient concentration

The interaction effects of soil and fertilizer on the pore-water N and P concentrations were significantly different (Table 7). The higher levels of pore-water N concentrations were found in the combination of SAU soil with different fertilizer treatments. The highest 12.13 mg L^{-1} at 20 DAT and 10.53 mgL^{-1} N at 40 DAT were found in S_1T_4 (SAU Soil + 50% inorganic fertilizer and 3.5 ton poultry manure ha^{-1}) treatment combination and highest yield was obtained from the same treatment combination. But at 60 DAT S_2T_4 (Singair Soil + 50% RDCF and 3.5 ton poultry manure ha^{-1}) showed the highest (7.93 mg L^{-1}) N concentrations. The lower levels of pore-water N concentrations were found in control fertilizer treatment with both soils.

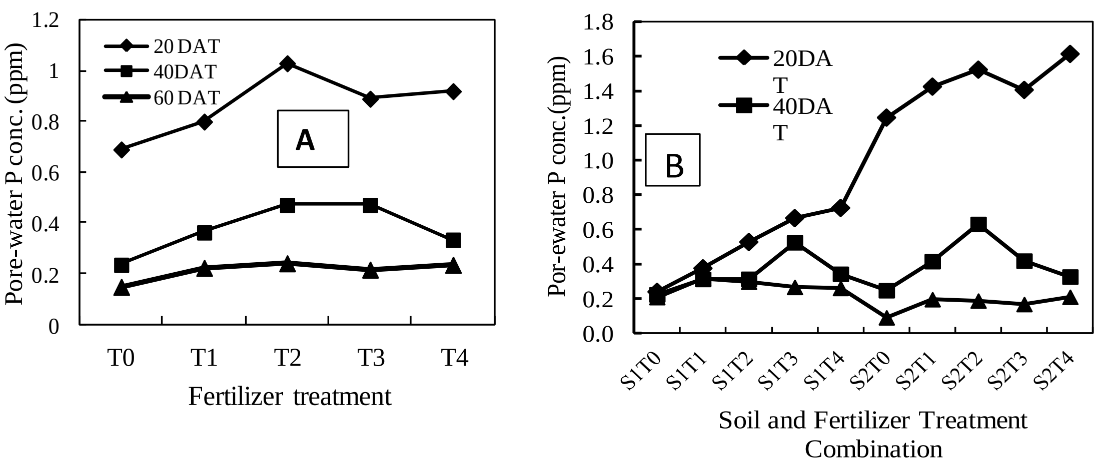
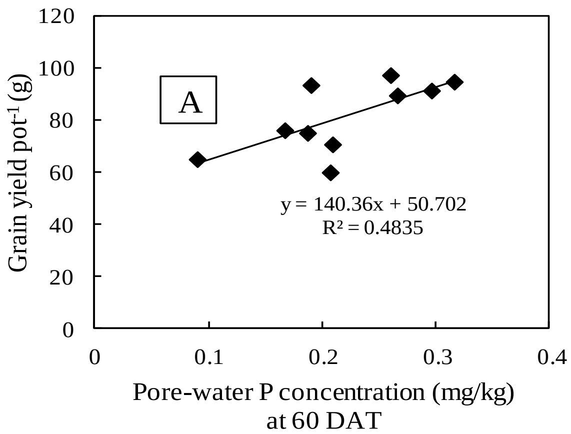


Fig. 1. Pore-water phosphorus concentrations in different fertilizer treatments (A) and soil-fertilizer treatment combinations (B) during different days after transplantation (DAT) of rice.



