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AGRONOMY | ORIGINAL ARTICLE

Bio-Economic Efficiency of Co-Composted Faecal Sludge Based Integrated Nutrient Management of Wheat under Different Irrigation Regimes

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ABSTRACT

Faecal sludge disposal is becoming a huge challenge in the urban areas of Bangladesh. Nowadays the focus is shifting from faecal sludge disposal to reuse as fertilizer and soil conditioner after decomposition. Keeping that in mind present study was undertaken to judge the efficacy and economic feasibility of integrating co composted faecal sludge with chemical fertilizers in increasing wheat productivity under different irrigation regimes. A two-factor experiment was laid out in a split-plot design with three replications. Factors included: a) four irrigation regimes: no irrigation, one irrigation at Crown Root Initiation (CRI) stage, one irrigation at flowering stage and two irrigations at CRI + flowering stage and b) five integrated nutrient management: recommended doses of chemical fertilizer (RCF), 100% RCF and co-compost @ 1 t ha^{-1}, 100% RCF and co-compost @ 2 t ha^{-1}, 75% RCF and co-compost @ 2 t ha^{-1} and 75% RCF and co-compost @ 4 t ha^{-1}. Wheat variety BARI Gom-33 was used as the plant material. Irrigation twice at CRI + flowering stages resulted in the highest wheat yield of 3.23 t ha^{-1} which was 1.08 t more than control (no irrigation). Grain yield of wheat was increased due to integration of co-compost with chemical fertilizers. Application of 75% RCF + co-compost @ 4 t ha^{-1} produced the highest grain yield (3.05 t ha^{-1}) which was statistically similar to that produced by 100% RCF + co-compost @ 2 t ha^{-1} (2.83 t ha^{-1}). The highest wheat grain yield (3.47 t ha^{-1}) was recorded from the interaction between two irrigations at CRI and flowering stages and 75% RCF + Co-compost @ 4 t ha^{-1} application statistically followed by the interaction between two irrigations at CRI and flowering stages and 100% RCF + Co-compost @ 2 t ha^{-1} application (3.40 t ha^{-1}). Economic analysis showed that the highest gross margin was recorded when wheat crop received two irrigations at CRI + flowering stages and fertilized with RCF + co-compost @ 2 t ha^{-1} (45,570 Tk ha$^{-1.}$ From productivity and economic viewpoints two irrigations at CRI + flowering stages and applying 100% recommended chemical fertilizers along with co-compost @ 2 t ha^{-1} may be practiced for wheat variety BARI Gom-33.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most common and extensively grown cereal crops in most of the countries around the world (Ahmed *et al.,* 2022). A Statistics published by Shahbandeh (2024) reported that worldwide wheat production comes to about 784.91 million metric tons. As Johansson *et al.* (2013) and Ma *et al.* (2020) stated, in terms of cultivated area, yield and food production, wheat is one of the major grains worldwide among cereal crops and it ranks second in importance after rice. Tadesse *et al.* (2019) opined that significant increase has occurred from 1961 in wheat production with a productivity level of 3.4 t ha^{-1}. However, it is needed to double wheat productivity by 2050 to ensure food security considering the rapid growth of the world's population (Seleiman, 2019).

In Bangladesh, wheat is the second most significant cereal crop after rice (Jahan *et al.*, 2021). But the average amount of wheat production is comparatively lower than other wheat growing countries (BER, 2017). As BBS reported (2022), Bangladesh currently yields an average of 3.3 t ha^{-1} from 1.09 million tonnes of wheat grown on 0.34 m ha of land. Optimum productivity of any crop including wheat largely depends on proper management strategies followed by the farmers during crop cultivation

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as well as favorable environmental condition under which crop is grown. In 2016, Karim and Aktar opined that farmers of Bangladesh mostly use chemical fertilizer over few decades for higher yield gain thinking that it will boost up the growth as well as the productivity of crop. They also claimed in their study that many of the farmers in Bangladesh are unaware of the negative effect of using excessive amount of chemical fertilizer. Indiscriminate and continuous use of chemical fertilizer causes soil health degradation thus reducing productivity, stability and sustainability (Selim and Al-Owied, 2017; Selim, 2018) that ultimately accounts for lower yield of crop. Recently agricultural specialists and farmers recognized the importance of using organic fertilizer solely or with chemical fertilizer to enhance soil fertility. Cowdung, compost, green manure, farmyard manure, vermicompost and other types of urban waste are some popular organic manures. Cowdung is mostly used as fuel specially for cooking purposes in different districts of Bangladesh. Green manuring is not that much feasible as agricultural land is limited. Hence, it is necessary to find other sources of organic manure.

Humanure, a compost made from human waste and urine is a potential source of organic matter. As Enayetullah and Sinha (2013) and Aktar *et al.* (2018) stated, co-composting faecal sludge and municipal solid waste promotes the growth of agricultural crops. Co-composting is the process of simultaneously composting two or more raw materials, such as solid waste and faecal sludge or other organic materials like bark, sawdust, wood chips, animal manure, sludges, or solid residues from enterprises (Enayetullah and Sinha, 2013; Giagnoni *et al.*, 2020). It has been confirmed that co-composting increases soil fertility and enhances plant biological activity (Islam *et al.*, 2016) and crop productivity (Mahmud et al., 2024).

In Bangladesh wheat is grown in rabi season in November to March under rainfed conditions. Generally, no significant precipitation takes place during rabi season. In 2019, Neupane and Guo reported that irrigation water with adequate frequency and intensity is a crucial factor for proper plant growth and productivity. Therefore, irrigation regime under which wheat will be cultivated is considered vital component for every stage of wheat growth especially in crown root initiation (CRI) stage and flowering stage. Alshallash *et al.* (2022) claimed that organic manure enhance water holding capacity of soil. Integration of organic component with chemical fertilizer improve soil physical conditions allowing to store more water in soil thus increase productivity. As both irrigation regime and INM are complementary to each other, it is necessary to ensure optimum irrigation with integrated nutrient management approach for sustainable wheat production. Under the circumstances stated above, this research work was designed to study the effect of co-compost based integrated nutrient management on wheat growth and yield under different irrigation regimes.

