DOI: https://doi.org/10.5281/zenodo. 10755386

GU JOURNAL OF PHYTOSCIENCES

GU. J. Phytosci. 4(1): 298-307 (2024)

Efficacy of Inorganic and Organic Amendments on Wheat Crop (*Triticum aestivum* L.) Productivity

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Abstract

Wheat stands as the predominant staple food crop in Pakistan, covering the largest agricultural expanse. Despite its widespread cultivation, the per-acre yield lags considerably behind global benchmarks. This lower productivity can be attributed to various factors, including suboptimal soil health, elevated pH levels and deficient organic matter in soil. The significance of organic matter has been underappreciated in this context. In light of the crucial role played by organic matter, this study was conducted at the warehouse of Ghazi University in Dera Ghazi Khan. The primary objective was to explore the combined impact of organic and inorganic fertilizers application on wheat growth and productivity. The study specifically aimed to evaluate the efficacy of Recommended NPK alone and in combination with Zinc-coated DAP, Vermicompost (VC), Farmyard manure (FYD), Poultry manure (PM), and rice husk (RH).The experiment was meticulously designed following a Completely Randomized Design (CRD) having three replicates. Each experimental pot contained 10kg of loamy soil, and the wheat genotype used was 'Faisalabad 2008.' The experimental findings revealed that the introduction of organic amendments significantly influenced various parameters of wheat crop growth. Notably, the combinations of NPK+PM and NPK+RH demonstrated the most favourable results. Furthermore, these organic amendments led to improvements in both the fresh and dry biomass of the wheat.

Keywords: Organic Amendments; Productivity; *Triticum aestivum*

1. Introduction:

Wheat, a crucial staple food crop deeply ingrained in human culture, plays a significant role in the dietary habits and food security of millions. In Pakistan, an agriculturally rich country, wheat production spans a significant 22 million hectares, yielding 26,394 tons and achieving a productivity rate of 2,940 kilograms per hectare. Despite its widespread cultivation across the nation, wheat production in Pakistan lags behind that of other developing countries. This shortfall can be attributed to conventional farming practices, insufficient governmental measures, pest infestations, diseases, suboptimal fertilizer management, and inadequate irrigation facilities (Economic Survey of Pakistan, 2022).

One major impediment to agricultural productivity in tropical regions is the depletion of soil fertility due to the reduction of organic matter and nutrient loss (Israr *et al.*, 2017). In Pakistan, the majority of soils are inherently poor, necessitating the use of both inorganic and organic fertilizers for

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© 2024 (Accepted for publication in November 2023)
Published by Department of Botany, Selection and/or peer-review under supervision of Executive Committee, Ghazi University, DG Khan, 32200 Pakistan

successful crop cultivation. Soil nutrient depletion has become a significant concern, particularly in intensively cultivated areas, where continuous planting and improper replacement of harvested material contribute to erosion and leaching losses. This gradual increase in soil nutrient depletion poses a substantial threat to crop production, intertwining with soil properties, landscape, and cultural practices. (Tsegaye and Bekele, 2010). The prevalent reliance on synthetic fertilizers in the crop production poses threats to soil fertility, sustainability, and broader natural resource bases. The unnecessary use of chemical fertilizers leads to the decline of soil physico-chemical properties and reduced crop yields over time (Barrow, 2012; Pingali, 2012).

To address these challenges and enhance soil fertility and crop production sustainability, there is a pressing need to transition from sole reliance on chemical fertilizers to an integrated approach involving both organic and inorganic sources. Organic substances, proven to enhance soil aggregation, fertility, structure, and microbial diversity, play a pivotal role in improving moisture-holding capacity and, consequently, crop yield (Hargreaves *et al.*,2008). While mineral fertilizers remain essential for maintaining soil fertility, rising costs and environmental concerns necessitate the supplementation or replacement of these with available organic resources (Chaudhry *et al.*, 2013). Maintaining an optimal level of soil organic carbon is vital for effective soil fertility management and agricultural productivity. However, due to the low nutrient contents with slow-releasing process of organic inputs alone, they may not fully meet the nutrient demands of the high-yielding crop varieties (Efthimiadou *et al.*, 2010). Various constituents of organic carbon, such as polysaccharides, humus and microbial biomass carbon, play crucial roles in the formation and stability of aggregates. A balanced ratio of phytonutrients, essential for maintaining productivity in poor socio-economic conditions and regions with low and irregular rainfall, can be achieved through a combined application of inorganic and organic sources of nutrients (Martens and Frankenberger, 1992). Utilizing organic matter like farmyard manure (FYM), vermicompost, and chicken manure contributes significantly to maintain soil fertility and productivity. The application of various organic fertilizers to wheat crops can serve as an additional nutrient source under field conditions. The conversion and reapplication of rice husk residue to rice husk biochar (RHB) as a soil conditioner is a sustainable cultivation method that can enhance soil structure and increase fertilizer effectiveness when used alongside inorganic fertilizer.

