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Yield Maximization of Rice (*Oryza sativa*) through Integrated Nutrient Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This experiment was conducted on a permanent layout at the west byde of BRRI farm, Gazipur during T. Aman 2019 to Boro 2021-22 to find out the suitable management practices for yield maximization of rice and soil health. Seven treatments in Randomized Complete Block (RCB) Design with three replications were imposed and each treatment was assigned in 5m × 4m sized plot. The treatments combinations were T1= Absolute Control (No nutrient supply), T2 = BRRI dose N-P-K-S@83-17-53-12 kg ha-1 in T. Aman and 138-21-75-21 kg ha-1 in Boro season, T3= Soil Test Based (STB) Fertilizer Dose N-P-K-S @ 67-10-40-10 kg ha-1 in T. Aman and 134-16-75-10 kg ha-1 in Boro, T4 = STB dose + 1 t ha-1 Cowdung, T5 = STB dose + 1 t ha-1 Poultry manure, T6 = STB dose + 1 t ha-1 Vermicompost and T7 = STB dose + 0.33 t ha-1 CD + 0.33 t ha-1 PM + 0.33 t ha-1 VC. Thirty-days old seedling of BRRI dhan87 in T. Aman and fourty-two days old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm × 20 cm spacing in both seasons. All manures, soil and plant samples analysis were done by the help of soil Science Division BRRI, Gazipur. Initial soil (0-15 cm depth) properties were: soil texture, clay loam; pH, 6.94; organic Carbon, 1.59%; Nitrogen, 0.18%; Phosphorus, 21.88 ppm and Potassium, 0.19meq/100g soil. Thirty days old seedling of BRRI dhan87 in T. Aman and 42 days old seedling of BRRI dhan89 in Boro season were transplanted at 20cm x 20cm spacing. Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different integrated nutrient management during both T. Aman and Boro season. Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different nutrient management in both T. Aman and Boro season. Poultry manure related treatments and BRRI recommended dose performed better than the others in all the parameter except 1000-grain weight. On the other hand, Absolute Control (No nutrient supply) produced the lowest result. Every parameter, Poultry manure treatments have been performed the best. STB dose with one t ha-1 poultry manure is better for maximization of rice yield.

Keywords: Cowdung; poultry manure; vermicompost; yield maximization; soil fertility; rice (Oryza sativa).

1. INTRODUCTION

Rice is the staple food for the 170 million people of the country and is grown on around 10.5 million ha [1]. It's an indispensable food for more than 50% of the world's population. Its requirement is increasing rapidly for fulfilling the demand of ever growing human population. To meet the rising demand, different approaches are being practiced such as maximizing rice production with the application of different fertilizers [2,3], the integrated use of organic fertilizer with inorganic fertilizer. The global annual production of rice is about 496.40 million tons from 162.06 million hectares of land in 2019–2020 [4]. Globally, agriculture is becoming challenging because of climate change and soil health degradation. Organic matter (OM) is a vital component to keep soil alive and productive and for providing better ecosystem services [5,6,7]. Along with global agriculture, Bangladesh also faces the challenge of producing crops from its limited land resources to meet the huge demand from its population. Moreover, every year, cultivated land is being reduced due to human settlement and rapid urbanization and industrialization. Therefore, the intensification of land with modern crop varieties for increased production is crucial [8]. Although modern rice varieties have the highest yield, there is still a serious yield gap. In Bangladesh, the lack of judicial nutrient management is considered as the major causes of yield gap in rice production. An imbalanced use of inorganic fertilizers and pesticides without organic fertilizers has led to deterioration of soil health and crop yield loss which has become a concern. More dependency on chemical fertilizers and imbalanced nutrient management practices has impaired the productivity of soils in many Asian countries including Bangladesh. Increased the cropping intensity and regular cultivation of high-yielding rice varieties has increased the removal of nitrogen (N), phosphorus (P), potassium (K) and other macro and micro-nutrients from the soils in Bangladesh [9].