2. Materials and Methods

2.1. Location and site

The experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from November 2022 to March 2023. Geographically, the Agronomy Field Laboratory, BAU is located at 24°75′ N latitude and 90°50′ E longitude at an elevation of 18 m above the sea level belonging to non-calcareous dark grey floodplain soil under Old Brahmaputra Floodplain Agro-ecological zone- “AEZ-9”. The land was medium high with silty clay loam texture. The soil of the experimental land belongs to the Sonatola series of the non-calcareous dark-grey floodplain soil under the Old Brahmaputra Alluvial Tract. The experimental field was of a medium high land having silty clay loam soil. The soil characteristics have been presented in Table 1. The experimental site belongs to the subtropical area. The information in respect of rainfall pattern, sunshine hours, temperature fluctuation and relative humidity during the period of the current study have been presented in Table 2.

Table 1. Soil characteristics of the experimental site

Soil properties/constituents	Values	Critical level
Soil pH	6.7	--
Organic carbon (%)	0.86	--
Total nitrogen (%)	0.16	0.12
Available P (ppm)	17.05	10.00
Available K (me/100g soil)	0.10	0.15
Zinc (ppm)	10.35	1.15
Sulphur (ppm)	5.85	8.00
Boron (ppm)	1.12	0.20
Molybdenum (ppm)	0.063	0.10

Result obtained from the mechanical analysis of the initial soil sample done in the Department of Soil Science, Bangladesh Agricultural University, Mymensingh

Table 2. Weather data from November 2022 to March 2023 at the experimental site during the growing season of wheat

	Month and year				
	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23
Max air temp (°C)	30.4	25.4	24.02	26.8	30.65
Mini air temp (°C)	18.3	13.5	12.15	15.54	17.7
Avg air temp (°C)	24.4	19.8	19.22	21.28	23.76
Total rainfall (mm)	0	17.7	0	1.17	1.9
Avg relative humidity (%)	81.6	80.2	84.35	83	73.19
Total suns-hine (hr)	187.8	201	227.2	164.8	208.2

Max: maximum; Min: minimum: Avg: average; hr: hours

2.2. Experimental setup

The experiment comprised four irrigation regimes which were- no irrigation (I_0), One irrigation at crown root initiation (CRI) stage (I_1), One irrigation at flowering stage (I_2), Two irrigations at CRI and flowering stages (I_3) and five Co-compost based Integrated Nutrient Management e.g. Only recommended chemical fertilizer (RCF) (N_1), 100% RCF and co-compost @1 t ha^{-1}(N_2), 100% RCF and co-compost @2 t ha^{-1} (N_3), 75% RCF and co-compost @2 t ha^{-1} (N_4), 75% RCF and co-compost @4 t ha^{-1} (N_5). The two factors experiment was laid out in a split-split plot design with three replications. Irrigation was assigned in the main plots and integrated nutrient management was assigned in the sub plots. The total number of plots was 60 (treatment 20 × replication 3). The unit plot size was 5 m^2 (2.5 m × 2.0 m). Block to block and plot to plot distances were 1 m and 0.5 m, respectively.

2.3. Details of the experimental materials

2.3.1. Description of the wheat variety BARI Gom-33

The seeds of BARI Gom-33, a modern wheat variety released by Wheat Research Centre, BARI in 2017 were collected. Leaf and stem both are dark green in color, tillers are semi-erect during heading. Flag leaf is wide and droopy. It takes about 60-65 days for heading and 110-115 days to get physiological maturity. Glaucosity is weak in spike. It is a Zn-enriched and wheat blast resistant variety. The weight of 1000 seeds are 45-50 g. Grain yield under optimum management is upto 4-5 t ha^{-1}.

2.3.2. Collection and analysis of co-composted faecal sludge (CCFS)

Prepared and ready to use co-compost was collected from NGO Forum for Public Health, Mymensingh. NGO forum is producing co-compost as a part of implementing a project titled “Resilient, Inclusive and Innovative Cities in Bangladesh Project” to establish a functional Fecal Sludge Management (FSM) system in Mymensingh City Corporation from 2018. They produced CC by mixing of fecal sludge collected by special vehicle from the pit toilers or septic tanks and solid waste collected from households from the households, institutions, and companies or markets under the municipality area of Mymensingh. First, fecal sludge (FS) is discharged from the sludge collection vehicle (Vacutug) to the drying bed, where last at least 14 days to separate the liquid part. Secondly, a lot of unwanted materials like plastic and stone are separated from the bulk volume of the collected solid waste and kitchen materials. After getting the sorted organic waste materials and 14 days dried FS, mixture of the two materials is done at the ratio 3:1, *i.e.*, 75% from organic solid waste and 25% from FS. After that, the total mixture is transferred to the composting box for at least 40 days maintaining temperature 60–65°C. To make the final product, the mixed materials are being kept into co–compost maturing box at least 10–15 days. The safe Co–compost is ready for use in Agricultural sector.

The collected co-compost was analyzed for organic carbon (OC, dry ashing method), nitrogen (N), phosphorus (P), potassium (K), sulphur (S) (spectrophotometric method) and heavy metals (zinc (Zn), cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr) and copper (Cu) by atomic absorption spectrophotometric method). In general, the nutritional status of the co-compost was as per Soil Resource Development Institute (SRDI) standard range (according to government regulation): OC=14.38% N =2.04% P =0.728 ppm K=1.34% and S =0.445 ppm. Looking at the common heavy metals, Zn, Cd, Pb, Ni, Cr and Cu level were 0.062%, 2.8, 10.51, 10.97, 7.38 ppm and 0.0077 %, respectively. All the heavy metals level was also within the standard range.