Utilizing organic matter such as farmyard manure (FYM), vermicompost, and chicken manure contributes significantly to maintaining soil fertility and productivity. (Dwivedi *et al.*, 2016). Application of various organic fertilizers to wheat crops can serve as an additional nutrient source under field conditions. The conversion and reapplication of rice husk residue to rice husk biochar (RHB) as a soil conditioner is a sustainable cultivation method that can enhance soil structure and increase fertilizer effectiveness when used alongside inorganic fertilizer (Rekhi *et al.*, 2000). Farm yard manure is another organic source for improving soil characteristics and nutrient availability (Iqbal *et al.*, 2005). Vermicompost is a valuable organic fertilizer that can substitute the chemical fertilizers, promote plant growth and improve crop quality, and prevent plant diseases. Combined soil fertility management, which includes both the use of organic and inorganic nutrient sources simultaneously, is the most effective way to improve soil fertility and increase yield (Shah and Wu, 2019). This technique is important not only for improving soil fertility and increasing crop yield but also enhances nutrient use efficiency (Vanlauwe *et al.,* 2015). In summary, this study aims to bridge the gap in understanding the combined use of organic and nitrogen fertilizers to enhance level of soil fertility, increase wheat yield, and improve nutrient use efficiency. The objectives include investigating the efficiency of integrated inorganic and organic fertilizer application in enhancing soil fertility, assessing the effects of sole and mixed application of organic and inorganic fertilizers on soil physico-chemical properties, and determining the impact of sole and combined use of inorganic and organic sources of fertilizers on wheat yield and yield components.

1.1. Objectives:

The study was undertaken with the following aims:

- Evaluate the efficacy of integrating organic and inorganic fertilizers to enhance soil fertility.
- Assess the impacts of applying organic and inorganic fertilizers alone and in combination on soil physico-chemical characteristics.
- Determine the influence of individual and combined applications of organic and inorganic fertilizers on wheat yield and its components.

2. Materials and Methods:

2.1. Experimental Design:

To investigate the impact of organic media on the growth and yield of wheat, a pot experiment was conducted during the winter of 2021-2022 at the Soil and Environmental Sciences Department, Ghazi University, Dera Ghazi Khan. Various organic and inorganic amendments were employed, including recommended NPK, vermicompost, farmyard manure, poultry manure, and rice husk. The experiment comprised 21 plots with three replications for each of the seven treatments. The primary objective was to assess the effects of different organic and inorganic treatments on soil health.

In each experimental pot, 10 kg of soil was filled, and in each pot five seeds of wheat cultivar "Faisalabad 2008" were sown. The applied treatments included: control, recommended NPK, recommended NPK + DAP zinc coated, recommended NPK + vermicompost, recommended + farmyard manure, recommended + poultry manure, and recommended + rice husk. Basal doses of NPK were administered at the fully recommended rates (120:60:60 kg ha^{-1}) to each pot, excluding control, at the commencement of experiment. Zinc-coated DAP was applied at sowing. The NPK sources used were Di-ammonium phosphate (DAP), and sulfate of potash (SOP).

The calculated doses of Zinc-coated DAP, vermicompost, farmyard manure, poultry manure, and rice husk, in addition to the recommended NPK, were mixed into the soil before sowing. The Urea, SOP and DAP were the sources of inorganic fertilizer for nitrogen, potash and phosphorus, respectively. The recommended inorganic fertilizers were split into three doses, with the first dose applied before sowing and mixed with the soil, while the remaining two doses were given at one-month intervals. Rice husk was obtained from a nearby rice mill (Chotti Zareen) and ground using a grinder, while farmyard manure was collected from a local village. Irrigation was performed every 7 days.