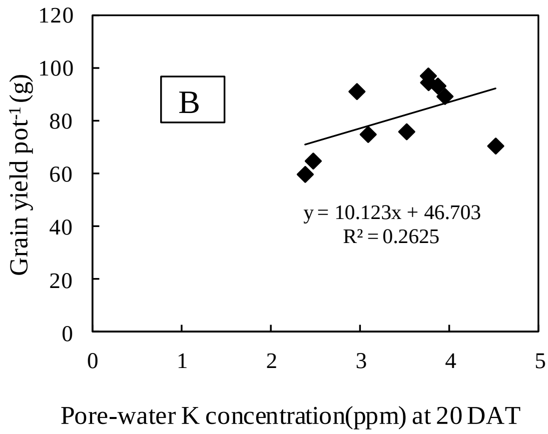


Fig. 2 The relationship between grain yield of rice and pore- water P of 60 DAT (A), pore- water K of 20 DAT (B).

The higher P concentrations were found in the Singair soils compared to SAU soil. The pore-water P concentration decreased with increasing days after transplantation of rice (Fig. 1 A & B). At 20 DAT, the highest pore-water P concentration (1.61 mg L^{-1}) was found in S_2T_4 and (1.52 mg L^{-1}) in S_2T_2 treatments which were closely similar to S_2T_1 and S_2T_3. At 40 DAT, the highest pore-water P concentration (0.63 mg L^{-1}) was found in S_2T_2 treatment which was closely similar to S_1T_3 treatment and the lowest was found in both soils with control treatments. Again at 60 DAT, the highest pore-water P concentration (0.32 mg L^{-1}) was found in S_1T_1 treatment which was closely similar to S_1T_2 treatment and the lowest (0.09 mgL^{-1}) was found in S_2T_0 treatment.

The interaction effects of soils and fertilizer on the pore-water K concentrations were not significantly different at 40 and 60 DAT and higher pore-water K concentrations were found in S_1T_4 and S_2T_4 treatment combinations (Table 7). At 20 DAT, S_2T_4 showed the highest pore-water K concentration (4.52 mg L^{-1}) which was statistically different from all other treatments and lowest pore-water K concentration (2.38 mg L^{-1}) was found in S_1T_0 combination. The interaction effects of soils and fertilizer on the pore-water sulphur concentrations were not significantly different (Table 7). At different DAT the pore-water sulphur concentrations were not affected by the combined effects of soils and fertilizer and manure application.

There was a positive relationship between pore-water nutrient concentrations and grain yield of rice and rice yield increased with increasing levels of pore-water N, P and K concentrations. The positive correlation was mentioned between pore-water nutrient (N, P, K) concentrations and grain yield of rice (Fig. 2 A & B). The positive correlation between pore-water nutrient concentrations and rice yields were also noticed by Khan *et al*. 2021a and Khan *et al*. 2021b.

2.3 Nutrient concentration in grain and straw

2.3.1 Effect of soils on nutrient concentrations in grain and straw

The grain N, P, K, S and straw P and S concentrations were not significantly affected by soils. Singair soil showed higher grain N, K and straw P, K and S concentrations than SAU soil (Table 8). Between these two soils, SAU soil showed the higher grain P concentration (0.268%) than Singair soil (0.258%). The higher grain K concentration (0.224%) was found in Singair soil in comparison to the grain (0.215%)

of SAU soil. Similar grain S concentrations were found in SAU and Singair soil.

The straw N and K concentrations were significantly affected by different soils. The higher N concentration (0.515 %) was obtained in SAU than the straw N (0.480 %) of Singair soil. Singair soil showed higher straw K (1.618 %) and S (0.056%) concentration than K (1.481 %) and S (0.050%) concentrations of SAU soil. Similar straw P concentrations were found in SAU and Singair soils.

2.3.2 Effects of fertilizer on nutrient concentrations in rice grain and straw

Nitrogen, phosphorus, potassium and sulphur concentrations in rice grain and straw showed significant variation due to the application of different fertilizer and manure treatments (Table 9). The grain and straw N, P and K concentrations significantly increased due to application of fertilizers and manure. The higher levels of grains N, K and S concentrations were recorded in the combined application of fertilizer and manure compared to the chemical fertilizer alone. The highest grain (1.290%) and straw N (0.547%) concentrations were recorded from T_3 (50% RDCF + 5 ton compost ha^{-1}) and T_4 (50% NPKS and 3.5 ton poultry manure ha^{-1}) treatments, respectively which were similar to all other treatments except control. The lowest grain (0.987%) and straw (0.410 %) N concentrations were found with T_0 treatment. A significant increase in N content in rice grains due to the application of organic manure and fertilizers have been reported by Azim, 1999 and Hoque, 1999.