2.4. Conduction of the experiment

The land was prepared in the third week of November 2022. It was prepared by repeated ploughing by a power tiller. After levelling, the experimental plots were laid out as per the treatment and experimental design. One-third of the nitrogenous fertilizers and the entire amounts of other fertilizers were applied at the rate of 235 kg ha^{-1} of urea, 145 kg ha^{-1} of triple super phosphate (TSP), 110 kg ha^{-1} of muriate of potash, 120 kg ha^{-1} of gypsum, 7.5 kg ha^{-1} of boric acid were applied before final land preparation. The remaining two-thirds of urea was top-dressed in two equal splits on 20 and 55 days after sowing (DAS) (BWMRI,2023). Co-compost was applied as basal dose per experimental treatments. Seeds were sown continuously @140 kg ha^{-1} with line spacing 20 cm on first December, 2022. Intercultural operations like irrigation (as per experimental treatments) and weeding (20 & 55 DAS) were done to ensure the normal growth of the crop. At full maturity, the wheat variety was harvested on 21 March 2023. The harvested crop of each plot was bundled and separately tagged and brought to the clean threshing floor. The bundles were sun-dried, threshed and then the grains were cleaned.

2.5. Sampling and data recording

For collecting data on plant characters, five hills were selected at random and uprooted from each plot prior to harvesting. The grain and straw yields were recorded plot-wise at 14% moisture basis and expressed as t ha^{-1}. The data on Plant height, Spikes m^{-2}, Spikelets $spike^{-1,}$ Grains $spikelet^{-1}$, Grains $spike^{-1}$, 1000 grain-weight, Grain yield, Straw yield and Harvest index (%) were recorded. Economic analysis was performed to determine the profitability of different treatments. Labor wages, price of different inputs and products were calculated based on local rate/market price. Total variable cost, gross return and gross margin were calculated.

2.6. Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package MSTAT at 5% level of probability. The mean differences among the treatments were adjudged by Duncan’s Multiple Range Test (DMRT).

3. Results

3.1. Effect of irrigation regime on the growth and yield performance of wheat

The study investigated the impact of irrigation frequency on the growth and productivity of wheat, revealing that irrigation had a substantial positive effect on various parameters (Table 3). As the frequency of irrigation increased, there were gradual improvements in key growth traits such as plant height, number of spikes, spikelets per spike, grains per spikelet, and overall grain yield. The plants subjected to two irrigations at critical growth stages—CRI (crown root initiation) and flowering—showed the most significant improvements.

These plants achieved the tallest height (88.23 cm) and the highest number of spikes per square meter (175.87 spikes m^{-2}). In terms of reproductive traits, the number of spikelets and grains per spike also increased with irrigation, with two irrigations leading to more than a 50% increase in spikelets and a nearly 200% increase in grains per spike compared to the control (no irrigation). Grain and straw yields were notably higher with irrigation, with the highest yield (3.23 t ha^{-1} and 3.88 t ha^{-1}, respectively) observed with two irrigations (Figure 1). Similarly, 1000-grain weight was highest under two irrigations, reaching 42.58 g. The harvest index, which indicates the efficiency of grain production relative to total biomass, also showed an increase with irrigation, peaking at 45.50% with two irrigations. Overall, the study highlights the importance of adequate irrigation at critical growth stages for improving wheat productivity, with two irrigations (at CRI and flowering) being the most beneficial for maximizing growth, yield, and overall plant health (Table 3).

3.2. Effect of integrated nutrient management on the growth and yield performance of wheat

The study highlighted the significant positive effects of integrating co-compost with chemical fertilizers on wheat growth and yield (Table 4). It was observed that the combination of co-compost and chemical fertilizers led to notable improvements in key yield attributes such as plant height, number of spikes per square meter, number of spikelets per spike, number of grains per spikelet, number of grains per spike, and 1000-grain weight. Wheat plant height was increased up to 5 cm due to integration of co-compost with chemical fertilizers compared to application of only recommended chemical fertilizers (RCF). Specifically, treatments using 75% recommended chemical fertilizers (RCF) + co-compost @ 4 t ha^{-1} and 100% RCF + co-compost @ 2 t ha^{-1} produced the tallest plants (83.87 cm and 83.00 cm, respectively). Application of 100% RCF + co-compost @ 2 t ha^{-1} and 75% RCF + co-compost @ 4 t ha^{-1} resulted in the statistically similar and the highest number of spikes, spikelets, and grains, compared to the control, which only utilized recommended chemical fertilizers. These integrated treatments also resulted in significant increases in harvest index (Table 4). The grain yield saw a remarkable improvement, up to a 39% increase compared to the control treatment, with 75% RCF + co-compost @ 4 t ha^{-1} yielding the highest at 3.05 t ha^{-1}. Straw yield was also significantly boosted with integrated nutrient management, especially in treatments with co-compost (Figure 2). Overall, the results demonstrate that integrating co-compost with chemical fertilizers not only promotes better wheat growth but also enhances both grain and straw yield, supporting the idea that sustainable and efficient nutrient management practices are crucial for improving wheat production.

3.3. Effect of interaction between irrigation regime and integrated nutrient management on the growth and yield performance of wheat

All the growth, yield parameters and yield of wheat were significantly affected by interaction between irrigation regime and integrated nutrient management (Table 5 and Figure 3).

Table 3. Effect of irrigation regime on yield attributes and yield of wheat

Irrigation	Plant height (cm)	No. of spike m^{-2}	No. of spikelet $spike^{-1}$	No. of grains $spikelet^{-1}$	No. of grains $spike^{-1}$	1000-grain weight (g)	Harvest index (%)
I_O	76.21d	106.93d	10.81d	1.99b	22.15c	38.01d	43.83c
I_1	78.69c	121.67c	12.06c	2.11b	26.17c	38.59c	44.01b
I_2	82.71b	133.80b	14.05b	2.52a	35.96b	40.72b	44.76b
I_3	88.23a	175.87a	16.35a	2.71a	44.40a	42.58a	45.50a
Sig. level	**	**	**	**	**	**	*
CV (%)	7.45	4.86	9.73	9.58	5.14	4.80	8.48

Means with the same letters within the same column do not differ significantly whereas means with dissimilar letter(s) differed significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, CV = Co-efficient of variation; I0 = No irrigation; I1 = Irrigation at crown root initiation stage; I2 = Irrigation at flowering stage; I3 = Irrigation at CRI and flowering stage