2.2. Experimental Procedure:

2.2.1. Plant and Soil Analysis:

Prior to commencing the experiment, surface soil samples (0–30 cm) were collected to assess the physical and chemical characteristics, with due consideration given to all recommended safety precautions for soil sampling (Margesin *et al.,* 2005). These samples were transported to the laboratory, where they underwent air drying and crushing to pass through a sieve with a mesh size of 20 mm. The processed soil samples were then subjected to a thorough analysis of their physical and chemical properties. Pre-sowing soil analyses were also conducted. The chemical profile of the soil (Table 1) revealed an alkaline nature (pH=7.98), an ECe of 9.00 mS/m, and a saturation percentage of 37%.

Table 1: Physico-chemical characteristics of the experimental soil

Characteristics	**Value** (0-30 cm soil)
Physical Characteristics	
Texture	Loam
Chemical Characteristics	
pH	7.975
Electrical conductivity	9.00
Saturation Percentage	37

2.2.2. Treatment Details:

In the experimental setup, various treatments were applied to investigate their impact on wheat Crop. The treatment details are as follows:
T1: Control
T2: Recommended NPK
T3: Recommended NPK + DAP zinc coated
T4: Recommended NPK + Vermicompost
T5: Recommended NPK + Farmyard Manure
T6: Recommended NPK + Poultry Manure
T7: Recommended NPK + Rice Husk
These treatments were carefully selected to assess their individual and comparative effects on the growth and yield of the wheat. The experiment aimed to evaluate the agronomic performance of wheat Crop under different nutrient and organic input conditions.

2.2.3. Preparation of Vermicompost:

A pit was excavated for the preparation of vermicompost. In the first sub-layer of each pit, organic waste was evenly spread. Subsequently, 4 kg of cow dung was blended with 80 liters of water, meticulously sprinkled over the organic waste to foster microbial activity in the second sub-layer. To facilitate moisture retention and act as a buffer during biodegradation in the third sub-layer, 60 kg of dry soil was uniformly applied to the soaked biomass. This layer-by-layer filling process continued until the pit was completely filled. Once filled, the biomass was covered with a layer of soil 3-inch thick and sealed with a mixture of cow dung and mud plaster. Moisture levels were maintained at 60-80 percent.

The microbial inoculants comprised a combination of microbes, including cellulolytic fungus (*Trichoderma viride*, *Pleurotus sajor*), phosphate-solubilizing bacteria (*Bacillus polymyxa*), and free-living nitrogen-fixing bacteria (*Azotobacter chroococcum*). Cellulolytic fungal cultures of *Trichoderma viride* were inoculated at the rate of 300 g per ton of raw material, while Bacillus polymyxa was applied at the rate of 500 g per ton of raw material. Carrier-based inoculants of Azotobacter were introduced to achieve a population of 100 x 10^6 per 100 kg of organic material.

The inoculation with the cellulolytic fungi was done at the beginning of the composting process, whereas the addition of the nitrogen fixers and phosphate solubilizers was done after 28-30 days to protect them from direct exposure to extra heat produced during the initial composting. Cultures such as Trichoderma, Azotobacter, and phosphate-solubilizing bacteria were sprinkled in layers to expedite the process of composting.

To enhance micronutrient content of the compost, a salt solution of gypsum at 12 kg per ton and zinc sulfate at 200 g per ton of compost was externally sprayed during the final turning stage of the composting mass. Water was added to maintain moisture levels at 70-80%. The material was turned three times throughout the composting process—after 15, 30, and 60 days from filling the pits—to ensure thorough mixing and decomposition. At each turning, the materials were moistened with water and then returned to the pit.

2.2.4. Determination of Plant Parameters:

The study aimed to provide a comprehensive understanding of plant growth and productivity by assessing various plant parameters. Plant height, leaf length, shoot weight, root length, fresh and dry weight of plants were measured at harvest. Plant height was recorded using a meter scale, while leaf length was measured at three intervals using a scale meter. Shoot weight was determined using an electric weight balance in grams, and root length was measured in centimeters. Fresh weight was recorded immediately after harvesting, and dry weight was calculated after oven drying. Tiller number was documented for each pot at the harvest stage, and effective tillers (those with spikes) were counted from pot to pot. The average length of the shoot and root was statistically calculated. The total number of tillers was recorded for each pot at the harvest stage. Yield parameters, including spike length, grain number, test weight, and grain yield, were also measured after harvesting. The length of spikes was measured from the neck node to the tip, and then average was calculated. Grain numbers were counted and averaged per spike. Test weight was converted to grams for small tillers. After threshing, grains were separated from straw, cleaned, and the grain yield was recorded pot-wise. The study aimed to determine the optimal treatment for different types of crops.

