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Effect of water and fertilizer management on the yield and yield components of *Boro* rice under SRI method

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Abstract

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to delineate proper management of water and fertilizer to obtain maximum yield of *Boro* rice. Two levels of water management *viz.* (i) SRI water management (moist soil, water at field capacity) and (ii) BRRI water management (5-6cm standing water), and five fertilizer management practices *viz.* (i) BRRI fertilizer managements (120, 60, 40, 10, 5 kg N, P_2O_5, K_2O, S and Zn kg ha^{-1}, respectively), (ii) cowdung @ 10 t ha^{-1}, (iii) poultry manure @ 5 t ha^{-1}, (iv) 50% of BRRI recommended fertilizer + 50% of the cowdung, (v) 50% BRRI recommended fertilizer + 50% poultry manure were arranged in split-plot design with three replications. The results showed that SRI water management produced higher grain and straw yields than that of BRRI water management. Number of total tillers $hill^{-1}$, bearing tillers $hill^{-1}$, total spikelets $panicle^{-1}$ and sterile spikelets $panicle^{-1}$ gave similar trends to that of grain and straw yields. BRRI recommended fertilizer management produced the highest grain yield and the second highest grain yield was obtained in 50% of the BRRI recommended fertilizer + 50% of the poultry manure. The lowest grain yield was obtained in cowdung @ 10 t ha^{-1}. In terms of interaction, SRI water management in combination with BRRI fertilizer management produced the highest grain yield and the second highest grain yield was obtained in BRRI water management × BRRI fertilizer management and in SRI water management × 50% BRRI fertilizer management + 50% of the poultry manure. The lowest grain yield was found in BRRI water management × cowdung @ 10 t ha^{-1}.

Keywords: SRI, Water and fertilizer management, Yield, *Boro* rice

Introduction

Commonly rice is grown under continuous flooding with about 5 cm depth of standing water throughout the growing season. Almost all rice varieties show better growth and higher productivity under continuous flooding conditions than ones exposed to water deficit at certain growth stages. The use of irrigation water for production of lowland rice can potentially be reduced by lowering the depth of standing water and by allowing the soil to dry before the next application of irrigation water (i.e., alternate soil wetting-drying) or keeping the soil moist all the time i.e. water at field capacity. Reduction in water requirements is a particular benefit of SRI (Satyanarayana *et al.*, 2007). Several research workers showed that rice can grow normally with high yield under shallow water depth than under deep submergence because shallow water causes rising up of the water temperature during the day but a decrease during the night that allow more tillering and better growth. Most of the rice varieties produce higher grain yield when water content of the soil was kept near saturation throughout the season and this was comparable to that of continuous flooding (RRTC, 2001). That means better yield not necessarily requires standing water on the soil surface and water applications can be reduced through adoption of SRI method without sacrificing yield, and indeed a small increase in yield can be attained with less water application on well-drained soils (Randriamiharisoa, 2006; Ceesay *et al.*, 2006; Sato and Uphoff, 2007). This is probably the most complicated variable in SRI. The principle is clear, rice roots should not have to grow in a hypoxic, anaerobic environment caused by continuous flooding and saturated soil. When this happens, most of the rice plant roots stay in the top 6 cm of soil and most of them degenerate by the time of panicle initiation, when grain formation is beginning (Uphoff, 2002).

SRI challenges the common notion that rice performs best under flooded conditions. Instead, intermittent irrigation is practiced in SRI during vegetative growth to keep the soil just saturated or moist enough to avoid drought stress, which typically results in water savings as compared to continuous flooding.