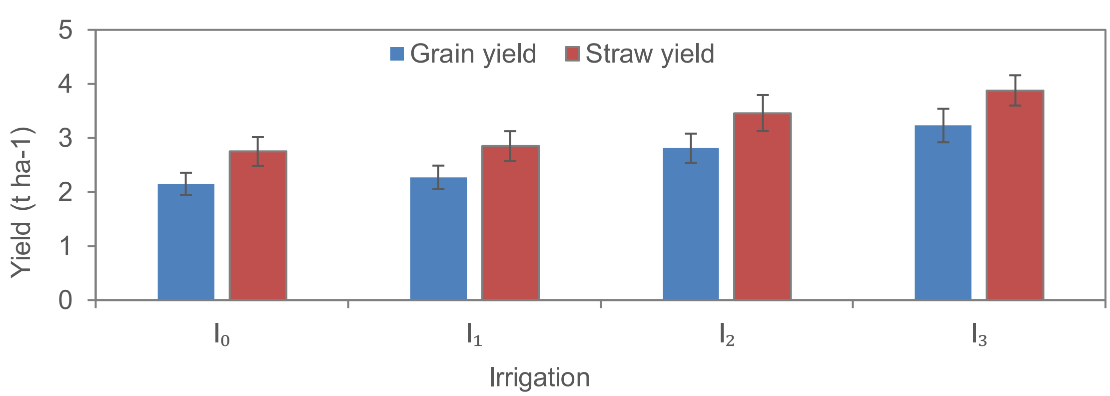

Figure 1. Effect of irrigation regime on the grain and straw yield of wheat. I0 = No irrigation; I1 = Irrigation at crown root initiation stage; I2 = Irrigation at flowering stage; I3 = Irrigation at CRI and flowering stage

Table 4. Effect of nutrient management on yield attributes and yield of wheat

Irrigation	Plant height (cm)	No. of spike m^{-2}	No. of spikelet $spike^{-1}$	No. of grains $spikelet^{-1}$	No. of grains $spike^{-1}$	1000-grain weight (g)	Harvest index (%)
N_1	78.67b	120.25c	11.51c	1.76c	21.18c	38.12d	44.08b
N_2	80.93ab	129.83b	13.57b	2.24b	31.60b	39.53c	43.91c
N_3	83.00a	143.33a	14.35ab	2.68a	38.52a	41.10a	44.29b
N_4	80.86ab	133.17b	12.22c	2.33b	29.34b	40.21b	44.80ab
N_5	83.87a	146.25a	14.96a	2.66a	40.20a	40.92a	45.54a
Sig. level	*	**	**	**	**	**	*
CV (%)	5.36	7.45	8.18	10.53	7.34	6.95	5.47

Means with the same letters within the same column do not differ significantly whereas means with dissimilar letter(s) differed significantly as per DMRT. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, CV = Co-efficient of variation; I0 = No irrigation; N1 = Recommended chemical fertilizer (RCF); N2 = RCF + co-compost @ 1 t ha^{-1}; N3 = RCF + co-compost @ 2 t ha^{-1}; N4 = 75% RCF + co-compost @ 2 t ha^{-1}; N5 = 75% RCF + co-compost @ 4 t ha^{-1}

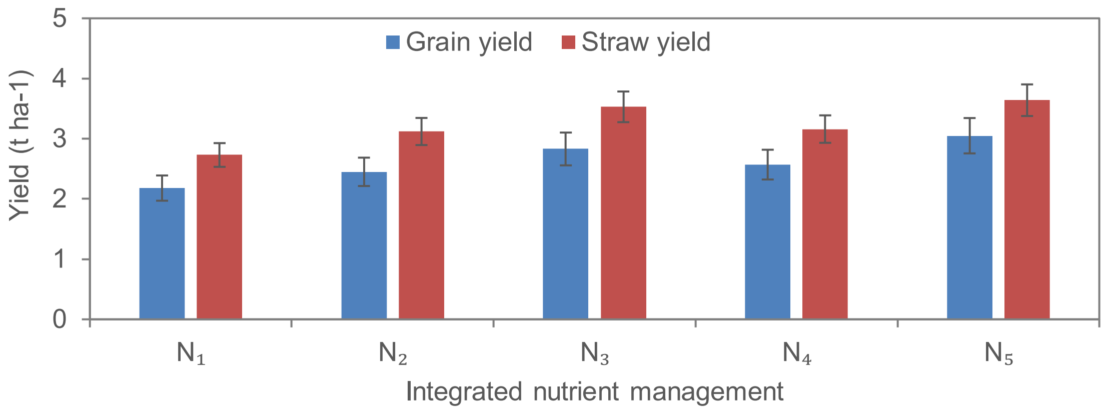

Figure 2. Effect of integrated nutrient management on the grain and straw yield of wheat. N1 = Recommended chemical fertilizer (RCF); N2 = RCF + co-compost @ 1 t ha^{-1}; N3 = RCF + co-compost @ 2 t ha^{-1}; N4 = 75% RCF + co-compost @ 2 t ha^{-1}; N5 = 75% RCF + co-compost @ 4 t ha^{-1}

In general, no irrigation irrespective of nutrient management always resulted in poorest performances for all the parameters under study. And application of only recommended chemical fertilizers performed worse in terms of yield parameters and yield than integrated nutrient management at all the irrigation regimes. In all the cases two irrigation at CRI and flowering stages coupled with 75% RCF + Co-compost @ 4 t ha^{-1} resulted in the best performances due to the availability of sufficient nutrients and moisture as well. The highest wheat grain yield (3.47 t ha^{-1}) was recorded from the interaction between two irrigations at CRI and flowering stages and 75% RCF + Co-compost @ 4 t ha^{-1} application statistically followed by the interaction between two irrigations at CRI and flowering stages and 100% RCF + Co-compost @ 2 t ha^{-1} application (3.40 t ha^{-1}); all other nutrient managements coupled with two irrigations at CRI and flowering stages also resulted in statistically similar grain yield (Figure 3).

