Indian Journal of Agronomy **46** (4) : 584–591 (December 2001)

Effect of fertilizer and pre-monsoon crops on productivity of rice (*Oryza sativa*)-cropping based systems

M.A. QUAYYUM, J. TIMSINA[1], F. HAQ, G. S. TOROFDER AND D. J. CONNOR[2]

Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Received : January 2001

ABSTRACT

A field experiment involving wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–mungbean (*Phaseolus radiatus* L.) and maize (*Zea mays* L.)–rice (*Oryza sativa* L.) sequences (with varying mungbean residue management and fertilizer doses as treatments) was conducted under irrigated conditions at Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, during 1996–99. Seed yield of mungbean was very low (0.25–0.61 tonne/ha) due to heavy pre-monosoon rainfall at maturity but considerable amount of green biomass (2.57–9.08 tonnes/ha) was obtained. Maize yield of 1.93–3.25 tonnes/ha was also affected by rainfall. Rice yield was 3.83–4.62 tonnes/ha, whereas wheat yield of 1.98–4.08 tonnes/ha in different treatments. All the 4 crops responded to fertilizer, with greatest response in wheat and maize. Mungbean (stubble removed or retained) in cropping system did not show any marked difference in total system productivity in terms of mean rice-equivalent yield for 3 years, but the system productivity was increased by increasing fertilizer dose. The mean rice-equivalent yield was greater by 12–13% for soil-test based fertilizer treatments than farmers' fertilizer treatments. Mean rice-equivalent yield involving maize was higher than that involving mungbean. But higher benefit : cost ratio was obtained from wheat–mungbean (removed)–rice followed wheat–mungbean–rice with farmers fertilizer dose.

Key words : Fertilizer management, Mungbean residue management, Rice, Wheat, Mungbean, Maize system, Productivity, Rice equivalent

The rice–wheat system is the most widely adopted cropping system and the mainstay of cereal production in Bangladesh. Inclusion of short-duration pulses, such as mungbean after wheat and before rice, may be beneficial to the rice–wheat system by increasing the total system productivity while improving structure, fertility, and health of soil, i.e. the sustainability of the overall agro-system. This is possible because pulses can increase total yield, save N fertilizer, and build up soil fertility through biological sources. Pulses are considered to be even more beneficial

Present address : [1,2]Institute of Land and Food Resosurces, University of Melbourne, Australia

than inorganic sources of N (Kumar and Prasad, 1999). For example, Kumar Rao *et al.* (1998) reported that grain legumes can add 20–60 kg/ha residual N to the succeeding wheat crop. Hedge (1992) also reported that rice and wheat yields increased by 9.6 and 5.3%, respectively, on incorporation of mungbean stover after picking of pods.

The present experiment was designed to improve the performance of the existing rice–wheat cropping system by evaluating fertilizer requirements and the inclusion of mungbean for high productivity. Maize was included to compare a rice–wheat system consisting of only cereals, with that of cereals and legumes.

MATERIALS AND METHODS

The experiment was conducted at the Central Research Station of Bangladesh Agricultural Research Institute, Joydebpur (24°N, 92.3°E, 8 m above sea-level) Gazipur, from 1996–97 to 1998–99. Joydebpur is above river flood level within the Modhupur tract of Agro-ecological zone 28 (BARC, 1997). The soil was silty clay of the Chhiata series of Grey Terrace soil having moderately slow permeability and moderately neutral pH of 6.0 (Bramner, 1996). The soil site was low in organic matter and N (0.1%). The soil had available P (9.2 ppm), DTPA-extractable Zn (3.4 ppm), available S (9.0 ppm) and available K (0.1 meq/100 g). The experiment was laid out in randomized complete-block design with 4 replications. Plot size was 20 m × 10 m. The treatments were: T_1, wheat–mungbean (stubble removed)–transplanted, aman rice, fertilizers for all crops based on soil test; T_2, wheat–mungbean (stubble removed)–transplanted aman rice; farmers' fertilizer dose based on survey of farmers' practice; T_3, wheat–mungbean (stubble retained)–transplanted aman rice, fertilizers based on soil test; T_6, wheat–maize–transplanted aman rice, farmers' fertilizer dose based on survey. The fertilizers for soil–test-based treatments were for wheat 120, 22, 66, 20 and 2 kg N, P,K,S, and B/ha; mungbean 20,20 and 20 kg N, P and K/ha; maize 120,26, 33 and 20 kg N, P, K and S/ha and for rice transplanted aman 90, 26, 33 and 20 kg N, P, K, and S/ha, whereas farmers' practice fertilizer included levels fertilizer for wheat 60, 11 and 25 kg N, P and K/ha; mungbean 0,0 and 0 kg N, P and Kha; maize 60, 13 and 17 kg N, P and K, and for rice 60, 9,17 and 10 kg N, P, K and S kg/ha.