On the other hand, long time intensive use of chemical fertilizers creates some fertility problems through soil exhaustion as well as through interactions with other elements causing micronutrients deficiency (Rahman and Mian, 1997). Furthermore, chemical fertilizers pollute soil and water making environment even more harmful for both terrestrial as well as aquatic life. Application of inorganic nitrogenous fertilizers has always been expensive inputs for crop production, especially in a developing country like Bangladesh. In near future fertilizer N is likely to be even more costly. This situation poses a serious threat to food security of the vast millions of people of this country. The use of manure and its proper management may reduce the need for chemical fertilizers allowing the small farmers to save part of the cost of crop production. Observations indicate that yields with SRI methods gradually increase from year to year. A good part of this increase apparently comes from improved soil quality, assessed in biological rather than chemical terms. Organic materials are used as a complement to a recommended and balanced amount of mineral fertilizers *i.e.* organic materials should not be used as the primary nutrient source (Dawe *et al.*, 2003). The plant, soil, water and nutrient management practices combined in SRI probably enrich the soil microbiologically, but this remains to be investigated and demonstrated. Research work with SRI warrants due attention under Bangladesh perspective especially on the water and fertilizer management aspects. The present study was, therefore, undertaken to unveil the impact of water and fertilizer management aspects through adoption of SRI method in *Boro* rice production.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from January to June 2006. The experimental site belongs to Old Brahmaputra floodplain (AEZ 9) with medium high topography and loamy texture. The pH of the soil was 6.81. The organic Carbon, total N content, available P, available S, Exchangeable K and cation exchange capacity were 0.463%, 0.085%, 13.20 ppm, 5.13 ppm,0.21 me/100 g soil and 11.12 me/100 g soil, respectively. The experimental treatments comprised two water management *viz.* (i) SRI water management (moist soil, water at field capacity) and (ii) BRRI water management (5-6cm standing water); and five fertilizer management practices *viz.* (i) BRRI fertilizer management (120, 60, 40, 10 and 5 kg N, P_2O_5, K_2O, S and Zn kg ha^{-1}, respectively), (ii) cowdung @ 10 t ha^{-1}, (iii) poultry manure @ 5 t ha^{-1}, (iv) 50% of BRRI recommended fertilizer + 50% of cowdung, (v) 50% BRRI recommended fertilizer + 50% poultry manure. BRRI dhan29, a high yielding *Boro* rice variety, was used as plant material. The experiment was conducted in split-plot design with three replications assigning water management in the main plot and fertilizer management in the sub-plot. The unit plot size was 4.0m × 2.5m. The bunds around individual plots were made fine enough to control water movement within the plots. Ten-day old seedlings were transplanted on 22 January 2006 in the well-puddled plots maintaining 35 cm × 35 cm spacing. Urea was top dressed in three equal splits at 15, 30 and 45 days after transplanting (DAT). The full doses of triple supper phosphate (TSP), muriate of potash (MOP), gypsum, zinc and poultry manure were applied at final land preparation as per treatment. Intercultural operations were done as and when necessary. The first weeding was done at 15 DAT and subsequent weedings were done at 15-day intervals up to 70 DAT.

Plants from the central $5m^2$ harvest area of each plot were harvested at full maturity when 90% of the grains turned golden yellow for recording data on grain and straw yields. Five-plant samples $plot^{-1}$ excluding harvest area and border rows were selected randomly for recording data on crop characters and yield components. The harvested crop was then threshed, cleaned, sun dried and weighed to record the yields of grain and straw at 14% moisture content. The yields of grain and straw were then converted into t ha^{-1}. The recorded data were analysed using "Analysis of variance" and mean differences were adjudged with Duncan's New Multiple Range Test.

Results and Discussion

Grain yield and its components were significantly influenced by water management (Table 1). It was observed that number of total tillers $hill^{-1}$, number of bearing tillers hill-^{1}, number of total spikelets $panicle^{-1}$, number of grains $panicle^{-1}$ were higher in SRI water management compared to BRRI water management. Finally, grain yield of *Boro* rice (cv. BRRI dhan29) was higher in SRI water management than that of BRRI water management. Improvement of yield components viz. number of bearing tillers $hill^{-1}$ and grains $panicle^{-1}$ were mainly responsible for this higher grain yield. Straw yield also exhibited similar trend as that of grain yield mainly due to the tallest plant and higher number of total tillers $hill^{-1}$. There are reports that higher grain yield of rice can be obtained through SRI water management (Randriamiharisoa, 2006; Ceesay *et al.*, 2006; Sato and Uphoff, 2007).