3.4. Economic performance

Economic analysis showed that the highest gross margin was recorded when wheat crop received two irrigations at CRI + flowering stages and fertilized with RCF + co-compost @ 2 t ha^{-1} (45,570 Tk ha^{-1}) (Table 6). This interaction was closely followed by two irrigations at CRI + flowering stages & fertilized with RCF (44,870 Tk ha^{-1}) and two irrigations at CRI + flowering stages & fertilized with RCF + co-compost @ 1 t ha^{-1} (43,620 Tk ha^{-1}) (Table 4). The cost-return analysis also shows that only one irrigation at CRI stage was found less remunerative (8,500 Tk ha^{-1}) than no irrigation treatment (11,091 Tk ha^{-1}) but one irrigation at flowering stage was more remunerative (31,953 Tk ha^{-1}) than no irrigation treatment. Two irrigations at CRI + flowering stages came out with the highest gross margin (41,625 Tk ha^{-1}). Among the integrated nutrient management treatments, RCF + Co-compost @ 2 t ha^{-1} appeared as the most remunerative one (29,001 Tk ha^{-1}) followed by RCF + co-compost @ 1 t ha^{-1} (22,663 Tk ha^{-1}) and 75% RCF + co-compost @ 4 t ha^{-1} (22,228 Tk ha^{-1}) (Figure 4).

4. Discussion

The irrigation regime in this study had a substantial impact on growth, yield traits and yield of wheat. Different yield attributes and yield of wheat viz. plant height, number of spikes m^{-2}, spikelets $spike^{-1}$, number of grains $spikelet^{-1}$, number of grains $spike^{-1}$ and 1000-grain weight (g), grain yield, straw yield and harvest index were significantly affected by irrigation regime. With the increase of frequency of irrigation, the value of all the yield attributes and yield was increased gradually as compared to control irrigation due to having sufficient moisture for growth and development.

Table 5. Cost-return analysis of wheat under different irrigation regime and integrated nutrient management interactions

Irrigation Regime × Integrated Nutrient Management	Variable cost (Tk ha-1)					Gross return (Tk ha^{-1})	Gross margin (Tk ha^{-1})
	Variable cost†	Irrigation cost	Fertilizer cost	Co-compost cost	Total variable cost		
I_0N_1	48,500	-	16,505	-	65,005	74,625	9,620
I_0N_2	48,500	-	16,505	10,000	75,505	87,700	12,195
I_0N_3	48,500	-	16,505	20,000	85,505	96,625	11,120
I_0N_4	48,500	-	12,378	20,000	80,878	91,075	10,197
I_0N_5	48,500	-	12,378	40,000	100,878	113,200	12,322
I_1N_1	48,500	8,000	16,505	-	73,005	76,800	3,795
I_1N_2	48,500	8,000	16,505	10,000	83,005	89,725	6,720
I_1N_3	48,500	8,000	16,505	20,000	93,005	109,200	16,195
I_1N_4	48,500	8,000	12,378	20,000	88,878	93,375	4,497
I_1N_5	48,500	8,000	12,378	40,000	108,878	120,175	11,297
I_2N_1	48,500	8,000	16,505	-	73,005	98,050	25,045
I_2N_2	48,500	8,000	16,505	10,000	83,005	111,125	28,120
I_2N_3	48,500	8,000	16,505	20,000	93,005	136,125	43,120
I_2N_4	48,500	8,000	12,378	20,000	88,878	119,225	30,347
I_2N_5	48,500	8,000	12,378	40,000	108,878	141,925	33,047
I_3N_1	48,500	16,000	16,505	-	81,005	125,875	44,870
I_3N_2	48,500	16,000	16,505	10,000	91,005	134,625	43,620
I_3N_3	48,500	16,000	16,505	20,000	101,005	146,575	45,570
I_3N_4	48,500	16,000	12,378	20,000	96,878	138,700	41,822
I_3N_5	48,500	16,000	12,378	40,000	116,878	149,125	32,247

† (excluding irrigation, fertilizer and co-compost); I1 = Irrigation at crown root initiation stage; I2 = Irrigation at flowering stage; I3 = Irrigation at CRI and flowering stage; N1 = Recommended chemical fertilizer (RCF); N2 = RCF + co-compost @ 1 t ha^{-1}; N3 = RCF + co-compost @ 2 t ha^{-1}; N4 = 75% RCF + co-compost @ 2 t ha^{-1}; N5 = 75% RCF + co-compost @ 4 t ha^{-1}; Labor wage=Tk 500 day^{-1}; Urea = Tk 27 kg^{-1}; TSP = Tk 27 kg^{-1}; MoP = Tk 25 kg^{-1}; Gypsum = Tk 12 kg^{-1}; Boric acid = Tk 400 kg^{-1}; Co-compost = Tk 10 kg^{-1}; Wheat grain = Tk 40 kg^{-1}; Wheat straw = Tk 2.5 kg^{-1}