2.2.5. Soil Analysis:

After the harvesting of the wheat, the soil samples were collected from each experimental unit for soil analysis. The electrical conductivity (EC) and soil pH were measured by using a 1:1 and 1:0 ratio, respectively, employing a EC meter and pH meter. Organic matter (OM) of soil was assessed by using Walkley-Black method. The determination of soil available phosphorus was conducted using a spectrometer, while potassium levels were determined using a flame photometer. All these procedures were carried out in accordance with established protocols (U. S. Salinity Laboratory Staff, 1954).

2.3. Statistical Analysis:

The experimental wheat crop and economic parameters were analyzed using standard techniques to compare different treatments. Analysis of variance was employed, and the LSD test at a 5% probability level was employed to assess differences among the means of various treatments. The collected data were tabulated and analyzed for validity.

3. Results:

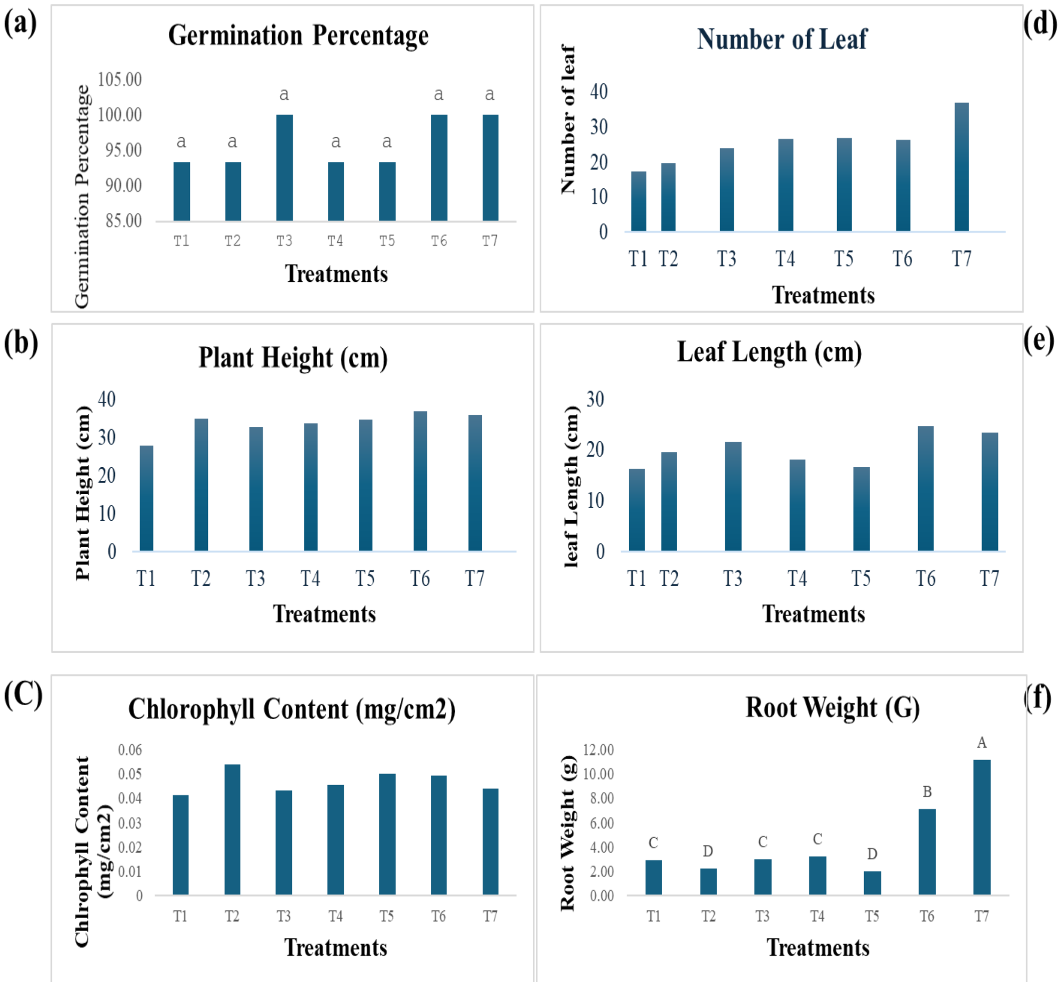
3.1. Effect of Inorganic and Organic Amendments on Wheat Growth and Development:

The conducted pot experiment, evaluating the impact of various inorganic and organic amendments on wheat germination and subsequent growth, revealed noteworthy outcomes. Germination percentages were not significantly affected by the amendments; however, T3 (recommended NPK + DAP zinc coated), T6 (recommended NPK + Poultry Manure), and T7 (recommended NPK + rice Husk) demonstrated maximum germination compared to the control (Fig. 1). Examining plant height (Fig. 1.a), T4 (Recommended NPK + Vermicompost) exhibited the tallest plants (82.33 cm), followed by T5 (Recommended + Farmyard Manure), outperforming the control. Conversely, T2 (Recommended NPK) and T1 (Control) had the shortest plants with values 69.66 cm and 75 cm, with significant differences among treatments. Interestingly, T1 (control), T3 (recommended NPK + DAP zinc coated), T5 (recommended NPK + farmyard Manure), T6 (recommended NPK + Poultry Manure), and T7 (recommended NPK + rice Husk) showed non-significant effects on each other. Chlorophyll content

(Fig. 1.c) revealed uniform values (0.05 mg/cm2) for T2 (recommended NPK), T4 (recommended NPK + vermicompost), T5 (recommended NPK + farmyard Manure), and T6 ((recommended NPK + Poultry Manure), while T1 (Control), T3 (recommended NPK + DAP zinc coated), and T7 (recommended NPK + rice Husk) exhibited lower values (0.04 mg/cm2). Leaf count (Fig. 1.d) highlighted T7 (recommended NPK + rice Husk) with the maximum count (37), followed by T5, while T1 and T2 had the minimum number of leaves. Leaf length (Fig. 1.e) displayed T6 (recommended NPK + poultry manure) with the longest leaves (24.6 cm), followed closely by T7 and T3. T1 (control) exhibited a minimum value of 16.2 cm, with significant values.

Root and shoot weights (Fig.s 1.f and g) showcased Treatment-7 (recommended NPK + rice Husk0 with the maximum values, emphasizing its superiority. Root weight revealed T7 at 11.16g, surpassing T6 (7.14g) and the control (2.93g). For shoot weight, Treatment-7 led with 15.95g, while the control had the minimum (3.80g), with significant variations. Root length (Fig. 1.i) demonstrated T7 (recommended NPK + rice Husk) with the longest roots (24 cm), followed by T3. T1 and T6 had the smallest root lengths (15.7 cm), showing the positive influence of amendments on root development. Fresh and dry weights (Fig.s 1.j and k) exhibited Treatment-7 (recommended NPK + rice Husk) with the highest values, indicating its substantial impact. While T1 (control) showed the minimum value in both fresh and dry weight. For spike length (Fig. 1.m), T3 (recommended NPK + DAP zinc coated) had the maximum (16.18 cm), surpassing other treatments, while T6 and T1 exhibited the minimum having values 15.09 cm and 13.56 cm. Spikelet count (Fig. 1.n) showcased T3 (recommended NPK + DAP zinc coated) with the highest (16.5), while the control had the minimum (13.8). Grains per plant (Fig. 1.o) revealed T3 (recommended NPK + DAP zinc coated) with the maximum count (325), emphasizing significant effects on productivity. While T1 (control) had the minimum grains per plant with 98.66.

Productive tillers (Fig. 1.p) displayed Treatment-7 (recommended NPK + rice husk) with the highest count (15.7), outperforming others. While T1 (control), showed minimum count with 3 per plant. In terms of 1000 grain weight (Fig. 1.q), Treatment-7 (recommended NPK + rice husk) again led with 64.3 g, showcasing diverse effects on productive tillers and grain weight. While in T1 (control) Showed minimum results in productive tillers and grain weight (Fig. 1.p



and q). These findings underscore the substantial impact of inorganic and organic sources on wheat plant characteristics and productivity.

