

Optimizing Wheat (*Triticum aestivum* L.) Growth and Yield Through Combined Application of Vermicompost and Sulphur

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ABSTRACT

The experiment was carried out at Soil Science Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh to evaluate different rates of vermicompost, and inorganic S (Sulphur) fertilizer for wheat production in rabi season 2022-23 and 2023-24 at the Soil Science Department Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. There were six systematically combined rates of vermicompost and sulfur during the study viz. T₁: Control (No fertilizer), T₂: 4 t ha⁻¹ VC + 0 kg S ha⁻¹, T₃: 3 t ha⁻¹ VC + 3 kg ha⁻¹, T₄: 2 t ha⁻¹ VC + 6 kg S ha⁻¹, T₅: 1 t ha⁻¹ VC + 9 kg S ha⁻¹, T₆: 0 t ha⁻¹ VC + 12 kg S ha⁻¹ which were designed in randomized complete block with three replications. The results asserted that application of 2 t ha⁻¹ vermicompost with 6 kg ha⁻¹ sulfur fertilizers improved significantly grain yield and wheat morphological and physiological characteristics such as plant height, number of tillers per hill⁻¹ number of spikes per spike, thousand grain weight, number of grains per spike, spike length and harvest index. The results of the experiments also indicated that vermicompost fertilizer can improve soil productivity and soil quality. The application of such fertilizers also enhances water retention in the soil. Therefore, for sustainable wheat production in the region, a combined dose of 2 t ha⁻¹ vermicompost and 6 kg ha⁻¹ sulfur can be practiced to achieve optimal crop performance while fostering long-term soil fertility.

Keywords: Integrated, organic fertilizer, inorganic compound, yield components, soil properties.

INTRODUCTION

Global food security is heavily reliant on cereal crops, with wheat serving as a particularly vital staple. It feeds about 35% of the world's population, providing essential carbohydrates, protein, and micronutrients (Shewry 2009; Shewry and Hey 2015). However, in Bangladesh, the annual production of wheat is 1.1–1.3 million tons (BBS 2022) fails to meet domestic demand, necessitating significant imports.

This low production is attributed to several yield-limiting factors. The availability of arable land for wheat is restricted to only about 3%, primarily due to the dominance of rice-based cropping systems (Hossain and Teixeira Da Silva 2013). Production is further challenged by drought in key regions and the exacerbating effects of climate change, such as erratic rainfall and temperature fluctuations. A critical underlying issue is the decline in soil fertility, caused by intensive cropping without sufficient nutrient replenishment, often leaving soil organic matter below optimal levels (FAO 2022; SRDI 2020). Compounding this is the imbalanced application of

fertilizers, characterized by excessive nitrogen use without adequate secondary nutrients, which disrupts soil health and contributes to yield stagnation (Adhikary 2012; Meena *et al.* 2020).

A specific nutritional oversight is the deficiency of sulphur, a secondary nutrient vital for chlorophyll formation, protein synthesis, and enzyme activation in wheat (Scherer 2001). Sulphur scarcity reduces nitrogen efficiency, and local studies indicate that application at 20 kg ha⁻¹ can increase wheat grain yield by up to 18% (Mahmud 2016). To address soil degradation holistically, the use of organic amendments like vermicompost is promising. Vermicompost, produced from earthworm-decomposed waste, is rich in humus, nutrients, and beneficial microbes. It improves soil structure, water retention, and microbial activity (Adhikary 2012; Oyege and Balaji Bhaskar 2023). Research shows vermicompost application can increase wheat yields by 12–26% while restoring soil health (Joshi *et al.* 2013; Lazcano *et al.* 2008).

Therefore, integrating vermicompost with sulphur fertilization presents a strategic approach to mitigate the challenges in Bangladesh's wheat production. This combination aims to correct nutrient imbalances, enhance soil organic matter and microbial activity, and improve overall nutrient use efficiency. The goal is to build soil fertility, increase crop resilience, and support sustainable yield improvements in the degraded floodplain soils of Bangladesh, thereby contributing to long-term food security.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted at the Soil Science Department Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh (25.70°N, 88.65°E), during the Rabi season 2022-2023 and 2023-2024. The experimental site falls under Agroecological Zone-1 (AEZ-1), Old Himalayan Piedmont Plain, characterized by a subtropical climate. The experimental soil is classified as a sandy loam, consisting of 51.2% sand, 31.6% silt, and 17.2% clay particles. Initial soil samples were collected from the 0–15 cm depth before planting and analyzed at the Soil Science Laboratory, HSTU, Dinajpur. Laboratory analysis revealed the soil was slightly acidic with a pH of 5.2, contained 1.05% organic matter (low), 0.021% total nitrogen (N, very low), 57.41 ppm available phosphorus (P, high), 0.09 meq 100 g⁻¹ exchangeable potassium (K, low), and 12.80 ppm available sulphur (S, medium). Soil chemical and physical properties were assessed following standard protocols to establish baseline fertility status.

