

PERFORMANCE OF WASTE CONCERN ORGANIC FERTILIZER ON THE GROWTH AND YIELD OF T. AMAN RICE IN TWO AEZs OF BANGLADESH

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Abstract

Two field experiments were conducted in two AEZs of Bangladesh viz. AEZ 28 and AEZ 3 to test the performance of waste concern organic fertilizer (WCOF) on the growth and yield of T. aman rice. The test sites were selected in the BRRI farm, Gazipur under AEZ 28 and BRRI farm Rangpur under AEZ 3. The experiments were done by using six treatments where T₁ = Absolute control, T₂ = NPKS @ 80-35-40-10 kg/ha, T₃ = T₂ + 1 t WCOF/ha, T₄ = 75% of T₂ + 1 t WCOF/ha, T₅ = 50% of T₂ + 2 t WCOF/ha and T₆ = 2 t WCOF/ha. The application of WCOF in combination with chemical fertilizer significantly increased plant height, panicle number, grain and straw yields of T. aman rice over control in both AEZs. It was observed that the application of WCOF @ 1 t/ha + 75% of T₂ (NPKS @ 80-35-40-10 kg/ha) produced higher yields. The study revealed that the treatments T₄ and T₅ may be the most economically viable fertilizer management packages for T. aman rice cultivation in AEZ 28 while the treatment T₄ may be recommended for AEZ 3.

Introduction

Global food production increased by 70% from 1970 to 1995 in developing countries, largely due to the green revolution technologies which use high-yielding inputs such as high-yielding varieties (HYVs), irrigation, chemical fertilizers and synthetic pesticides^(1,2). Though the green revolution technologies have increased crop yields and produced more food to meet the caloric requirements of the global population⁽³⁾. These technological development aggravates the situation with more environmental hazards, such as increased soil erosion, surface and groundwater contamination, greenhouse gas emissions, increased pest resistance and reduced biodiversity^(4,5). These concerns suggest that more sustainable methods of food production are essential to meet the food requirements of ever-increasing population but at the same time sustaining natural resource base by avoiding land degradation and mitigating climate change⁽⁶⁾. Over the last 2 - 3 decades, organic agriculture has been advocated as an alternative form of farming to produce food sustainably by reducing the impact on agriculture and the environment^(7,8).

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As a result of intensive agriculture, a significant amount of SOC stock has been lost from agricultural soils. This loss of SOC stock was approximately 60 and 75% of total SOC storage at the tropical ecosystems^(9, 10). In South Asia, soil C in the agricultural soils ranged from 8 to 10 g/kg, a low level resulting from nutrient depletion, intensive tillage, erosion, unbalanced fertilization, and residue removal⁽¹¹⁾. In Bangladesh alone about 16.2 Mg C/ha was removed from a soil between 1967 and 1995 due to intensive agricultural practices⁽¹¹⁾. A considerable decrease in crop production in long-term research sites across the South Asia also suggests a loss of SOC in agricultural soils in this region^(12, 13, 14). Depletion of inherent capacity of soil in sustaining crop production is the great challenge for improving food security and sustainability of agriculture⁽¹⁵⁾. Nutrient mining in Bangladesh soils has been noted as a serious threat for crop production. A study shows that a total loss of 1.25 million tons of N, P and K from the agricultural soils of Bangladesh every year where loss of K alone is the highest and has been reported to be more than one million tons per year⁽¹⁶⁾. In Bangladesh, nutrient depletion (kg/ha/year) in arable farming is seen for N (16), P (1) and K (26) where K depletion rate is highest⁽¹⁷⁾. Global soil nutrient depletion is related to yield reduction and the depletion rate is at an average rate (kg/ha/year) of N (18.7), P (5.1), and K (38.8) where K depletion rate is also highest⁽¹⁸⁾. Considering the above facts, an experiment was undertaken to evaluate the performance of WCOF on the growth and yield of T. aman rice.

Materials and Methods

The waste concern organic fertilizer (WCOF) developed by waste concern Jaiba Sar Company Bangladesh Ltd. is a nutrient enriched organic fertilizer. Physically, it is dark grayish brown in color, soft bodied granular size and odorless. Chemically, it contains 23% organic C, 2% total N, 1.7% P, 2.6% K, 0.25% S, 0.04% Zn and 16.3% moisture. The content of heavy metals is less than permissible level. Two field experiments were conducted at BRRI Farm, Gazipur and Rangpur during T. aman season, 2008. Soil samples were air-dried, ground and passed through a 2 mm sieve and preserved for the analyses of initial soil characteristics (Table 1). Organic carbon in soil was determined by the wet oxidation method⁽¹⁹⁾. Soil textural class was determined by hydrometer method⁽²⁰⁾. Soil pH was measured at a soil-water ratio 1 : 2.5 using Hanna 212 pH meter.