The highest grain P (0.310 %) and straw P (0.072%) concentrations were recorded from T_1 which was similar to T_4 and T_3 treatments and the lowest grain (0.208 %) and straw P (0.046%) in T_0 treatment. The highest grain (0.274%) and straw (1.679%) K concentrations were recorded in T_4 and T_2 treatments, respectively and highest straw K was closely similar to T_4 and T_1 treatment and lowest grain and straw K in control treatment. Singh *et al.* (2003) revealed that potassium content in grain and straw was increased due to application of organic manure and chemical fertilizers together. The highest (0.094 %) grain S concentration was recorded with T_2 and the lowest (0.045 %) S concentration was found from T_0 treatment. The highest straw S concentration (0.063 %) was recorded from T_4 which was closely similar to T_1 and T_3 treatments and the lowest S (0.036 %) was found in T_0.

2.3.3 Interaction effect of fertilizer and soils on nutrient concentrations in grain and straw of Boro rice

The combined effects of different fertilizer and soils did not significantly affect the concentration of grain N, P, K, S and straw N, P, K concentrations. The higher grain and straw N, P, K and S concentrations were found in the treatment combinations where organic plus inorganic fertilizers were applied. The highest grain (1.293%) and straw (0.560%) N concentrations were obtained from the S_1T_4 (SAU Soil + 50% inorganic fertilizer and 3.5 ton poultry manure ha^{-1}) treatment and the lowest grain N (0.980%) and straw N (0.393%) showed from S_1T_0 (SAU Soil + control treatment) treatment combinations (Table 10).

The highest grain (0.341%) and straw P (0.072%) concentrations were obtained from the S_1T_1 (SAU Soil + RDCF) treatment combination and lowest from S_2T_0 (Singair Soil + control treatment) treatment combination (Table 10). The higher grain and straw K concentrations were recorded in Singair soil with different fertilizer treatments. The highest grain (0.283%) and straw (1.861%) K concentrations were obtained from the S_2T_4 (Singair Soil + 50% RDCF and 3.5 ton poultry manureha^{-1}) treatment combinations and lowest grain (0.174%) and straw (0.393%) K concentrations were found in S_1T_0 (SAU Soil + control treatment) treatment combination. The highest grain S concentration (0.098%) was recorded in S_2T_2 (Singair Soil + 50% RDCF and 5 ton cow dung ha^{-1}) and the lowest (0.045%) in S_2T_0 treatment combination.

Table 8. Effect of soil on the nutrient concentration in grain and straw

Soil	Grain nutrient concentration (%)				Straw nutrient concentration (%)			
	N	P	K	S	N	P	K	S
S_1	1.195	0.268	0.215	0.076	0.515 a	0.059	1.481 b	0.050
S_2	1.201	0.258	0.224	0.074	0.480 b	0.061	1.618 a	0.056
SE(±)	NS	NS	NS	NS	0.010	NS	0.041	NS

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 9. Effect of fertilizer and manure on the grain N, P, K and S concentration

Fertilizer	Grain nutrient concentration (%)				Straw nutrient concentration (%)			
	N	P	K	S	N	P	K	S
T_0	0.987 b	0.208 c	0.176 b	0.045 d	0.410 b	0.046 d	1.271 b	0.036 c
T_1	1.237 a	0.310 a	0.216 b	0.069 c	0.420 a	0.072 a	1.644 a	0.062 a
T_2	1.213 a	0.276 abc	0.215 b	0.094 a	0.513 a	0.058 c	1.679 a	0.047 b
T_3	1.290 a	0.231 bc	0.216 b	0.082 b	0.497 a	0.065 b	1.485 ab	0.059 a
T_4	1.263 a	0.289 ab	0.274 a	0.084 b	0.547 a	0.058 c	1.668 a	0.063 a
SE(±)	0.044	0.017	0.012	0.008	0.016	0.004	0.065	0.003