Grain yield and its components were significantly affected by fertilizer management (Table 2). The highest grain yield was obtained in BRRI fertilizer management followed in order by 50% BRRI recommended fertilizer + 50% poultry manure, 50% of the BRRI recommended fertilizer + 50% of the cowdung, poultry manure at 5 t ha^{-1} and cowdung at 10 t ha^{-1}. However, cowdung at 10 t ha^{-1} was as good as poultry manure at 5 t ha^{-1} in respect of grain yield. Yield components viz. number of bearing tillers $hill^{-1}$ and number of grains $panicle^{-1}$ exhibited similar trend due to fertilizer management and ultimately resulted in the improved grain yield. It was observed that BRRI fertilizer management produced the tallest plant, which was similar to 50% BRRI recommended fertilizer + 50% poultry manure and 50% of BRRI recommended fertilizer + 50% cowdung followed in order by poultry manure at 5 t ha^{-1} and cowdung at 10 t ha^{-1}. Number of total tillers $hill^{-1}$ was the highest in BRRI fertilizer management followed in order by 50% BRRI recommended fertilizer + 50% poultry manure, 50% BRRI recommended fertilizer + 50% cowdung, poultry manure at 5 t ha^{-1} and cowdung at 10 t ha^{-1}. However, poultry manure at 5 t ha^{-1} was as good as cowdung at 10 t ha^{-1} in producing total tillers $hill^{-1}$ (Table 2). The highest straw yield was found in BRRI recommended fertilizer management, which was similar to 50% BRRI recommended fertilizer + 50% poultry manure followed in order by 50% BRRI recommended fertilizer + 50% cowdung, poultry manure at 5 t ha^{-1} and cowdung at 10 t ha^{-1} (Table 2). However, cowdung at 10 t ha^{-1} and poultry manure at 5 t ha^{-1} produced similar straw yield. Panicle length, number of sterile spikelets $panicle^{-1}$, weight of 1000-grains and harvest index were not significantly affected by fertilizer management (Table 2). Findings of the experiment revealed that organic matter either in the form of cowdung or poultry manure should not be used as a substitute of inorganic fertilizer. However, they can be used to supplement inorganic fertilizer, which is especially exhibited in the straw yield of rice. Similar findings are available elsewhere (Dawe *et al.*, 2003 and Edmeades, 2003).

Table 1. Effect of water management on yield and yield components of *Boro* rice cv. BRRI dhan 29 under SRI method

Water Management	Plant height (cm)	Number of total tillers hill^{-1}	Number of bearing tillers hill^{-1}	Number of non-bearing tillers hill^{-1}	Panicle length (cm)	Number of total spikelets panicle^{-1}	Number of grains panicle^{-1}	Number of sterile spikelets panicle^{-1}	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
SRI water management	112.34	54.33 a	43.73 a	10.6	23.88	172.0 a	148.46 a	21.80 a	21.29	6.41 a	6.9 a	48.96
BRRI water management	112.14	48.91 b	39.86 b	9.2	21.26	162.0 b	142.93 b	19.60 b	21.55	5.86 b	6.3 b	48.19
Level of significance	NS	0.05	0.01	NS	NS	0.05	0.05	0.05	NS	0.05	0.05	NS

In a column, figures with same letter(s) or without letter(s) do not differ significantly whereas figures within dissimilar letter differ significantly (as per DMRT).
NS = Not significant

Table 2. Effect of fertilizer management on yield and yield components of *Boro* rice cv. BRRI dhan 29 under SRI method

Fertilizer management	Plant height (cm)	Number of total tillers hill^{-1}	Number of bearing tillers hill^{-1}	Number of non-bearing tillers hill^{-1}	Panicle length (cm)	Number of total spikelets panicle^{-}	Number of grains panicle^{-1}	Number of sterile spikelets panicle^{-1}	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
F_1	115.4a	65.5a	51.33a	14.17a	25.30	173.7a	153.0a	20.67	21.76	8.07a	8.40 a	48.80
F_2	108.3c	42.67d	34.17e	8.5c	23.23	158.8b	137.8b	21.00	21.29	4.28d	4.90 c	47.60
F_3	109.4bc	44.77d	37.17d	7.66d	23.73	157.0b	137.7b	19.33	21.20	4.78d	5.5 c	47.80
F_4	112.8ab	49.33c	41.00c	8.66c	23.73	168.0ab	147.3ab	20.67	21.41	6.20c	6.46 b	48.9
F_5	115.3a	55.83b	45.33b	10.56b	24.61	173.5a	151.8a	21.83	21.41	7.35b	7.90 a	48.6
Level of significance	0.01	0.01	0.01	0.01	NS	0.01	0.01	NS	NS	0.01	0.01	NS

In a column, figures with same letter(s) or without letter(s) do not differ significantly whereas figures within dissimilar letter differ significantly (as per DMRT).
NS = Not significant
F_1 = BRRI recommended fertilizer
F_2 = Cowdung @ 10 t ha^{-1}
F_3 = Poultry manure @ 5 t ha^{-1}
F_4 = 50% BRRI recommended fertilizer+ 50% of the cowdung
F_5 = 50% BRRI recommended fertilizer + 50% of the poultry manure

Table 3. Interaction effect of water and fertilizer management on the yield and yield components of *Boro* rice cv. BRRI dhan 29 under SRI method