Experimental design and treatments: The experiment was conducted using a Randomized Complete Block Design (RCBD) with 6 treatments and 4 replications. Each experimental unit consisted of a plot measuring 2.5 m × 2 m (5 m²), providing sufficient area for accurate assessment of wheat growth and yield parameters. A spacing of 50 cm was maintained between adjacent blocks, and 25 cm was maintained between plots within each block. Six (6) treatment combinations were tested, with vermicompost (VC) and sulphur (S) applied as percentages of the recommended doses (FRG 2018). The treatments were: T₀: Control (No fertilizer), T₁: 4 t ha⁻¹ VC + 0 kg S ha⁻¹, T₂: 3 t ha⁻¹ VC + 3 kg S ha⁻¹, T₃: 2 t ha⁻¹ VC + 6 kg S ha⁻¹, T₄: 1 t ha⁻¹ VC + 9 kg S ha⁻¹, T₅: 0 t ha⁻¹ VC + 12 kg S ha⁻¹. Vermicompost and sulphur (as gypsum) were applied along with a basal dose of inorganic fertilizers (Urea, TSP, MoP, ZnSO₄, and boric acid) during the final land preparation, following the Fertilizer Recommendation Guide (2018) were incorporated into the soil 7 days before sowing as per treatment specifications.

Data collection: Soil and plant parameters were evaluated to assess the effects of the treatments on soil properties and wheat performance. Soil data collected included pH, organic matter (%), total nitrogen (%), available phosphorus (ppm), exchangeable potassium (meq 100 g⁻¹ soil), and available sulphur (ppm). Plant data included plant height (cm), tillers per hill, number of spikelets per spike, spike length after harvesting (cm), number of grains per spike, 1000-seed weight (g), grain yield, straw yield, and biological yield. Soil samples were analyzed at the Soil Science Laboratory, HSTU, Dinajpur, following standard protocols.

Soil chemical analysis was performed on both initial and post-harvest samples using standard methods. Soil pH was measured with a glass electrode, organic matter by wet oxidation (Walkley and Black 1934), total N via the semi-micro Kjeldahl method (Bremner and Mulvaney 1982), available P by the Olsen method (Olsen *et al.* 1954), exchangeable K by ammonium acetate extraction, and available S by CaCl₂ extraction (Page *et al.* 1982).

Statistical analysis: The data were presented as the mean value. Statistix 10 software was applied to perform statistical analysis. One-way analysis of variance (ANOVA), followed by Duncan’s Multiple Range Test (DMRT) was performed to determine significant differences among treatments. Values were observed as statistically cabalistic with $p < 0.05$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

Effect of Vermicompost and Sulphur on Growth and Yield Attributes of Wheat

The data presented in Table 1 illustrate the influence of different vermicompost and sulfur levels (T_0 to T_5) on various growth and yield parameters of wheat. The application of various treatments significantly enhanced plant height of wheat, treatment T_4 recording the tallest plants at 98.67 cm, which was 44.0% higher than the control (T_0). Similarly, tiller production per hill was highest in T_4 (21.54), representing a 74.6% increase over T_0 . Reproductive attributes such as the number of spikelets per spike (32.66 in T_4) and grains per spike (30.82 in T_4) showed substantial improvements, with increases of 70.8% and 52.9%, respectively, compared to the control. Spike length after harvesting followed a similar trend, peaking at 17.13 cm in T_4 (39.0% higher than T_0). Interaction of sulfur and vermicompost can significantly improve plant growth parameters (Solanki *et al.* 2022). The application of vermicompost enhances commercial crop production, total biomass, shoot biomass, and root biomass by 26%, 13%, 78%, and 57%, respectively (Blouin *et al.* 2019). It is many times reported in literature that supplementation of S fertilizer to soil improve wheat yield and grins quality and ultimately improve the baking properties of wheat and quality of proteins (Corpas and Palma 2020; Singh *et al.* 2018) Studies have confirmed the positive impact of vermicompost on wheat growth parameters such as plant height, tiller number, and dry matter accumulation (Verma *et al.* 2014; Dekhane *et al.* 2017; Choudhary *et al.* 2023).