Available sulphur was extracted with calcium di-hydrogen phosphate and was determined by turbid metrically⁽²¹⁾. Zinc was extracted using DTPA⁽²²⁾ and was determined by using an atomic absorption spectrophotometer 7000 manufactured by Shimadzu, Japan. Ammonium acetate extractable K⁽²³⁾ was determined by flame photometer 410 manufactured by Sherwood, Japan. Total nitrogen was determined by Kjeldahl's method as described⁽²⁴⁾. Available phosphorus from acid soil was extracted using the Bray 2 method⁽²⁵⁾. As per soil chemical datasets, the study sites belongs to strongly acidic to slightly acidic reaction with very low organic carbon contents⁽²⁶⁾.

The study sites bear low nutrients capacities specifically K deficient soils. A study shows that the lowest K was found in the rice based farming system where K mining is widespread⁽²⁷⁾.

Six treatment combinations were tested: T₁ = Absolute control (Native nutrients), T₂ = NPKS @ 80-35-40-10 kg/ha, T₃ = T₂ + 1 t WCOF/ha, T₄ = 75% of T₂ + 1 t WCOF/ha, T₅ = 50% of T₂ + 2 t WCOF/ha and T₆ = 2 t WCOF/ha. The experiments were laid out in randomized complete block design with four replications. The sources of nutrients were urea, triple superphosphate (TSP), muriate of potash (MoP) and gypsum, respectively. All TSP, MoP, gypsum and WCOF were applied at the time of final land preparation. Urea was applied into three equal splits: 1/3rd as basal, 1/3rd at early tillering stage and the remaining 1/3rd at 5 - 7 days before panicle initiation stage. BRRRI dhan31 and BRRRI dhan46 were used as a test crop at Gazipur and Rangpur sites, respectively. Thirty five days old 2-3 seedlings/hill were transplanted with 20 cm × 20 cm spacing. Necessary intercultural operations were done as required. At maturity, the crop was harvested from 5 m² area at the centre of each plot and grain yield was adjusted to 14% moisture. The plant height, tiller no, panicle no, grain and straw yields were recorded. The datasets were analyzed following IRRISTAT version 4.1⁽²⁸⁾. Finally economic analyses were made for added return, net return, and marginal benefit cost ratio (MBCR)⁽²⁹⁾.

Table 1. Initial soil characteristics of the experimental plots of BRRRI farm.

Parameters	BRRRI Farm, Gazipur	BRRRI Farm, Rangpur
Texture	Clay-loam	Sandy-loam
pH (1 : 2.5)	6.1	5.1
Organic C (%)	1.2	1.1
Total N (%)	0.07	0.08
Available P (mg/kg)	10.1	25.0
Exchangeable K (cmol/kg)	0.17	0.13
Available S (mg/kg)	6.1	3.9
Available Zn (mg/kg)	2.8	1.3

Results and Discussion

Application of WCOF in combination with chemical fertilizer significantly increased plant height, panicle number, grain and straw yield of BRRRI dhan31 and BRRRI dhan46 over control at both Gazipur and Rangpur sites (Tables 2 and 3). In BRRRI Farm, Gazipur, the treatments T₂, T₃, T₄ and T₅ produced statistically identical plant height and panicle number/m², which showed higher vegetative growth than that of treatment T₆ and T₁ (Table 2). The highest tiller number/m² (268) was obtained with treatment T₃ followed by T₅ (254). In BRRRI Farm, Rangpur, the highest plant height was found in treatment T₃

(126.6 cm) followed by T₄ (123.7 cm) and T₂ (123.2 cm). It was significantly higher than that of T₆ and T₁. The treatment T₃ produced the highest number of panicle/m² (225). It was also significantly higher than that of other treatments (Table 2).

Table 2. Effects of waste concern organic fertilizer on plant height (cm), tiller and panicle number in T. aman season at BRRi farms.

Treatments	Plant height (cm)		Tiller/m ²		Panicle/m ²	
	Gazipur site	Rangpur site	Gazipur site	Rangpur site	Gazipur site	Rangpur Site
T ₁	92.1 d	112.7b	203c	208	192b	188bc
T ₂	105.2 ab	123.2a	246b	247	234a	211ab
T ₃	107.0 a	126.6a	268a	252	251a	225a
T ₄	107.6 a	123.7a	251b	240	235a	210ab
T ₅	101.4 bc	119.2ab	254ab	237	243a	205abc
T ₆	96.5 c	113.4b	207c	204	196b	176c
LSD _{0.05}	5.3	7.9	15	NS	17	31
CV (%)	3.4	4.4	4.1	11	4.9	10

Means with same letter in a column are not significantly different at 5% level of probability.