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

Table 10. Effect of soils and fertilizer on the grain nitrogen, phosphorus, potassium and sulphur concentration

Soil and Fertilizer	Grain nutrient concentration (%)				Straw nutrient concentration (%)			
	N	P	K	S	N	P	K	S
S_1T_0	0.980	0.227	0.174	0.046	0.427	0.043	1.258	0.036 e
S_1T_1	1.220	0.341	0.214	0.069	0.513	0.072	1.695	0.064 b
S_1T_2	1.193	0.268	0.204	0.089	0.520	0.056	1.628	0.046 d
S_1T_3	1.287	0.225	0.215	0.091	0.553	0.066	1.347	0.057 bc
S_1T_4	1.293	0.277	0.265	0.085	0.560	0.057	1.475	0.050 cd
S_2T_0	0.993	0.189	0.177	0.045	0.393	0.049	1.283	0.035 e
S_2T_1	1.253	0.279	0.219	0.070	0.527	0.072	1.594	0.059 b
S_2T_2	1.233	0.285	0.225	0.098	0.507	0.060	1.731	0.049 cd
S_2T_3	1.293	0.238	0.217	0.073	0.440	0.065	1.622	0.061 b
S_2T_4	1.233	0.300	0.283	0.082	0.533	0.059	1.861	0.076 a
SE(±)	NS	NS	NS	NS	NS	NS	NS	0.004

In a column figures having similar letter (s) do not differ significantly at 5% level whereas figures with dissimilar letter (s) differ significantly as per DMRT.