Soil OM content is reported to be declining, which is considered as one of the most serious threats in Bangladesh agriculture [10]. The integration of all organic, natural and inorganic sources of nutrients is an efficient and

environmentally friendly technology of crop production which is known as integrated nutrient management (INM). Management practices such as diversified cropping systems and the application of different organic wastes and optimum fertilization, are believed to offer high potential for increasing the nutrient-use efficiency, carbon © levels in soils, and the crop yield [7,10,5,11]. In addition, the release pattern of inorganic fertilizers compared to organic ones are higher [8]. On the other hand, organic fertilizers are decomposed slowly and nutrients are available for a longer period of time which helps to maintain soil nutrient status. However, most of the soils of Bangladesh have an OM content that is less than 1.5% and, in many cases, it is less than 1% [12]. Hence, a large amount of N fertilizer is used to increase soil fertility and crop productivity. Excess N may enhance mineralization of OM, which may decrease soil C content and increase in carbon dioxide (CO_2) emission. Cowdung (Cd) Poultry manure (PM) and vermicompost (VC) are the potential organic sources of soil organic C and plant nutrients [13,14]. Many reports showed that Cd, PM and VC are the source of N, P, K, Ca, Mg, and S that can improve the soil fertility and plant can uptake more of these nutrients [8,13,7]. As Cowdung increases the fertility of the soil by increasing the nutrients in it. VC is rich in microbial activity and contains antagonistic organisms to control plant pathogens, it is also an effective biocontrol agent [15]. Jorgensen et al. [16] reported that adding cowdung, PM and VC in particular increases the contents of organic carbon (OC) and of microbial biomass, the cation exchange capacity, and the biological activities of soils. The above findings suggest that organic matter along with inorganic fertilizers can improve soil fertility as well as soil organic C than when applied alone. The soils of Bangladesh have low reserves of C and plant nutrients due to increasing cropping intensity, higher rates of decomposition of organic matter under prevailing hot and humid climate, use of lesser quantity of organic manure, and little or no use of green manure [8]. It is predicted that the crop production of Bangladesh would be tremendously vulnerable to climate change and, therefore, the food security will be at risk. The addition of C-enriched materials such as cowdung, PM and VC improves soil physical, chemical, and biological characteristics. The improvement of soil properties favors the development of the crop root system, elongating it both at the surface level and in the deep soil, which ultimately helps to accumulate more C in the soil. The continuous application of organic manure builds up the soil C content and ensures an adequate N supply. The soil organic C pool in agricultural land is capable of enhancing agricultural sustainability and serving as a potential sink of atmospheric CO_2. The objectives of this study were to find out the suitable integrated nutrient management practice for yield maximization of rice and soil health.

2. MATERIALS AND METHODS

This experiment was initiated on a permanent layout at the west byde of BRRI farm, Gazipur during T. Aman 2019 to Boro 2021-22 to find out the suitable management practice for yield maximization of rice and soil health. Seven treatments in Randomized Complete Block (RCB) Design with three replications were imposed and each treatment was assigned in 5m × 4m sized plot. The treatments combinations were T_1= Absolute Control (No nutrient supply), T_2 = BRRI dose N-P-K-S@83-17-53-12 kg ha^{-1} in T. Aman and 138-21-75-21 kg ha^{-1} in Boro season, T_3= Soil Test Based (STB) Fertilizer Dose N-P-K-S @ 67-10-40-10 kg ha^{-1} in T. Aman and 134-16-75-10 kg ha^{-1} in Boro, T_4 = STB dose + 1 t ha^{-1} Cowdung, T_5 = STB dose + 1 t ha^{-1} Poultry manure, T_6 = STB dose + 1 t ha^{-1} Vermicompost and T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC**.** Thirty**-**days old seedling of BRRI dhan87 in T. Aman and fourty-two days old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm × 20 cm spacing in both seasons. All manures, soil and plant samples analysis were done by the help of soil Science Division BRRI, Gazipur. Initial soil (0-15 cm depth) properties were: soil texture, clay loam; pH, 6.94; organic Carbon, 1.59%; Nitrogen, 0.18%; Phosphorus, 21.88 ppm and Potassium, 0.19meq/100g soil. Thirty days old seedling of BRRI dhan87 in T. Aman and 42 days old seedling of BRRI dhan89 in Boro season were transplanted at 20cm x 20cm spacing. The flooded water level at 5-7 cm depth was maintained during rice cultivation, and drained out the water 21 days before rice harvesting. Yield and Yield components were collected at harvesting time. Collected data were statistically analyzed using a standard statistical procedure (Crop stat 7.2).