Table 1. Effect of vermicompost and sulphur on growth and yield attributes of wheat (2 years mean data)

Treatments	Plant Height (cm)	No. of Tillers per hill ⁻¹	No. of Spikelets Spike ⁻¹	Spike Length at Harvest (cm)	No. of Grains Spike ⁻¹	1000-Seed Weight (g)	Grain Yield (t ha ⁻¹)	Straw Yield (t ha ⁻¹)	Biological Yield (t ha ⁻¹)
T_0	68.51f	12.34f	19.12f	12.32e	20.16f	47.84f	2.1f	3.4e	5.5e
T_1	85.34 e	17.63d	28.23d	14.77d	29.46b	53.18d	2.6e	3.99d	6.58d
T_2	89.87d	19.28c	30.14b	15.17c	28.27c	54.17b	3.4c	4.49c	7.89c
T_3	94.13b	19.68b	27.74e	15.22c	25.07d	53.67c	3.6b	4.88b	8.51b
T_4	98.67a	21.54a	32.66a	17.13a	30.82a	55.33a	4.39a	5.38a	9.8a
T_5	91.70 c	17.23e	29.62c	16.2b	23.43e	49.33e	3.29d	4.77b	8.04c
LSD	0.40	0.09	0.06	0.08	0.15	0.05	0.11	0.15	0.33
CV (%)	0.25	0.27	0.12	0.3	0.31	0.06	1.8	1.87	2.37
± SEm	0.18	0.04	0.03	0.04	0.07	0.02	0.05	0.07	0.07

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level probability. CV%= Coefficient of Variance and LSD = Least Significant Difference. Here, T_0 = Control (No fertilizer), T_1 = 4 t ha⁻¹ VC + 0 kg S ha⁻¹, T_2 = 3 t ha⁻¹ VC + 3 kg S ha⁻¹, T_3 = 2 t ha⁻¹ VC + 6 kg S ha⁻¹, T_4 = 1 t ha⁻¹ VC + 9 kg S ha⁻¹, T_5 = 0 t ha⁻¹ VC + 12 kg S ha⁻¹.

Yield components were markedly influenced, with T_4 yielding the highest grain yield of 4.39 t ha⁻¹ (109.0% increase over T_0), straw yield of 5.38 t ha⁻¹ (58.2% increase), and biological yield of 9.8 t ha⁻¹ (78.2% increase). The 1000-seed weight also reached its maximum in T_4 at 55.33 g (15.6% higher than T_0). Overall, T_4 outperformed other treatments across all parameters, while T_0 consistently showed the lowest values. Positive influence of sulphur fertilization on plant dry weight, grain yield and quality of wheat grain was investigated by Hrivna *et al.* (2015). Ramawtar *et al.* (2013) reported that combine application of vermicompost and sulfur gives significantly higher grain yield of succeeding wheat crop over control. Field studies in Bangladesh demonstrate that sulphur application at 20 kg ha⁻¹ increases wheat grain yield by up to 18% by improving plant height, spike length, and nutrient uptake (Mahmud, 2016). Research on rice and maize, crops with similar nutrient demands, further confirms that sulphur application at 20-40 kg ha⁻¹ increases yields by 15–25%, suggesting comparable benefits for wheat (Abukari *et al.* 2024; Scherer 2001).

Effect of Vermicompost and Sulphur on Soil Properties

The post-harvest soil nutrient status for total nitrogen (N) and potassium (K) across replicates and treatments is summarized in Table 2. The results of this research showed that application of elemental sulphur were significant on soil pH and caused increase in soil available phosphorus and sulphur. Organic manure like vermicompost increased soil organic carbon and soil nitrogen. Data represent three replicate sets for treatments T₀ to T₅, highlighting baseline variability. Treatment T₁ consistently showed the highest total N content (mean 0.10%), while T₅ exhibited the highest potassium levels (mean 0.16 meq/100 g soil). These values indicate moderate initial fertility, with T₅ displaying the lowest N and K across replicates. In Bangladesh, field experiments show that vermicompost application at 5 t ha⁻¹ increases wheat sulphur content by 10–15% and improves post-harvest soil nutrient status, enhancing soil fertility and crop yield (Bhuiyan *et al.* 2008). Addition of organic manure like vermicompost along with inorganic fertilizer had a beneficial effect in increasing the phosphate availability, which was also observed by Ferdous *et al.* (2023); Upadhyay *et al.* (2012). The application of vermicompost along with inorganic sulphur generally resulted in buildup of available S status of the soil. Singh *et al.* (2012) observed in an incubation study an increase in the soil microorganism population apparently utilize organically bound S and convert it into cystine and methionine, which are further converted in to inorganic sulphate by microorganisms. The buildup of available S in soil with the addition of vermicompost after the harvest of the crop has also been reported by Nambiar and Ghosh (1984). Choudhary *et al.* (2005) reported that the incorporation of vermicompost with inorganic fertilizers significantly improved the organic carbon content of the soil. The increase in the yield attributes with the application of vermicompost ascribed to improved physical, chemical and biological properties of soil, direct addition of plant nutrients and growth regulators and also due to increased microbial population of soil, which accelerated the process of humification, removal of obnoxious smell and detoxification of soil pollutants (Singh *et al.* 2021). Ahmadi *et al.* (2017) showed that application of elemental sulphur were significant on soil moisture, field capacity and soil pH and caused increase in soil EC and availability of soil zinc, iron, phosphorus, and sulphate. Also, organic manure like vermicompost increased soil organic carbon and soil nitrogen.