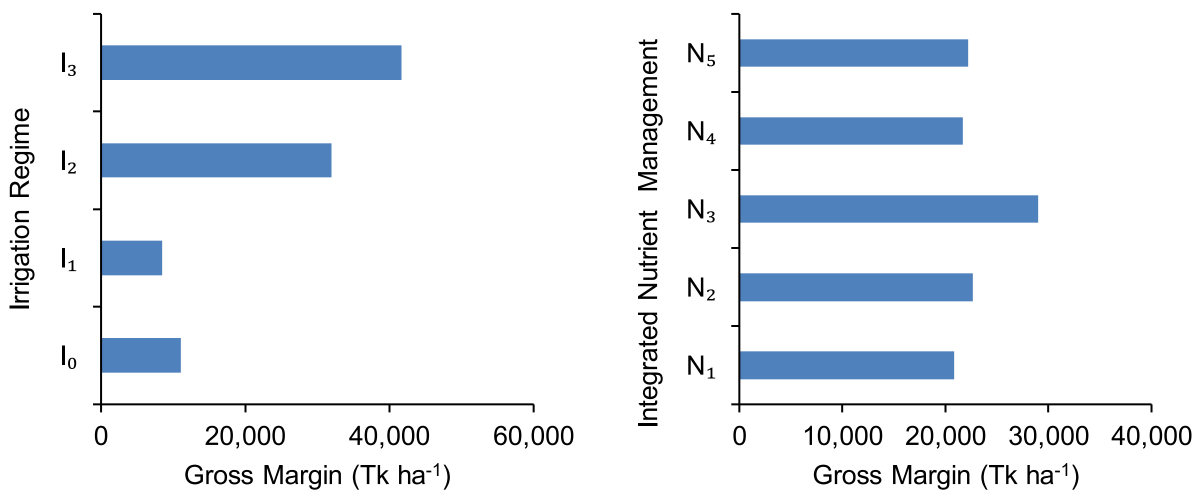

Figure 3. Gross margin of different irrigation regimes (average over integrated nutrient management) and different integrated nutrient management (average over irrigation regimes). I0 = No irrigation; I1 = Irrigation at crown root initiation stage; I2 = Irrigation at flowering stage; I3 = Irrigation at CRI and flowering stage; N1 = Recommended chemical fertilizer (RCF); N2 = RCF + co-compost @ 1 t ha^{-1}; N3 = RCF + co-compost @ 2 t ha^{-1}; N4 = 75% RCF + co-compost @ 2 t ha^{-1}; N5 = 75% RCF + co-compost @ 4 t ha^{-1}; Labor wage = Tk 500 day^{-1}; Urea = Tk 27 kg^{-1}; TSP = Tk 27 kg^{-1}; MoP = Tk 25 kg^{-1}; Gypsum = Tk 12 kg^{-1}; Boric acid= Tk 400 kg^{-1}; Co-compost = Tk 10 kg^{-1}; Wheat grain = Tk 40 kg^{-1}; Wheat straw = Tk 2.5 kg^{-1}

The minimum yield attributes and yield were recorded in the control plots in this study and it was due to lack of sufficient moisture content. Similar results were found in Zeng *et al.* (2023). They reported that wheat yield decreased to a greater extent when water stress was imposed at the anthesis stage and showed that critical irrigation at vegetative stage had positive impact on yield contributing parameters, resulting in greater wheat production.

Soil fertility management technique is considered one of the crucial components of any cropping system for sustainable production. As Mahajan and Gupta (2009) claimed, in today's intensive agriculture systems, no one source of plant nutrients such as chemical fertilizers, organic manures, crop residues and bio-fertilizers can supply all the nutrients a crop requires. Therefore, INM might be one of the best options available for mitigating nutrient deficiencies and sustainable agricultural productivity (Kumar and Tenua, 2012). In this study, application of only chemical fertilizers showed the lowest value of different yield traits and yield of wheat where the highest yield was obtained through judicious application of organic with chemical fertilizers. Improved soil physical, chemical and biological properties through application of customized fertilizer (organic + inorganic fertilizer) might be the possible reason for higher productivity of wheat. These results are in the conformity with those in earlier reports (Sharma*,* 2021 and Kaur *et al*., 2023). They noted that higher growth parameters viz. tiller, plant height, LAI, dry matter accumulation, yield traits and yield of wheat were recorded when applied 75% chemical fertilizer with rest of organic fertilizer. Similarly Panigrahi *et al.* (2022) claimed that yield traits of wheat could be attributed better through application of different integrated nutrient management treatments by making nutrient available during crop growth and reproductive stage and raised the number of spikelets spike^{-1}, spike length, grains spike^{-1}, yield and test weight. These findings are in the line with those of Singh *et al.* (2016), Patel *et al.* (2018) and Rathwa *et al.* (2018).

The study conducted by Maurya *et al.* (2019) revealed that applying 125% recommended dose of fertilizer + 25% N through vermicompost resulted in significantly higher numbers of tillers, spike length, number of grains per spike, grain yield, and straw yield of wheat. However, all these parameters remained comparable when applying 125% RDF + 25% N through FYM, 100% RDF + 25% N through FYM, and applying 100% RDF. They came to the conclusion that increased photosynthetic and nutritional availability, particularly during the growth of the crop's reproductive structures, led to a rise in all yield-attributing characteristics, which in turn increased the crop's productivity. These similar results also reported by other workers (Kaushik *et al*., 2012; Jat *et al*., 2013; Kumar *et al*., 2017). Additionally, Tripathi *et al.* 2016 claimed, integrated nutrition management is essential to maximize wheat productivity. Conversely, minimum yield was recorded in controlled plot due to inadequate availability of nutrient. The results substantiate the findings of Patel *et al.* (2018). Hence, it can be reported that the utilization of organic manures in conjunction with inorganic fertilizers yields the most noteworthy outcomes.

A crop's ultimate yield is largely determined by its yield attributes. Interaction between irrigation regime and INM vital impact on yield traits and yield of wheat. In this study, no irrigation irrespective of nutrient management showed the poorest performance for all the parameters in general. The highest wheat grain yield was recorded from the interaction between two irrigations at CRI and flowering stages and 75% RCF + Co-compost @ 4 t ha^{-1} application statistically followed by the interaction between two irrigations at CRI and flowering stages and 100% RCF + Co-compost @ 2 t ha^{-1} application. According to Brady and Weil (2002) 1% organic matter in 100 kg of dry soil may hold 30 kg of water, while 5% organic matter in the same amount of soil can hold 195 kg of water. Numerous researchers reached almost in similar conclusions in the same context (Yadav *et al*., 2000; Dawe *et al.,* 2003; Wahba *et al.,* 2007; Bastida *et al.,* 2008) as well as on the connection between soil productivity and soil structure (Yadav and Meena, 2009). Several researchers have also come to the conclusion that when combined with biofertilizers, organic and inorganic fertilizers can be used as a soil amendment to increase the amount of soil organic carbon (SOC), aggregate stability, and moisture retention capacity (Rathore *et al.,* 2011; Davari *et al.,* 2012; Aula *et al.,* 2016; Kumari *et al.,* 2017).