Interaction (Water xfertilizer)		Plant height (cm)	Number of total tillers hill^{-1}	Number of bearing tillers hill^{-1}	Number of non-bearing tillers hill^{-1}	Panicle length (cm)	Number of total spikelets panicle^{-}	Number of grains panicle^{-1}	Number of sterile spikelets panicle^{-1}	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
SRI water management	F_1	116.16	68.67a	53.00a	15.67a	25.36	175.3a	153.0a	21.33	21.76	8.37a	8.7	48.82
	F_2	107.60	45.67d	36.33e	9.33e	23.56	161.3de	139.7de	21.66	21.08	4.57g	5.26	48.03
	F_3	110.20	46.33d	38.33d	8.00fg	23.36	165.7b cd	145.0bcd	20.66	21.16	4.97f	5.76	47.28
	F_4	112.03	52.00c	43.00c	9.00fef	24.09	172.7ab	151.0ab	23.66	21.08	6.56d	6.83	48.99
	F_5	115.63	59.00b	48.00b	11.00c	24.23	177.7a	153.7a	20.00	21.36	7.60b	8.00	48.71
BRRI water management	F_1	114.63	62.33b	49.67b	12.67b	25.23	174.7a	154.7a	20.00	21.76	7.76b	8.10	48.95
	F_2	108.86	39.67e	32.00f	7.66g	24.05	156.3e	13.6.0ef	20.33	21.50	4.00h	4.70	47.23
	F_3	108.63	43.22e	36.00e	7.33g	23.60	148.3f	130.3f	18.00	21.23	4.60g	5.23	48.45
	F_4	113.53	46.67de	39.00d	8.83efg	24.60	163.3cde	143.7cd	19.66	21.75	5.83e	6.10	48.86
	F_5	115.06	52.67c	42.67c	10.00cd	25.00	170.0abc	150.0abc	20.00	21.50	7.10c	7.80	48.56
Level of sign.		NS	0.05	0.05	0.05	NS	0.05	0.05	NS	NS	0.05	NS	NS

In a column, figures with same letter(s) or without letter(s) do not differ significantly whereas figures within dissimilar letter differ significantly (as per DMRT).
NS = Not significant
F_1 = BRRI recommended fertilizer
F_2 = Cowdung @ 10 t ha^{-1}
F_3 = Poultry manure @ 5 t ha^{-1}
F_4 = 50% BRRI recommended fertilizer+ 50% of the cowdung
F_5 = 50% BRRI recommended fertilizer + 50% of the poultry manure

Number of total tillers $hill^{-1}$ was significantly influenced by the interaction effect of water and fertilizer management (Table 3). The highest number of total tillers $hill^{-1}$ was found in SRI water management × BRRI recommended fertilizer dose followed by BRRI water management × BRRI recommended fertilizer dose and the lowest one was found in BRRI water management × cowdung @ 10 t ha^{-1}, which was statistically identical to BRRI water management × poultry manure @ 5 t ha^{-1}. Number of bearing tillers $hill^{-1}$ was significantly affected by the interaction between water and fertilizer managements. The highest number of bearing tillers $hill^{-1}$ was observed in SRI water management × BRRI recommended fertilizer dose followed by BRRI water management × BRRI recommended fertilizer dose, which was statistically identical to SRI water management × 50% BRRI recommended fertilizer + 50% poultry manure treatment. The lowest number of bearing tillers $hill^{-1}$ was recorded in BRRI water management × cowdung @ 10 t ha^{-1}. Number of non-bearing tillers $hill^{-1}$ was also influenced by the interaction of water and fertilizer management. The highest number of non-bearing tillers $hill^{-1}$ was found in SRI water management × BRRI recommended fertilizer dose and the lowest one was in BRRI water management × poultry manure @ 5 t ha^{-1}, which was statistically identical to BRRI water management × cowdung @ 10 t ha^{-1}.

The number of total spikelets $panicle^{-1}$ and number of grains $panicle^{-1}$ were affected by water and fertilizer management. The highest number of spikelets $panicle^{-1}$ and number of grains $panicle^{-1}$ were found in SRI water management × BRRI recommended fertilizer dose, which was similar to that of SRI water management × 50% BRRI recommended fertilizer + 50% poultry manure and BRRI water management × cowdung @ 10 t ha^{-1}. The lowest number of spikelets $panicle^{-1}$ and number of grains $panicle^{-1}$ were found in BRRI water management × poultry manure @ 5 t ha^{-1} treatments.

Grain yield was significantly influenced by the interaction of water and fertilizer management. The highest grain yield was found in SRI water management × BRRI recommended fertilizer dose followed in order by BRRI water management × BRRI recommended fertilizer dose, which was statistically identical to SRI water management × 50% BRRI recommended fertilizer + 50% poultry manure. The lowest grain yield was obtained from BRRI water management × cowdung @ 10 t ha^{-1}. Plant height, panicle length, number of sterile spikelets $panicle^{-1}$, weight of 1000 grains, straw yield and harvest index were not significantly influenced by the interaction of water and fertilizer management.

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