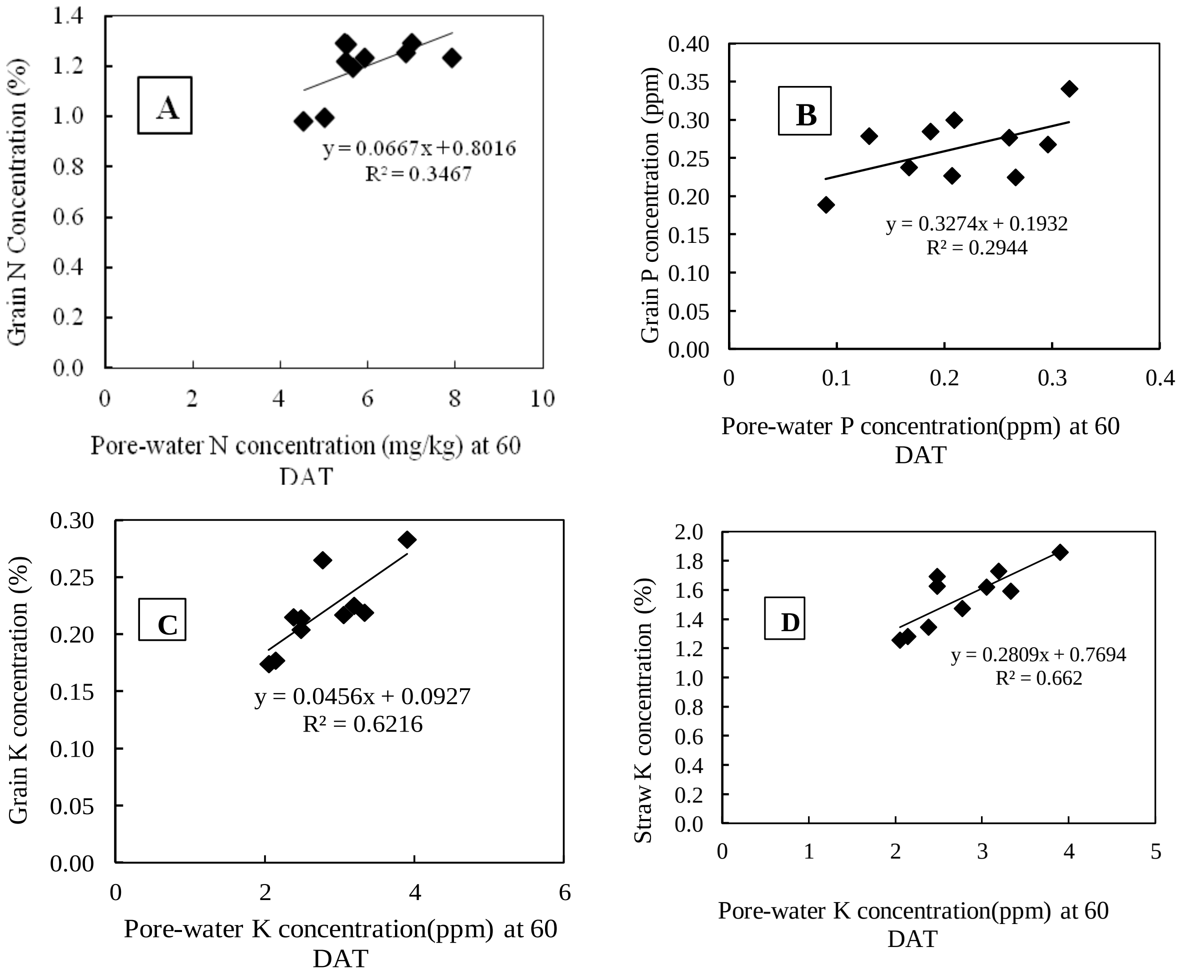


Fig.3. The relationship between pore-water N vs grain N concentration (A), pore-water P vs grain P concentration (B), pore-water K vs grain K concentration (C), pore-water K vs straw K concentration (D).

The combined effect of soils and different fertilizer and manure treatments on S concentration in straw of rice was significant. The highest straw S concentration (0.076 %) was recorded in S_2T_4 and the lowest (0.035 %) in S_2T_0 which was identical to S_1T_0 treatment combination.

There was a positive relationship found between pore-water nutrient and nutrient concentration in rice grain and straw. The grain and straw nutrient concentrations increased with increasing pore-water N, P and K concentrations.

The positive correlation was observed between pore-water nutrient (N, P, K) concentrations and nutrient (N, P, K) concentrations in rice grain and straw (Fig. 3 A, B, C & D). The higher levels of nutrient concentrations in rice grain and straw were observed in inorganic plus manure applied treatments and similar results was observed in the findings of Rahman *et al.* (2019).

4. Conclusions

The higher plant nutrient accumulation and boro rice yields were observed in SAU soil with the application of 50% RDCF plus 50% nutrient from manure. The pore-water nutrient concentrations varied with the soil and fertilizer treatments. The higher levels pore-water N, P, and K concentrations were found in the treatment combinations where 50% RDCF plus 50% nutrient from manures were applied in SAU soil or Singair soils. There was a significant positive correlation between pore-water nutrient concentration and yield of rice. The 50% RDCF plus 50% nutrient from manures were more effective in SAU soil in comparison to Singair soil. Poultry manure performed better in comparison to cowdung for increasing nutrient availability, accumulation and yield of rice.

5. Acknowledgement

The authors gratefully acknowledge the financial support from Ministry of Science and Technology, Bangladesh.

References

Ahmed A., Parvej MMR., Amin MHA., Paul AK., Khan MA. 2021. Modern Rice (*Oryza sativa* L.) Production Potentiality through a Sorts of Management Practice. *Acta Scientific Agriculture*, 5(5): 22-36.

Azim UH. 1999. Effect of different doses of N, P, K & S on the yield of BR11 variety of rice. *Rural Development Academy, Bogra*, 15-20 pp.