Applied fertilizer significantly increased the grain yield of rice at both locations (Table 3). In BRRi Farm, Gazipur, the highest grain yield of 3.66 t/ha was obtained with the treatment T₅ followed by the treatments T₄ and T₂. These treatments were statistically identical and showed higher vegetative growth than T₆ and T₁. Per cent grain yield increased over control treatment T₃ produced the significantly highest straw yield of 6.39 t/ha (Table 3).

In BRRi Farm, Rangpur the highest grain yield of 5.17 t/ha was obtained with the treatment T₃, which was statistically identical with that of T₄. The yield increased by 16 - 20% over the control plot. All the treated plots (T₂ - T₆) produced statistically identical straw yield (Table 3). From the above results, it is observed that the application of WCOF @ 1 t/ha + 75% of T₂ (NPKS @ 80-35-40-10 kg/ha) performed with higher yields.

The estimated total variable cost (TVC), gross return, for added return, net return and marginal benefit cost ratio (MBCR) are presented in Table 4. Economic analysis was done considering the fertilizer cost, fertilizer application cost and labor cost for the additional products. At Gazipur site, the application of fertilizer increased the gross and net return with all the treatments (Table 4b). The gross return from the control plot was only about Tk. 56,740.00 per ha and the application of fertilizer increased the gross return, where Tk. 66,680.00 per ha by the treatment T₆ and Tk. 77,000.00 per ha by the treatment T₅. The highest net-return of Tk. 58,644.00 per ha was obtained with the treatment T₆ followed by treatment T₄ (Tk. 58,522.00 per ha). The highest added-return of

Tk. 20,260.00 per ha was obtained with the treatment T₅ followed by treatment T₄ (Tk. 19,660.00). The highest MBCR was obtained with the treatment T₆ (1.24) followed by treatment T₅ (1.10) and treatment T₄ (1.00). The treatments T₄ and T₅ may be the most economically viable fertilizer management packages for T. aman rice cultivation at BRRF Farm, Gazipur under AEZ 28.

Table 3. Effects of waste concern organic fertilizer on grain and straw yield (t/ha) in T. aman season at BRRF farms.

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		% grain yield increase over control	
	Gazipur site	Rangpur site	Gazipur site	Rangpur site	Gazipur site	Rangpur site
T ₁	2.71 c	4.31 c	3.98 c	4.76 b	-	-
T ₂	3.39 ab	4.58 bc	5.38 b	5.48 a	25	6
T ₃	3.33 ab	5.17 a	6.39 a	5.54 a	23	20
T ₄	3.62 a	5.00 a	5.62 b	5.44 a	34	16
T ₅	3.66 a	4.63 abc	5.56 b	5.38 a	35	7
T ₆	3.25 b	4.45 bc	4.09 c	5.22 a	20	3
LSD _{0.05}	0.30	0.46	0.57	0.44		
CV (%)	6.0	6.5	7.3	5.5		

Means with same letter in a column are not significantly different at 5% level of probability.

For Rangpur site, similarly the application of fertilizer also increased the gross and added return (Tk/ha) in all the treatments. The gross return from the control plot was only about Tk. 87100.00 per ha and the application of fertilizer increased the gross return Tk. 90540.00 per ha in treatment T₆ and Tk. 104140.00 per ha in treatment T₃. The highest added-return of Tk. 17040.00 per ha was obtained with the treatment T₃ and Tk. 13780.00 per ha by the treatment T₄. In terms of MBCR, the treatments T₄ and T₃ (Table 4b) performed the best among the tested treatment here under AEZ 3.