Grain yield is closely associated with biomass accumulation, which is enhanced by the appropriate use of fertilizer and water. Three irrigations with an integrated supply of both organic and inorganic nutrients may be the best way to achieve a high grain production, according to Hati *et al.* (2001). These results are in the line with the present study and there was also positive correlation between yield and yield components like the increase in the number of spikes m^{-2}, grain spike^{-1}, individual grain weight the grain yield also increased. Increasing of dry matter accumulation eventually led to an increase in wheat straw yield.

5. Conclusion

The study's encouraging results demonstrate the clear benefit of combining chemical fertilizers with co-composted faecal sludge to boost up the growth productivity of wheat. Although the wheat variety BARI Gom-33 produced the highest yield when irrigated at CRI + flowering stages and received 75% recommended chemical fertilizers + co-compost @ 4 t ha^{-1} or 100% recommended chemical fertilizers + co-compost @ 2 t ha^{-1} but the application of 75% recommended chemical fertilizers + co-compost @ 4 t ha^{-1} were found less remunerative. Therefore, from economic view point irrigation twice at CRI + flowering stages and application of 100% recommended chemical fertilizers (Urea, TSP, MoP, gypsum and boric acid @ 200, 145, 110, 120 and 7.5 kg ha^{-1} respectively) + co-compost @ 2 t ha^{-1} may be practiced for higher productivity and profitability of wheat variety BARI Gom-33. In conclusion, co-composting may be a useful additional plant nutrition source to lessen the need for synthetic fertilizers in wheat cultivation.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Ahmed HGM, Zeng Y, Shah AN, Yar MM, Ullah A, Ali M 2022: Conferring of drought tolerance in wheat (*Triticum aestivum* L.) genotypes using seedling indices. *Front Plant Science* **13** 961049. doi: 10.3389/fpls. 2022.961049.

Aktar S, Islam MS, Hossain MS, Akter H, Maula S, Hossain SSF 2018: Effects of municipal solid waste compost and fertilizers on the biomass production and yield of BRRI dhan50. *Progressive Agriculture* **29**(2) 82-90.

Alshallash KS, Makled KM, Saeed KF, Shehab AA, Farouk ASM, Hamdy AE 2022: Drip irrigation and compost applications improved the growth, productivity and water use efficiency of some varieties of bread wheat. *Agronomy* **13**(1) 139.

Aula L, Macnack N, Omara P, Mullock J, Raun W 2016: Effect of fertilizer nitrogen (N) on soil organic carbon, total N and soil pH in long-term continuous winter wheat (*Triticum aestivum* L.). *Communications in Soil Science and Plant Analysis* **47**(7) 863–874. doi: https://doi.org/10.1080/00103624.2016.1147047, 2-s2.0-849644526e.

Bastida F, Kandeler E, Hernández T, García C 2008: Long-term effect of municipal solid waste amendment on microbial abundance and humus-associated enzyme activities under semiarid conditions. *Microbial Ecology* **55**(4) 651–66. doi: https://doi.org/10.1007/s00248-007-9308-0, 2-s2.0-42649105446.

BBS (Bangladesh Bureau of Statistics) 2022: Agricultural Statistical Yearbook of Bangladesh, Dhaka. Retrieved on June, 2023.

BER (Bangladesh Economic Review) 2017: Government of the People's Republic of Bangladesh, Ministry of Finance, Dhaka.

Brady NC, Weil RR 2002: The Nature and Properties of Soils. 13th Edition, Pearson Education Ltd., London. pp. 156-198.

Davari MR, Sharma SN, Mirzakhani M 2012: The effect of combinations of organic materials on productivity, grain quality, nutrient uptake and economics in organic farming wheat. *Journal of Organic Systems* **7**(2) 26–35.

Dawe D, Dobermann A, Ladha JK 2003: Do organic amendments improve yield trends and profitability in intensive rice systems? *Field Crops Research* **83**(2) 191–213.

Enayetullah I, Sinha AHMM 2013: Co-composting of municipal solid waste and faecal sludge for agriculture in Kushtia municipality, Bangladesh. Session 42: UNESCAP Special Session: Decentralized and Integrated Resource Recovery Centres in Developing Countries. ISWA World Congress, 7-11 October 2013 in Vienna. Online available at www.wasteconcern.org.

Giagnoni L, Martellini T, Scodellini R, Cincinelli A, Renella G 2020: Co-composting:an opportunity to produce compost with designated tailor-made properties (Chapter 9). pp. 185-211, Hettiarachchi H, *et al.* (eds.), Organic Waste Composting through Nexus Thinking. Online available at https://link.springer.com/content/pdf/10.1007/978-3-030-36283-69.pdf.

Hati KM, Mandal KG, Misra AK, Ghosh PK, Acharya CL 2001: Effect of irrigation regimes and nutrient management on soil water dynamics, evapo-transpiration and yield of wheat (*Triticum aestivum*) in Vertisol. *The Indian Journal of Agricultural Sciences* **71**(9) 581-586.

Islam MA, Hasina MR, Sarker MR 2016: Investigation on current air pollution status and its significant impacts on agriculture in Bangladesh. Bangladesh Agricultural University Research Program. pp. 27.

Jat, Kumar, Lokesh, Singh SK, Latare AM, Singh RS, Patel CB 2013: Effect of dates of sowing and fertilizer on growth and yield of wheat (*Triticum aestivum*) in an Inceptisol of Varanasi, *Indian Journal of Agronomy* **58**(4) 611-614.

Johansson E, Malik AH, Hussain A, Rasheed F, Newson WR, Plivelic T, Hedenqvist MS, Gällstedt M, Kuktaite R 2013: Wheat gluten polymer structures: the impact of genotype, environment, and processing on their functionality in various applications. *Cereal Chemistry Journal* **90** 367-376. doi: https://doi.org/10.1094/cchem-08-12-0105-fi.

Kaur C, Kumar S, Singh K 2023: Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.) under system of wheat intensification. *Journal of Cereal Research* **15**(2) 273-276.

Kaushik MK, Bishnoi NR, Sumeriya HK 2012: Productivity and economics of wheat as influenced by inorganic and organic sources of nutrients. *Annals of Plant and Soil Research* **14**(1) 61-64.