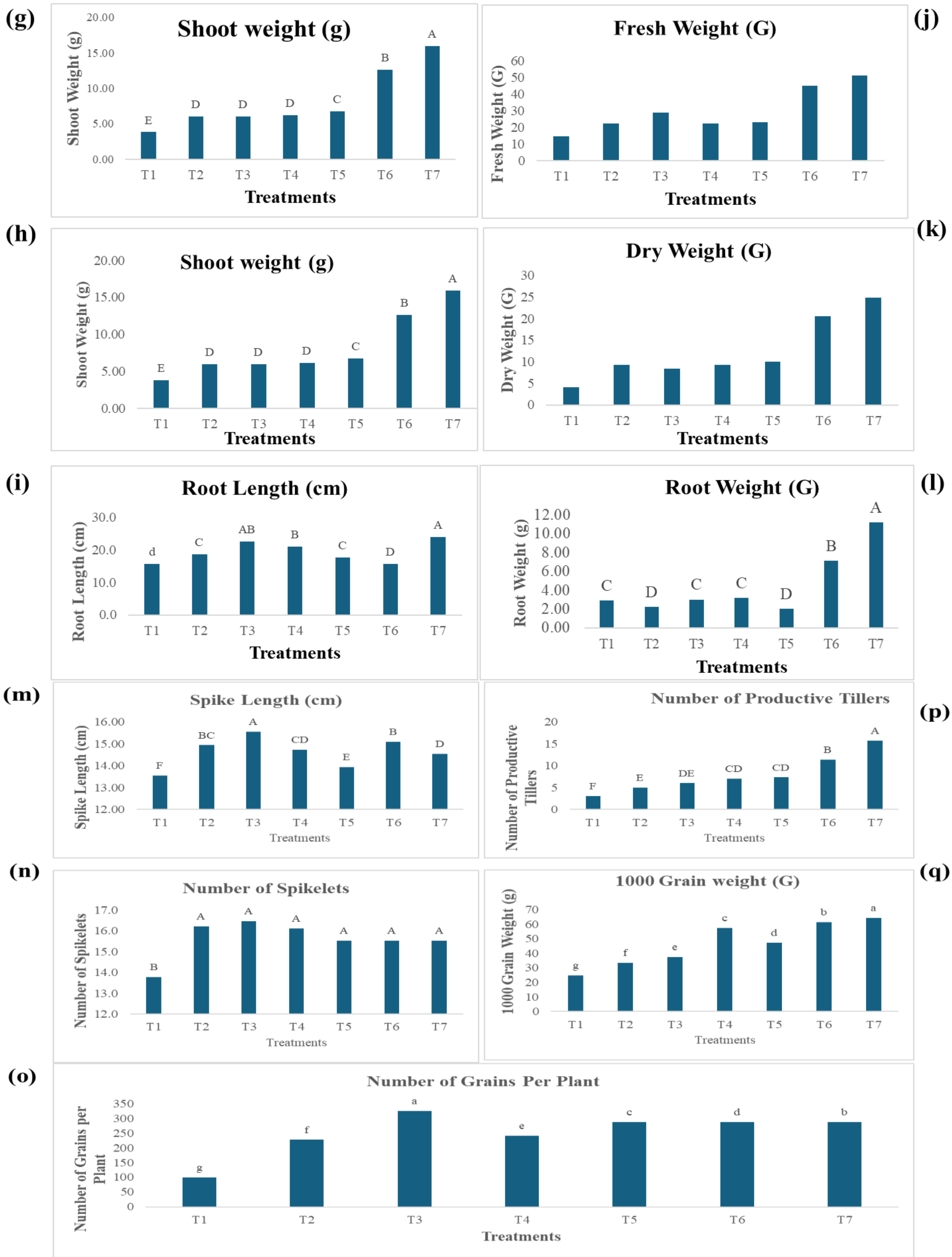


Figure 1: Effect of various treatments (T) including T1 (control), T2 (recommended NPK), T3 (Recommended NPK + DAP zinc coated), T4 (recommended NPK + vermicompost), T5 (recommended NPK + Farmyard manure),