3. RESULTS AND DISCUSSION

Grain yield, tiller number, panicle number, plant height and Grain number were significantly

affected by the different nutrient management in both T. Aman and Boro season. Poultry manure related treatments and BRRI recommended dose performed better than the others in all the parameter except 1000-grain weight. On the other hand, Absolute Control (No nutrient supply) produced the lowest result. The details have discussed below.

Plant height: Different nutrient management have significant effects in rice plant height. In T. Aman season 2019 and 2021, the tallest rice plant (126.27 cm) was found in the STB dose + 1 t/ha Poultry manure management. The smallest rice plant (114.40 cm) was found in the Absolute control plot (Table 1).

In T. Aman season 2020, the tallest rice plant (129.64 cm) was found in the BRRI recommended dose, which is statistically similar with other nutrient management doses except absolute control. The smallest rice plant (124.87 cm) was found in the Absolute control plot.

And in T. Aman season 2021, the tallest rice plant (125.69 cm) was found in the STB dose with 1 t ha^{-1} Poultry manure, which is statistically similar with other nutrient management doses except absolute control. The smallest rice plant (121.27 cm) was found in the absolute control plot (Table 1).

During Boro season 2019-20, 2020-21 and 2021-22 STB dose, BRRI dose, STB dose + 1 t/ha Poultry litter, STB dose + 1t/ha cowdung, STB dose + 1t/ha Vermicompost and STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC used plot gave almost similar plant height which was statistically significant from control plot. STB dose provides the tallest plant (101.99 cm) whereas control plot gave the smallest plant (96.40 cm) in 2019-20.

STB dose with 1 t/ha, poultry litter provides the tallest plant (105.03 cm) whereas control plot gave the smallest plant (96.98 cm) in 2020-21.

STB dose with 1 t ha^{-1} poultry manure showed the tallest plant (103.82 cm) whereas control plot gave the smallest plant (94.37 cm) in 2021-22. (Table 1)

Tiller number: Tiller production varies significantly among the different nutrient management in T. Aman season 2019-21. STB dose + 1t/ha poultry litter plot produced statistically highest tiller number followed by others treatment. In T.Aman 2019, STB dose + 1t/ha poultry litter gave the highest number of tiller (314 tiller m^{-2}) whereas control plot gave the lowest number of tiller (230 tiller m^{-2}) among all the treatments.

In T. Aman season 2020, STB dose + 1t/ha poultry litter gave the highest number of tiller (296 tiller m^{-2}) whereas control plot gave the lowest number of tiller (204 tiller m^{-2}) among all the treatments.

In T. Aman season 2021, STB dose + 1 t ha^{-1} poultry manure gave the highest number of tiller (286 tiller m^{-2}) and the second highest STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC (273 tiller m^{-2}) whereas control plot gave the lowest number of tiller (207 tiller m^{-2}) among all the treatments (Table 1).

Tiller production varies significantly among the different nutrient management in Boro season 2019-20, STB dose + 1t/ha poultry litter plot produced statistically highest tiller number (257 tiller m^{-2}) followed by others treatment. whereas control plot gave the lowest number of tiller (202 tiller m^{-2}) among all the treatments.