Bremner, JM., Mulvancy CS.1982. In A.L. Page et al. (ed.) Methods of Soil Analysis, Part 2, 23 *American Society of Agronomy Inc*, Madi, Wis. 595-624 pp.

Gomez KA., Gomez AA. 1984. Statistical procedures for Agricultural Research. John Wiley and Sons, New York. 122-124 pp.

Hunter AH. 1984. Soil Fertility Analytical Service in Bangladesh. Consultancy Report BARC, Dhaka.

Islam MS., Howlader MIA., Rafiquzzaman S., Bashar HMK., Al-Mamun MH. 2008. Yield response of chili and T. Aman Rice to NPK fertilizers in Ganges Tidal Floodplain. *Journal of Soil and Nature*, 2(1): 07-13.

Islam MMAF., Khan MA., Bari ASMF., Hosain MT., Sabikunnaher. 2013. Effect of fertilizer and manure on the growth, yield and grain nutrient concentration of boro rice (*Oryza sativa* L.) under different water management practices. *The-Agriculturists*, 11(2): 44-51.

Khan MA., Shampa SA., Hossain MB. 2021a. Plant Nutrient Availability in Soils of Rice Root Zone and Root Free Areas under Different Management Practices. *Banglades Agricultural Univ*ersity, 19(1): 44-52.

Khan MA., Shampa SA., Hossain MB. 2021b. Effects of Irrigation, Fertilizer and Manure on Pore- Water Nutrient Availability, Yield and Change of Soil Chemical Properties with Rice-Rice Cropping. *Communications in Soil Science and Plant Analysis*, 52(20): 2597-2608.

McLean EO. 1982. Soil pH and lime requirement. In: Methods of soil analysis, Part 2, Chemical and microbiological properties, A. L. Page, (eds.), *American Society of Agronomy.* Inc., Madison, WI, USA. pp. 199-224.

Nayak DR., Babu X., Adhya TK. 2007. Long-term application of compost influences mineral biomass and enzyme activities in a tropical Aeric Endoaquept planted to rice under flooded condition. *Soil Microbiology and Biochemistry*, 39(8): 1897-1906.

Nimbiar KKM. (1997b). Soil health and organic matter-changing scenario. Proc. National Academy of Science. India Special Issue, 141-160 pp.

Olsen SR., Cole CV., Watanabe FS., Dean LA. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. Department of Agriculture Circ., 929 p.

Page AL., Miller RH., Keeney DR. (ed). 1982. Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA, 403-430 pp.

Rahman MM., Khan MA., Paul AK., Haque MA. 2019. Effect of fertilizer, manure and irrigation on nutrient availability in soil of boro rice field. *Eurasian Journal of Soil Science,* 8(4):282-288.

Rahman MN., Islam MB., Sayem SM., Rahman MA., Masud MM. 2007. Effect of different rates of sulphur on the yield and yield attributes of rice in old Brahmaputra floodplain soil. *Journal of Soil and Nature*, 1(1): 22-26.

Rahman MS., Islam MR., Rahman MM., Hossain MI. 2009. Effect of cowdung, poultry manure and urea-N on the yield and nutrient uptake of BRRI dhan29. *Bangladesh Research Publications Journal*, 2: 552-558.

Reddy BGM., Pattar PS., Kuchanur PH. (2005). Response of rice to poultry manure and graded levels of NPK under irrigated conditions. *Bangladesh Research Publications Journal,* 2: 552-558.

Walkley A., Black DR. 1975. An examination of the digestion method for determining soil organic matter and proposed modification of the chronic acid titration method. *Soil Science*, 37: 29-38.

Xu Y., Wang Z., Li Z., Guo Y., Wang BJ. 1997. Methane productivity of two rice soils as affected by application of fertilizer. *Acta Agronomica Sinica*, 232(2): 137-143.

Yang CM., Yang L., Yang Y., Ouyang Z. 2004. Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. *Agricultural Water Management*, 70 (1): 67-81.