Table 2. Effect of Vermicompost and Sulphur on Soil Properties (2 years mean data)

Treatments	pH	Organic matter (%)	Total Nitrogen (%)	Available Phosphorus (ppm)	Available Sulfur (ppm)	Excachngable Potassium (meq/100g soil)
T ₀	5.3 f	0.98 e	0.05 e	35.17 e	14.71 f	0.09 f
T ₁	6.5 a	1.30 a	0.10 a	45.43 a	22.03 c	0.14 b
T ₂	6.2 b	1.26 b	0.08 c	43.15 b	23.54 b	0.13 c
T ₃	6.1 c	1.24 b	0.09 b	42.33 c	25.27 a	0.16 a
T ₄	5.9 d	1.12 c	0.06 d	45.44 a	21.52 d	0.12 d
T ₅	5.5 e	1.07 d	0.05 e	37.09 d	20.51 e	0.11 e
LSD	0.044	0.033	3.11	0.365	0.079	4.717
CV%	0.41	1.58	2.39	0.48	0.21	2.08
±SEm	0.019	0.015	0.39	0.163	0.036	0.117

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level probability. CV%= Coefficient of Variance and LSD = Least Significant Difference. Here, T₀= Control (No fertilizer), T₁= 4 t ha⁻¹ VC + 0 kg S ha⁻¹, T₂= 3 t ha⁻¹ VC + 3 kg S ha⁻¹, T₃= 2 t ha⁻¹ VC + 6 kg S ha⁻¹, T₄= 1 t ha⁻¹ VC + 9 kg S ha⁻¹, T₅= 0 t ha⁻¹ VC + 12 kg S ha⁻¹.

Heatmap correlation

The heatmap correlation analysis reveals a remarkably strong and positive interrelationship among all evaluated growth and yield parameters of wheat, underscoring the synergistic impact of the combined application of vermicompost and sulphur (Figure 1). Grain yield exhibits exceptionally high positive correlations with biological yield (r = 0.996), straw yield (r = 0.978), and plant height (r = 0.924), suggesting that the enhancements in vegetative biomass, likely driven by improved soil properties, directly translate into superior grain production. Furthermore, tillers per hill (r = 0.915) and the number of spikelets per spike (r = 0.844) are significantly and

positively correlated with the final grain yield, highlighting the critical importance of optimizing early-stage growth through effective nutrient management.

The robust relationship between spike length ($r = 0.899$) and grain yield further emphasizes that treatments enhancing structural development also boost reproductive efficiency and sink capacity. Even specific yield components like 1000-seed weight ($r = 0.730$) and the number of grains per spike ($r = 0.613$) show substantial positive links to the total yield, indicating that the integration of organic vermicompost and inorganic sulphur improves both the quantity and the physical quality of the produce. These findings collectively suggest that this integrated nutrient management strategy effectively optimizes the physiological, morphological, and yield-contributing traits of wheat simultaneously. By enhancing soil fertility and nutrient availability, these amendments facilitate more efficient resource utilization. This holistic interconnectedness, as demonstrated by the heatmap, confirms that management practices aimed at boosting specific growth attributes will lead to a comprehensive increase in the overall productivity of the wheat crop.