In Boro season 2020-21, STB dose + 1t/ha poultry litter gave the highest number of tiller (283 tiller m^{-2}) whereas control plot gave the lowest number of tiller (210 tiller m^{-2}) among all the treatments

In Boro season 2021-22, STB dose + 1 t ha^{-1} poultry manure plot produced statistically the highest tiller number (275 tiller m^{-2}) followed by others treatment whereas control plot gave the lowest number of tiller (202 tiller m^{-2}) among all the treatments (Table 1).

Panicle number: Panicle production was significantly affected by all the nutrient management during T. Aman season 2019-21. Here BRRI fertilizer dose and STB dose + poultry litter used plot gave statistically similar panicle number. In T. Aman 2019, the highest number of panicle (303 panicle m^{-2}) found in STB dose + 1t/ha poultry manure. The lowest number of panicle (223 panicle m^{-2}) among all the treatments was observed in control plot.

In T. Aman 2020, the highest number of panicle (274 panicle m^{-2}) found in STB dose + 1t/ha poultry manure and the lowest number of panicle (180-panicle m^{-2}) among all the treatments was observed in control plot.

Table 1. Yield and yield components of rice under different fertilizer management in T. Aman 2019-2021 and Boro 2019-2022

Treatments	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain $panicle^{-1}$ (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})
T. Aman (BRRI dhan87), 2019						
T_1	114.40	230	223f	98	24.10	3.90
T_2	125.33	302	292	110	23.67	5.12
T_3	122.60	252	241	99	24.17	4.34
T_4	125.53	294	283	101	24.43	4.98
T_5	126.27	314	303	117	24.27	5.52
T_6	123.90	264	255	112	24.40	4.56
T_7	124.43	279	268	99	23.98	4.67
LSD at 5% level	2.22	10.45	11.02	10.12	0.84	0.42
CV %	2.98	9.55	8.46	8.90	3.48	9.55
Boro (BRRI dhan89), 2019-20						
T_1	96.40	202	198	110	24.59	3.16
T_2	100.54	253	244	154	24.99	7.90
T_3	101.99	245	238	139	24.73	6.32
T_4	99.22	249	242	153	24.63	7.36
T_5	101.10	257	254	158	24.87	8.16
T_6	98.98	247	238	141	24.67	6.54
T_7	99.55	248	240	149	24.97	7.00
LSD at 5% level	2.25	7.45	8.92	9.12	0.75	0.48
CV %	3.28	7.98	7.66	7.09	3.32	7.67
T. Aman (BRRI dhan87), 2020						
T_1	124.87	204	180	90	22.10	3.40
T_2	129.64	278	257	102	22.57	5.89
T_3	126.87	263	246	97	22.34	5.46
T_4	128.30	281	267	96	22.47	5.75
T_5	129.23	296	274	104	22.52	6.53
T_6	128.57	285	266	104	22.43	6.11
T_7	128.57	278	255	98	22.37	5.64
LSD at 5% level	3.32	13.50	12.23	8.89	0.68	0.48
CV %	3.77	10.12	9.54	9.12	5.09	10.95