Kumar B and Tenua OVS 2012: Studies on integrated nutrient management in wheat. Department of Agronomy, Amar Singh (P.G.) College, Lakhaoti -245 407 Bulandshahr, (U.P.), India. *Environmental Science, Nutrient Management.*

Kumar D, Prakash V, Singh P, Kumar S, Kumar A, Kumar C 2017: Effect of nutrient management modules on growth, yield attributes and yield of wheat. *International Journal of Current Microbiology and Applied Science* **6**(12) 366-369.

Kumari R, Kumar S, Kumar R 2017: Effect of long-term integrated nutrient management on crop yield, nutrition and soil fertility under rice-wheat system. *Journal of Applied and Natural Science* **9**(3) 1801–1807. doi: https://doi.org/10.31018/jans.v9i3.1442.

Ma M, Sun QJ, Li M, Zhu KX 2020: Deterioration mechanisms of high-moisture wheat-based food: a review from physicochemical, structural, and molecular perspectives. *Food Chemistry* **318** 126-495. doi: https://doi.org/10.1016/j.foodchem.2020.126495

Mahajan A, Gupta RD 2009: Integrated nutrient management (INM) in a sustainable rice-wheat cropping system. Berlin, Germany, *Springer Science and Business Media*. doi: 10.1007/978-1-4020-9875-8.

Mahmud NB, Anwar MP, Yeasmin S, Sultana N, Ghosh S, Islam AKMM, Jaman S. 2024: Co-composted faecal sludge based integrated nutrient management for sustainable aman rice production. *Journal of Science and Technology Research* **6(1)** 149-159. doi: https://doi.org/10.3329/jscitr.v6i1.77386

Maurya RN, Singh UP, Kumar S, Yadav AC, Yadav RA 2019: Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.). *Indian Journal of Chemical Studies* **7**(1) 770-773.

Panigrahi T, Singh S, Mondal BK, MK A, Kashive AV, Gupta A 2022: Influence of integrated nutrient management in yield and nutrient uptake of wheat crop (*Triticum aestivum* L.). *The Pharma Innovation Journal* **11**(7) 2598-2601.

Patel GG, Sadhu AC, Patel HK, Shan SN, Lakum YC 2018: Effect of organic and inorganic fertilizers in comparison with humic acid on growth and yield of wheat (*Triticum aestivum* L.). *International Journal of Agriculture Sciences* **10** 6524- 6527.

Patel RN, Upadhyay PN 1993: Response of wheat (*Triticum aestivum*) to irrigation under varying levels of nitrogen and phosphorus. *Indian Journal of Agronomy* **38** 113-115.

Rathore DS, Purohit HS, Yadav L, Sharma SR 2011: Effect of integrated nutrient management on soil properties and crop yield under black gram-wheat cropping system in a typic haplustept, Annals of Arid Zone. *Journal of Cereal Research* **50**(1) 21–26.

Rathwa PG, Mevada KD, Ombase KC, Dodiya CJ, Bhadu V, Purabiya VS 2018: Integrated nitrogen management through different sources on growth and yield of wheat (*Triticum aestivum* L.). *Journal of Pure and Applied*

Microbiology **12**(2) 905-911.

Seleiman MF, Hasanuzzaman M, Nahar K, Hossain M 2019: Use of plant nutrients in improving abiotic stress tolerance in wheat. Wheat Production in Changing Environments. Springer, Singapore 481-495. doi: https://doi.org/10.1007/978-981-13-6883-7_19.

Selim M 2018: Potential role of cropping system and integrated nutrient management on nutrients uptake and utilization by maize grown in calcareous soil. *Egypt Journal of Agronomy* **40**(3) 297-312. doi: https://doi.org/10.21608 /agro.2018.6277.1134.

Selim MM, Al-Owied AJA 2017: Genotypic responses of pearl millet to integrated nutrient management. *Bioscience Research* **14**(2) 156–169.

Shahbandeh M 2024: Worldwide production of grain in 2023/24. https://www.statista.com/statistics/263977/world-grain-production-by-type/. Retrieved on 15th April 2024.

Sharma PK 2021: Effect of organic and inorganic sources of nitrogen on yield, quality of wheat and soil fertility in Inceptisol of Varanasi (Doctoral dissertation, Banaras Hindu University Varanasi 221005 India).

Singh RK, Kumar PA, Prasad BI, Das AK, Singh SB 2016: Effect of split application of nitrogen on performance of wheat (*Triticum aestivum* L.). *International Journal of Agricultural Sciences* **12**(1) 32- 37.

Tadesse W, Sanchez GM, Tawkaz S, El HS, Skaf P, El BA, Eddakir K, El SK, Thabet S, Assefa SG, Baum M 2019: Wheat Breeding Handbook ICARDA. The International Centre for Agricultural Research in the Dry Areas (ICARDA). doi: https://repo.mel.cgiar.org/handle/20.500.11766 /10723.

Tripathi SC, Chander, Subhash, Meena, Pal R 2016: Maximizing wheat yield through integrated use of farmyard manure and fertilizers. *SAARC Journal of Agriculture* **14**(1) 103–110.

Wahba MM 2007: Influence of compost on morphological and chemical properties of sandy soils, Egypt. *Journal of Applied Sciences Research* **3** 1490–1493.

Yadav RL, Dwivedi BS, Prasad K, Tomar OK, Shurpali NJ, Pandey PS 2000: Yield trends, and changes in soil organic-C and available NPK in a long-term rice-wheat system under integrated use of manures and fertilisers. *Field Crops Research* **68**(3) 219–246. doi: https://doi.org/10.1016/s0378-4290(00)00126-x, 2-s2.0-0033662305.

Yadav RL, Meena MC 2009: Available micronutrients status and their relationship with soil properties of Degana soil series of Rajasthan. *Journal of the Indian Society of Soil Science* **57**(1) 90-92.

Zeng R, Lin X, b Welch SM, Yang S, Huang N, Sassenrath GF, Fengmei Y 2023: Impact of water deficit and irrigation management on winter wheat yield in China. *Agricultural Water Management* **287** 108431.