Wheat ('Kanchan'), mungbean ('Kanti'), maize ('Barnali') and rice ('BR 32') were used with a spacing of 20 cm in solid line for wheat, 25 cm × 10 cm for mungbean, 75 cm × 25 cm for maize and 25 cm × 15 cm for rice. Seeds of wheat were sown on 26 November, 25 November and 8 December in 1996, 1997 and 1998; of mungbean / maize on 10, 13 and 6 April in 1997, 1998 and 1999; and rice was transplanted on 5,9 and 1 August in 1997, 1998 and 1999 respectively. For wheat, two-thirds of N and all other fertilizers were broadcast at sowing, while the remaining N was top-dressed at crown-root initiation (CRI) stage. Three irrigations were given to wheat, 1 each at crown-root initiation (CRI), maximum tillering (MT) and grain-filling (GF) stages. Irrigation was not given to mungbean and maize crop but 1 supplementary irrigation was given for transplanted man rice. For mungbean, all fertilizers were applied at sowing, while for maize one-third N and the remaining two-thirds N was top-dressed in equal amounts 21 and 42 days after sowing (DAS). For rice, fertilizer other than N was applied at the time of final land preparation, while N was applied in 3 equal splits 15,30 and 45 days after transplanting (DAT).

Mungbean pods were hand-picked twice 60 and 70 days after sowing, and plant residues were incorporated into the soil (stubble retained) and removed (stubble removed). Maize straw was removed from the field but roots were incorporated.

Intercultural operations such as weeding, mulching and earning up (only in maize) were performed as and when necessary. Harvest dates in 1997, 1998 and 1999 were 25, 18 and 23 March for wheat; 25, 28 and 15 June for mungbean; 15, 10 and 10 July for maize; and 16, 25 and 29 November for rice respectively. Data were analysed by mean comparison test using LSD. Rice-equivalent yield was calculated using commodity price of individual crop.

Weather data were recorded on daily basis but mean monthly (temperature and solar radiation) and monthly total rainfall are shown in Table 1. Overall, the soil may be rated poor in fertility. Soil analysis before sowing of wheat crop (initial) and after 2 years of experimentation, showed that organic matter content (1.78%) increased in mungbean stubbles-incorporated soil.