Boro (BRRI dhan89), 2020-21						
T_1	96.98	210	190	110	22.28	4.48
T_2	104.53	275	258	148	22.82	8.52
T_3	104.63	258	242	146	22.83	7.89
T_4	105.03	265	248	145	22.90	8.10
T_5	104.55	283	263	152	22.88	8.90
T_6	104.40	269	257	147	22.85	8.49
T_7	104.60	260	242	147	22.81	7.95
LSD at 5% level	2.84	7.45	8.92	9.12	0.67	0.46
CV %	3.28	7.98	7.66	7.09	3.32	9.80
T. Aman (BRRI dhan87), 2021						
T_1	121.27	207	188	95	22.25	3.23
T_2	125.43	266	251	101	22.55	5.59
T_3	122.20	258	242	98	22.12	5.20
T_4	120.27	271	259	99	22.68	5.42
T_5	125.69	286	271	102	22.56	5.81
T_6	123.33	266	257	102	22.32	5.39
T_7	122.37	273	254	97	22.38	5.34
LSD at 5% level	3.33	10.95	7.58	4.31	0.65	0.21
CV %	2.17	8.92	8.51	9.05	3.14	10.20
Boro (BRRI dhan89), 2021-22						
T_1	94.37	202	182	108.02	22.30	4.16
T_2	103.27	274	246	139.54	22.46	6.78
T_3	101.60	258	237	139.28	22.47	6.37
T_4	101.33	270	247	138.98	22.49	6.48
T_5	103.82	275	250	139.77	22.56	7.02
T_6	102.93	268	246	139.28	22.53	6.65
T_7	102.17	264	240	140.15	22.57	6.47
LSD at 5% level	6.11	9.24	10.82	2.97	0.16	0.16
CV %	2.36	8.14	7.75	4.20	2.57	8.87

T_1 = Absolute control; T_2 = BRRI recommended dose N-P-K-S@83-17-53-12 kg ha^{-1}
T_3 = Soil Test Based (STB) Fertilizer dose N-P-K-S@67-10-40-10 kg ha^{-1}
T_4 = STB dose + 1 t ha^{-1} cowdung
T_5 = STB dose + 1 t ha^{-1} poultry manure
T_6 = STB dose + 1 t ha^{-1} vermicompost and
T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33t ha^{-1} PM + 0.33 t ha^{-1} VC.

During T. Aman season 2021, the highest number of panicle (271 panicle m^{-2}) was found in STB dose + 1 t ha^{-1} poultry manure used plot. The lowest number of panicle (188-panicle m^{-2}) among all the treatments was observed in absolute control plot (Table 1).

Panicle production was significantly affected by all the nutrient management during Boro season 2019-20, 2020-21 and 2021-22. Here STB dose + poultry litter used plot gave statistically highest panicle number. The lowest number of panicle among all the treatments was observed in control plot (Table 1).

Grain number and grain weight: During T. Aman season 2019, STB dose + 1 t/ha Poultry litter provides the highest number of grain per panicle (117 grain panicle^{-}1) whereas control plot gave the lowest number of grain (98 grain panicle^{-1}). And there was no significant difference among the treatments in case grain weight.

In T.Aman 2020, STB dose + 1 t/ha Poultry litter and STB dose + 1 t/ha vermicompost plot provide the highest number of grain per panicle (104 grain panicle^{-}1) whereas control plot gave the lowest number of grain (90 grain panicle^{-1}). In addition, there was no significant difference among the treatments in case grain weight.

In T. Aman season 2021, the all-nutrient management plot except absolute control plot gave almost similar number of grains per panicle. STB dose + 1 t ha^{-1} Poultry manure and STB dose + 1 t ha^{-1} vermicompost plot gave the highest number of grains per panicle (102 grain panicle^{-}1) whereas control plot gave the lowest number of grain (95 grain panicle^{-1}). In addition, there was no significant difference among the treatments in case grain weight (Table 1).

During Boro season 2019-20, STB dose + 1 t/ha Poultry litter provides the highest number of grain per panicle (158 grain panicle^{-}1) whereas control plot gave the lowest number of grain (110 grain panicle^{-1}).

In Boro season 2020-21, STB dose + 1 t/ha Poultry litter provides the highest number of grain per panicle (152 grain panicle^{-}1) whereas control plot gave the lowest number of grain (110 grain panicle^{-1}). On the other hand, there was no significant difference among the treatments in case grain weight.

In Boro season 2021-22, STB dose + 1 t ha^{-1} Poultry manure, BRRI dose, STB dose + 1 ha^{-1} cowdung STB dose + 1 t ha^{-1} VC, STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC and STB dose used plot gave almost similar number of grains per panicle which was statistically significant from control plot. STB dose + 1 t ha^{-1} Poultry manure provides the highest number of grains per panicle (139.77 grain panicle^{-1}) whereas control plot gave the lowest number of grain (108.02 grain panicle^{-1}). On the other hand, there was no significant difference among the treatments in case of grain weight (Table 1).