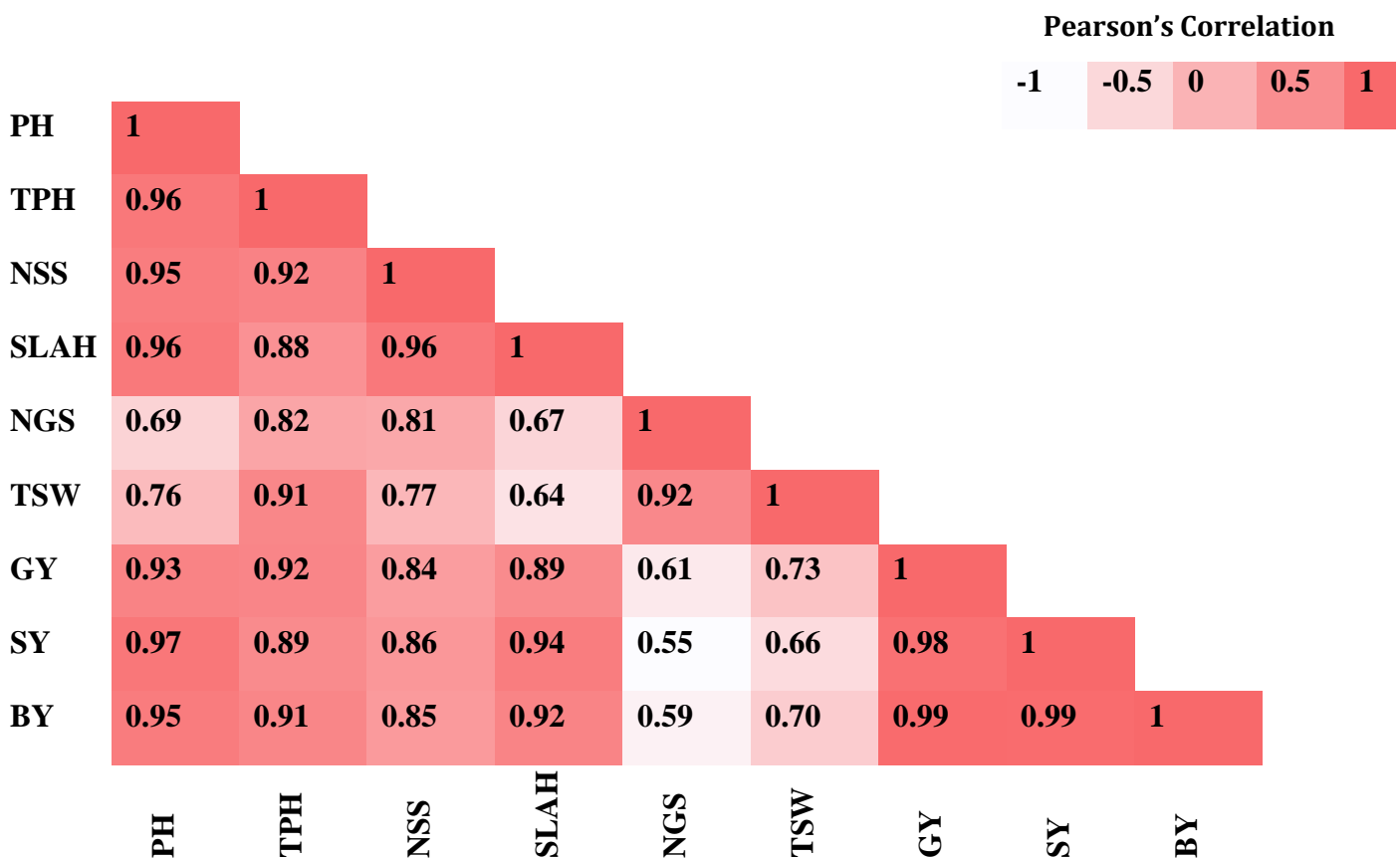


Figure 1: Heatmap showing the Pearson correlation coefficients between various agronomic traits. The color intensity indicates the strength of the correlation, with darker colors representing stronger positive correlations. Here, PH = Plant Height, TPH = Tillers per hill⁻¹, NSS = No. of Spikelets Spike⁻¹, SLAH = Spike Length after Harvesting, NGS = No. of Grains Spike⁻¹, TSW = Thousand Seed Weight, GY = Grain Yield SY= Straw Yield and BY = Biological Yield.

CONCLUSION

Combining sulfur and vermicompost can create a powerful synergy for soil and plant health. The sulfur gradually acidifies the soil, which improves the availability of essential nutrients like phosphorus and micronutrients. Meanwhile, the vermicompost contributes beneficial microbes, improves soil structure, and provides a broad spectrum of organic nutrients. The organic matter in the vermicompost can also help buffer extreme pH changes as the sulfur works, creating a more stable environment. Ultimately, this combination can lead to enhanced plant growth, vigor, and yield by simultaneously optimizing the soil's chemical and biological properties.

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