Soil organic carbon equilibrium means that SOC remains stable when land use, land management, and environmental properties (such as climate, CO₂ concentration or nitrogen deposition) do not change either. An equation proposed by ⁽³⁰⁾, which is most appropriate to explain the SOC equilibrium situation in the soils of Bangladesh. The equation is $dc/dt = -kC + A$. Where, dc/dt = rate of SOC change, k = decomposition constant, C = SOC content at a time t , A = Accretion constant. The magnitude of A depends on land use and management. So, the difference between kC and A that determines the rate of SOC change. Soil degradation processes decrease SOC and increase the magnitude of decomposition constant k , and, in contrast, soil restorative processes increase SOC and decrease the magnitude of decomposition constant k ⁽³¹⁾. In

Table 4. Economic analysis on waste concern organic fertilizer during T. aman season at BRRI farms

Treat- ments	Fertilizer costs		Fertilizer application costs		Labor costs		TVC	
	Rangpur site		Rangpur site		Rangpur site		Rangpur site	
	Gazipur site	Rangpur site	Gazipur site	Rangpur site	Gazipur site	Rangpur site	Gazipur site	Rangpur site
T ₁	0	0	0	0	0	0	0	0
T ₂	19676	19676	280	280	952	378	20908	20334
T ₃	23176	23176	280	280	868	1204	24324	24660
T ₄	18161	18161	280	280	1274	966	19715	19407
T ₅	16838	16838	280	280	1330	448	18448	17566
T ₆	7000	7000	280	280	756	196	8036	7476

Price (Tk./kg): Urea = 12, TSP = 77, MoP = 48, gypsum = 5, WCOF = 3.5, labor wage rate = Tk. 140/day. Two additional man-days/ha are required for applying fertilizer and ten men-days/ha and ten men-days/ha for per ton additional products including byproducts.

Treat- ments	Yield (t/ha)		Total variable costs (TVC) (Tk./ha)		Gross		Return Added		Net		MBCR	
	Straw		RS		GS		RS		GS		RS	
	GS	RS	GS	RS	GS	RS	GS	RS	GS	RS	GS	RS
T ₁	2.71	4.31	3.98	4.76	0	0	56740	87100	0	0	56740	87100
T ₂	3.39	4.58	5.38	5.48	20908	20334	71780	93400	15040	6300	50872	73066
T ₃	3.33	5.17	6.39	5.54	24324	24660	72720	104140	15980	17040	48396	79480
T ₄	3.62	5.00	5.62	5.44	19715	19407	76400	100880	19660	13780	56685	81473
T ₅	3.66	4.63	5.56	5.38	18448	17566	77000	94100	20260	7000	58552	76534
T ₆	3.25	4.45	4.09	5.22	8036	7476	66680	90540	9940	3440	58644	83064

GS = Gazipur site, RS = Rangpur site, Rice grain price = Tk. 18 /kg, Rice straw price = Tk. 2 /kg.

Bangladesh, agricultural land use practices that increase k due to the effects of continuous cultivation, residue removal, low input subsistence agriculture, excessive tillage etc. The rate of sequestration in the soils of Bangladesh is very slow because of their low SOC contents. If the soil is continuously cultivated (Bangladesh situation), its SOC content declines until an equilibrium level (C_e) is achieved. The magnitude of C_e depends on the climate, land use and cropping pattern etc. The equation is $C = C_e + (C_0 - C_e)e^{-rt}$ where C = SOC constant at time t , r = Fraction of C decomposed/year, t = Time in years, C_e = Equilibrium level, $C_0 - C_e$ = Difference in SOC = Gaseous emission into the atmosphere and losses due to soil erosion and leaching as dissolved and particulate carbon. In Bangladesh, SOC has perhaps declined to an equilibrium level, and further decline may not occur unless soil management practices changes further.

Soil organic carbon level is very low in the study sites for crop productivity purposes in comparison of the statement⁽³²⁾ on SOC threshold values in tropical agro-ecosystems. They found that soil organic carbon threshold for sustaining soil quality is widely suggested to be about 2% (20 g/kg) below which deterioration occurs. It is reported that some of the minimum and maximum thresholds of SOC, above or below which the effects of SOC on soil functions are noticeable⁽³³⁾. However,⁽³⁴⁾ argued that other than defining such maximum values, it is reasonable if minimum SOC levels (2% e.g. 20 g/kg) are established to inform the farming community on levels below which there would be loss of important soil characteristics. SOC at 2% is considered optimum for soil aggregate stability maintenance while above this level no further increase in productivity or aggregate stability is expected⁽³⁵⁾. Good soil structure and fertility can be maintained when SOC is > 2% but most soils in Bangladesh have less than 1% SOC^(16,24). So, the inherent capacity of the experimental soils is very much unresponsive for the growth of crop production but the supplied fertilizer sources is very much supportive to accelerate the growth and yield of rice plants as the source material is very much enriched with nutrient contents.

Finally, it is recommended that the treatment T_4 where WCOF was applied @ 1 t/ha in combination with 75% of NPKS @ 80-5-40-10 kg/ha, saved 25% chemical fertilizers and produced substantially higher yield. So, the integrated use of organic and inorganic fertilizer is the need of time for sustaining crop production and soil health as well.

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