Grain yield: During T. Aman season 2019-21 Grain yield was significantly affected by different nutrient management practices. In 2019, STB dose + 1 t/ha poultry manure (5.52 t ha^{-1}) and BRRI dose (5.12 t ha^{-1}) gave the highest and statistically similar grain yield. The lowest yield was observed in control plot (3.90 t ha^{-1}).

During T. Aman season 2020, STB dose + 1 t/ha poultry manure (6.53 t ha^{-1}) and STB dose + 1 t/ha Vermicompost (6.11 t ha^{-1}) gave the highest grain yield and the lowest yield was observed in control plot (3.40 t ha^{-1}).

In T. Aman 2021, STB dose + 1 t ha^{-1} poultry manure (5.81 t ha^{-1}) and BRRI recommended dose (5.59 t ha^{-1}) produced the highest grain yield and the lowest yield observed in absolute control plot (3.23 t ha^{-1}) (Table 1).

During Boro season 2019-20, 2020-21 and 2021-22, grain yield was significantly affected by different nutrient management practices. In 2019-20, STB dose + 1 t/ha poultry manure (8.16 t ha^{-1}) and BRRI dose (7.90 t ha^{-1}). The lowest yield was observed in control plot (3.16 t ha^{-1}).

In 2020-21, STB dose + 1 t/ha poultry manure (8.90 t ha^{-1}), BRRI dose (8.52 t ha^{-1}) and STB dose + 1 t/ha VC (8.49 t ha^{-1}) gave the highest and statistically similar grain yield and the lowest yield was observed in control plot (4.48 t ha^{-1}).

In Boro season 2021-22, STB dose + 1 t ha^{-1} poultry manure gave the highest grain yield (7.02 t ha^{-1}). The lowest yield was observed in control plot (4.16 tha^{-1}) (Table 1).

Initial soil (0-15 cm depth) properties: Initial soil (0-15cm depth) properties of this experimental field were: soil texture, clay loam; pH, 6.94; organic Carbon, 1.59%; Nitrogen, 0.18%; Phosphorus, 21.88 ppm and Potassium, 0.19meq/100g soil (Table 2).

Table 2. Initial soil (0-15 cm depth) properties were-

Soil texture	pH	% OC	% Total N	Available P (ppm)	Available K (meq/100g soil)
Clay loam	6.94	1.59	0.18	21.88	0.19

Table 3. Chemical properties of soil after rice harvest under different fertilizer management in T. Aman and Boro seasons

Treatment	% OC	% Total N	Available P (ppm)	Available K (meq/100g soil)	Available S (ppm)
T1	1.160	0.117	19.150	0.134	26.035
T2	1.210	0.110	17.933	0.130	23.263
T3	1.240	0.131	21.200	0.137	26.223
T4	1.280	0.126	21.300	0.147	29.425
T5	1.210	0.128	23.833	0.141	29.948
T6	1.170	0.124	22.100	0.133	24.435
T7	1.190	0.112	20.750	0.128	24.835

Chemical properties of soil after harvest: The highest % OC and available K (meq/100g soil) were found from the treatment T_4 = STB dose + 1 t ha^{-1} cowdung application plot. The highest % total N was found from the treatment T_3 = Soil Test Based (STB) Fertilizer dose N-P-K-S@67-10-40-10 kg ha^{-1} application plot. The highest available P (ppm) and available S (ppm) were found from the treatment T_5 = STB dose + 1 t ha^{-1} poultry manure application plot (Table 3).

4. CONCLUSIONS

Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different integrated nutrient management practices during both T. Aman and Boro season. Every parameter, Poultry manure treatments have been performed the best. This study indicates STB dose with one t ha^{-1} Poultry manure is better for maximization of rice yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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