T6 (recommended NPK + poultry manure), and T7 (recommended NPK + rice husk) on growth and development of Wheat. Each bar represents the mean values for each treatment. (a = Germination Percentage, b = Plant Height, c = Chlorophyll Content, d = Number of leaf, e = Leaf Length, f = Root Weight, j = Fresh Weight, k = Dry weight, l = Root Weight, m = Spike Length, n = Number of Spikelet's, o = Number of Grains per Plant, p = Number of productive Tillers, q = 1000 Grain Weight)

3.2. Effect of Inorganic and Organic Amendments on Soil Physiochemical Properties:

The study demonstrates the significant impacts of various inorganic and organic amendments on soil properties. Application of organic matter with inorganic fertilizers enhances soil organic matter (OM), increases soil electrical conductivity (EC), and reduces soil pH. Furthermore, organic amendments improve crop efficiency in absorbing available potassium and phosphorus (Fig. 2). In this experiment, the addition of organic amendments with recommended NPK leads to increased soil OM, with the highest observed in T6 followed by T5 compared to the control (Fig. 2.r). Soil EC also increases with the use of organic amendments with recommended NPK, reaching the maximum in T7 followed by T3 compared to the control (Fig. 2.t). Furthermore, the utilization of organic amendments not only increases the overall productivity of the soil but also contributes to elevated nitrogen levels when compared to the control group. In treatment-3 (Recommended NPK + DAP Zinc Coated), the presence of nitrogen reached its peak, with T4 (Recommended NPK + Vermicompost) closely trailing, surpassing the nitrogen levels observed in the control group (Fig. 2.u). A significant reduction in soil pH is noted with the use of both organic and inorganic amendments, with the highest decrease observed in T5, similar to T6, followed by T3 (Fig. 2.s). Moreover, amendments lead to a reduction in soil-available potassium (Fig. 2.w) and phosphorus (Fig. 2.v) compared to the control, attributed to enhanced nutrient absorption by crops amended with organic materials.