RESULTS AND DISCUSSION

Grain and straw yields of wheat

There was a trend of decreasing grain yield in all the treatments from 1997 to 1999. The lowest yields in 1998–99 were possibly due to heat stress during grain filling temperature ranged from 30 to 34°C during February to March and delayed sowing of wheat. Grain yields were not significantly influenced by the treatments in 1997–98 but in other years the mean were significant. Timsina *et al.* (1998) also reported significant response of wheat yields to N in rice–wheat system of northern Bangladesh. Wheat crops following mungbean stubble incorporation or removal or maize cropping did not show responses in grain yield either with or without added N. Straw yields showed similar response to grain yields (Table 2). During the wheat-growing season in 1996–97, there was no rain before and after sowing on 26 November. Hence a pre-sowing irrigation was given for proper establishment. Rainfall was low (65 mm) during the wheat-growing season. In 1997–98, there was no rainfall in November and up to 8 December; so a post-sowing irrigation was given on 25 November for establishment. In 1998–99, heavy rainfall (109 mm) from 21 to 23 November affected the land preparation and delayed the sowing of wheat. After that there was no rain up to harvesting. The maximum temperature during the grain-filling of wheat ranged from 22 to 35°C, while the minimum temperature ranged from 9 to 25°C. During the wheat season, maximum temperature ranged from 29 to 37°C while the minimum temperature ranged from 9 to 26°C. Maximum temperatures during the grain-filling period exceeded 35°C, while the minimum temperatures were between 20 and 30°C.

Table 1. Mean monthly weather data for experimental site (Joydebpur, 1996–99)

Month	1996–97				1997–98				1998–99			
	Temp. (°C)		Rain (mm)	Solar radiation (MJ/m²/day)	Temp. (°C)		Rain (mm)	Solar radiation (MJ/m²/day)	Temp. (°C)		Rain (mm)	Solar radiation (MJ/m²/day)
	Max.	Min.			Max.	Min.			Max.	Min.		
November	30.1	18.2	0.0	14.0	30.2	19.1	0.0	12.7	30.1	20.6	113.8	13.0
December	26.6	13.7	0.0	12.1	24.3	14.3	21.8	9.8	27.1	15.1	0.0	13.2
January	24.3	14.6	5.0	12.1	21.9	12.6	23.4	10.0	26.0	12.6	0.0	13.8
February	26.5	13.9	23.0	14.7	27.6	15.9	2.0	13.6	29.7	15.7	0.0	16.7
March	31.3	20.4	37.0	17.9	29.9	17.8	69.8	17.7	33.9	19.9	0.0	18.5
April	30.3	20.4	165.0	17.6	32.2	22.5	192.8	17.0	35.2	25.1	8.6	19.2
May	33.2	24.2	167.6	18.9	32.7	24.9	291.2	15.7	33.1	24.8	325.0	15.1
June	32.9	25.4	326.2	15.2	33.7	27.7	98.9	16.7	33.0	26.4	338.2	15.6
July	31.3	26.3	520.8	13.9	31.6	26.2	892.6	12.3	31..5	27.1	663.3	N.A.
August	32.2	26.2	347.8	13.9	31.7	26.6	381.3	13.7	31.6	26.2	401.4	13.1
September	31.5	25.5	509.0	11.8	32.7	26.3	324.6	12.5	21.4	25.9	381.4	12.0
October	31.7	22.3	13.8	15.4	32.9	25.5	52.4	13.7	31.5	24.4	298.0	12.9

Seed and green biomass yield of mungbean and maize

Seed yield were significantly influenced by the various treatments in all the 3 years. On average, higher seed yields were recorded in 1997 and 1999 than in 1998. Treatment T_1 resulted slightly greater seed yield than other treatments in 1997 and 1999, but less yield in 1998 (Table 3). These yield variations were mainly due to rainfall. In 1998, high rainfall (885 mm) occurred within 30 days during pod maturity to harvest. Seed yield was reduced by 9 to 45% in farmers' fertilizer dose compared to the soil test-based fertilizer dose. Green biomass also differed significantly across treatments and year. Treatment T_3 resulted in highest biomass in 1997 and 1998 but T_1 had highest in 1999. Although seed yields of mungbean were low in all the treatments, green biomass yields were quite high. Seed yields in all years were much less than potential, due to

Table 2. Grain and straw yields of wheat as affected by fertilizer level and cropping pattern

Treatment	Grain yield (tonnes/ha)				Straw yield (tonnes/ha)			
	1996–97	1997–98	1998–99	Mean	1996–97	1997–98	1998–99	Mean
T_1	4.08	2.97	2.41	3.15	4.15	3.52	3.61	3.76
T_2	2.98	2.87	1.98	2.61	3.08	3.39	3.18	3.22
T_3	4.07	3.10	2.40	3.19	4.03	3.59	3.60	3.74
T_4	3.11	2.59	2.02	2.57	3.25	3.11	3.22	3.19
T_5	4.05	3.04	2.30	3.13	4.10	3.61	3.50	3.74
T_6	2.98	2.62	2.02	2.54	3.25	3.15	3.22	3.21
CD (P=0.05)	0.21	NS	0.16	0.18	0.06	NS	0.24	0.15

Details of treatments are given under Materials and Methods

Table 3. Seed and green biomass (seed + straw) yields of mungbean and grain and dry straw yields of maize as affected by fertilizer level and cropping pattern

Treatment	Seed yield (tonnes/ha)				Biomass yield (tonnes/ha)			
	1997	1998	1999	Mean	1997	1998	1999	Mean
T_1	0.61	0.26	0.58	0.48	7.08	3.37	7.73	6.06
T_2	0.55	0.31	0.45	0.44	6.94	3.00	6.00	5.31
T_3	0.56	0.45	0.54	0.52	9.08	3.80	6.93	6.60
T_4	0.51	0.23	0.49	0.42	6.80	3.15	5.47	5.14
T_5	3.25	3.07	2.44	2.92	3.40	4.49	3.10	3.66
T_6	2.85	2.42	1.93	2.40	3.05	4.05	2.57	3.22
CD (P=0.05)	0.12	0.19	0.12	0.14	0.54	0.41	0.70	0.55

Details of treatments are under Materials and Methods damage caused by heavy rainfall at harvest. Hossain *et al.* (1990), however, obtained high seed yields of mungbean during the pre-rice season in Bangladesh. The slightly reduced seed and biomass yields in farmers' management plots compared to the soil test-based plots indicate the mungbean response to N. In all years, grain yields were significantly higher in soil test-based fertilizer plots compared to farmers' fertilizer plots, and were reduced by 12, 22 and 21% respectively in farmers' fertilizer plots compared with soil-test-based plots. Grain yields were almost similar in 1997 and 1998 and were higher than in 1999 (Table 4). High rainfall (272 mm) within 15 days before harvesting reduced grain yield in 1999. These low yields were, however, also a consequence of water logging caused by high rainfall in that year. In 1997, 112 mm of rain fell in 15 days (from 2 to 8 April) and 290 mm in 21 days (from 19 June to 10 July). In 1998, mungbean and maize were sown on 13 April, and after sowing about 159 mm rain occurred which affected germination. About 291 mm and 99 mm rains were recorded in May and June, respectively, but high rainfall (884 mm) occurred within 30 days during pod maturity to harvest. During harvesting of maize, there was 775 mm rain in 11 days, which damaged grain and ultimately resulted in low yield. Straw yields behaved similarly as grain yields in all the years.

Grain and straw yields of rice

In general, there was a trend of decreasing grain yield with N application from 1997 to 1999. The exception was, however, for treatments T_1, T_5 and T_6 where yields increased from 1998 to 1999 (Table 4). Timsina *et al.* (2001) also reported substantial grain yields of rice in rice–wheat system in plots without N in northern Bangladesh. Incorporation of mungbean residues did not increase the grain yield but their removal did slightly. Thus, averaged across years, highest grain yield (4.5 tonnes/ha) was recorded from treatment T_1. Hegde (1992) however, reported increasing productivity of rice–wheat system by the incrorporation of

Table 4. Grain and straw yields of transplanted aman rice as affected by fertilizer level and cropping pattern

Treatment	Grain yield (tonnes/ha)				Straw yield (tonnes/ha)			
	1997	1998	1999	Mean	1997	1998	1999	Mean
T_1	4.62	4.05	4.44	4.37	4.85	4.60	5.09	4.85
T_2	4.07	3.97	3.87	3.97	4.25	4.51	4.50	4.42
T_3	4.50	3.97	3.92	4.13	4.68	4.50	4.87	4.68
T_4	4.26	3.95	3.83	4.01	4.45	4.45	4.45	4.45
T_5	4.59	3.77	4.11	4.16	4.77	4.30	4.99	4.69
T_6	4.33	3.75	3.83	3.92	4.55	4.26	4.41	4.41
CD (P=0.05)	0.32	0.26	0.44	0.34	0.35	0.11	0.41	0.29

Details of treatments are given under Materials and Methods mungbean residues after picking pods. Wheat–mungbean (stubble removed)–rice system resulted in similar rice yield to wheat–maize–rice system but lower than in wheat–mungbean (stubble retained)–rice system. Straw yields were about 10% greater than grain yields and the response of straw to fertilizer and mungbean residue were similar to grain yield in all years. In 1997, average rainfall recorded during the growing season was 823 mm but there was no rain during grain-filling period of rice. During 1998, total rainfall recorded was 729 mm, whereas in 1999, 1,090 mm during rice-growing season, but high rainfall during flowering to maturity caused lodging (20–60%).

Yield trend

Both grain and green matter yields of mungbean were greater for N-added treatments. There was a trend of decreasing grain and straw yields of maize during the experiment. Reduction in grain yield may be due to continuous growing of cereal crops or by possible exhaustion of the nutrients. Over the years, there were no significant cumulative effect of mungbean residues (either retained or removed) on rice and wheat grain yields but there were significant effects of fertilizer. Grain yields of wheat were greatest in the first year and smallest in the third year. Similarly, rice grain yields were greatest in the first year (4.07 to 4.62 tonnes/ha with N) and smallest in the third year (3.83 to 4.44 tonnes/ha with N). Rice straw yields responded similarly across years where yields ranged from 4.25 to 5.09 tonnes/ha with N.

Cropping system productivity

The highest rice-equivalent yield was obtained from a wheat–maize–rice cropping pattern with soil test-based fertilizer application. Overall, the soil test- based fertilizer treatments showed higher rice-equivalent yields than the farmers' fertilizer treatments and the increase was 12–13%

Table 5. Rice-equivalent yield and economic analysis of total productivity system as affected by fertilizer level and cropping pattern (average)

Treatment	Rice-equivalent yield (tonnes/ha)	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	Benefit : cost ratio
T_1	9.35	58,079	26,082	31,957	2.23
T_2	8.20	51,075	21,455	29,623	2.38
T_3	9.24	57,533	26,665	25,724	2.16
T_4	8.14	50,708	22,038	28,670	2.30
T_5	10.61	66,408	30,462	35,947	2.18
T_6	9.27	57,937	24,704	33,233	2.34
CD (P=.05)	0.65				

Details of treatments are given under Materials and Methods across the treatments (Table 5). Inclusion of mungbean in the system did not improve performance over that with maize due to low mungbean yield in all the years. Mungbean incorporation was not effective to increase grain yield of rice. Highest gross return (Rs 66,408/ha) was obtained from wheat–maize–rice cropping system with soil test-based fertilizer dose but this treatment showed the highest cost of cultivation among the treatments. Similar trend was followed in case of net return but benefit : cost ratio was highest from wheat-mungbean (removed)–rice, followed by wheat–maize–rice and wheat–mungbean (removed)–rice with farmers fertilizer dose (Table 5). All the treatments involving farmer fertilizer dose showed lower cost of cultivation due to low use of fertilizer which resulted higher benefit than soil test-based fertilizer dose.

Under present condition, inclusion of mungbean as short-duration crop in rice–wheat system with soil test-based fertilizer doses offers higher and sustainable productivity by maintenance of soil fertility.

ACKNOWLEDGEMENT

This research is part of the project 'Nutrient and irrigation management for sustainable rice–wheat cropping systems of Bangladesh and Australia' funded by Australian Center for International Agricultural Research (ACIAR), Canberra, Australia.

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