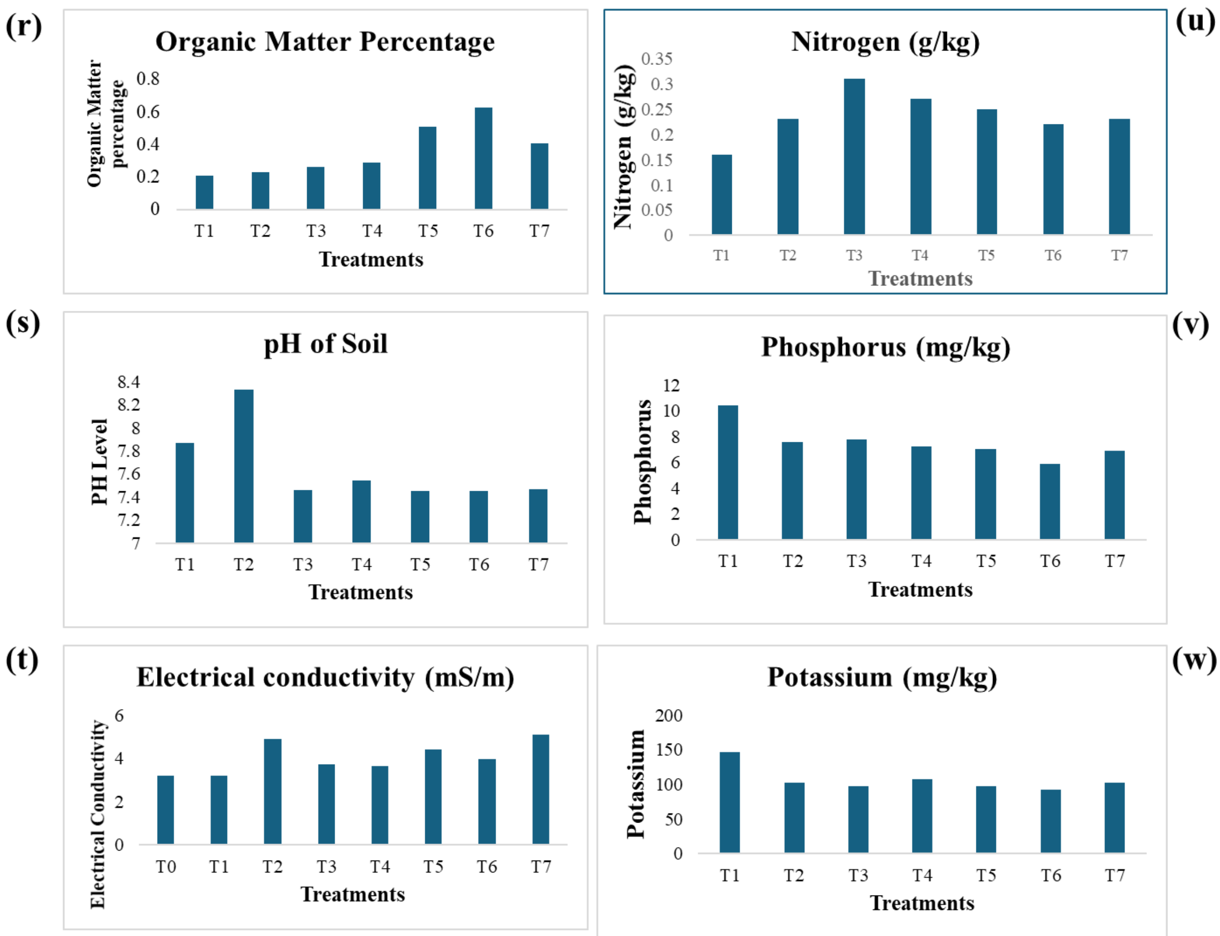


Figure **2:** Experimental treatments assessing the impact of different organic amendments on soil properties. T1 represents the control, while T2 to T7 correspond to treatments involving recommended NPK, recommended NPK with DAP zinc-coated, recommended NPK with vermicompost, recommended NPK with farmyard manure, recommended NPK with poultry manure, and recommended NPK with rice husk. Whereas r = organic matter, s = pH, t = Electrical Conductivity, u = Nitrogen, v = Phosphorus, w = Potassium.

4. Discussion:

The application of organic manures along with inorganic amendments enhances soil fertility. This is due to increase in organic matter content in the soil. The addition of organic matter content in the soil has at the benefit of enhancing soil organic matter through various chemical properties such as soil porosity, saturation percentage cation exchange capacity and soil nutrient turnover rate. The research also indicated that application of organic matter to a soil leads to increase the availability of nutrients to the plants (Braschi *et al*., 2003). This correlation can be due to the improvement in soil cation exchange capacity at the addition of every new growing season study, which is also the result of nutrient release which is mainly due to the organic matter decomposition from the applied organic manures (Zhao *et al*., 2009). Our results are also supported by the findings of Kumar *et al.* (2006).

Application of organic matter significantly lowered soil pH. Indeed, higher activity of soil microorganisms may indicate increased nitrogen content in the soil, thereby decreased soil pH. Our findings are also in line with Kumar *et al.* (2006). Ammonium is the main form of nitrogen taken up by plants, which leads to the release of hydrogen ions, resulting in the loss of soil pH within the rhizosphere soil (Bezdicek-Fauci, and Schwab, 2002). The increase in Organic matter enhances the activities of soil enzymes that greatly affect soil pH (Zhao *et al*., 2009). According to Liao *et al.* (2016), the soil organic carbon plays a remarkable role in determining soil pH. Application of organic amendments with recommended NPK significantly improved plant growth. The enhancement in plant height was due to increase in soil OM along with recommended NPK. These findings are in line with the results of Dalal *et al.* (2014) who observed that the height of plant was enhanced by the application of various organic manure and potting media. The data related root and shoot weight also showed that application of organic amendments especially rice husk showed a better performance for root shoot weight. These findings are in line with the results of Devan *et al.* (2013). The applications of organic amendments with recommended NPK enhanced root and shoot weight (Saravanan and Panneerselvam 2014). Dalal *et al.* (2014) compared the influence of organic and chemical fertilizers on the quality and growth yield of chilli and brinjal, finding that the latter produced longer shoots, a greater total production yield, and more branches than the former. The application of organic amendments along with inorganic fertilizer enhances the chlorophyll content of the crop as well. Rehman *et al*. (2017) stated that the integrated application of organic and inorganic amendments enhances the transpiration rate, stomatal conductance, chlorophyll contents and the photosynthetic rate of wheat crop. The application of organic amendments along with recommended NPK also showed better performance on yield attributes of wheat. The use of organic amendments especially rice husk showed a prominent impact on spike length, number of spikletes, productive tillers, and number of grains per spike and 1000 grain weight as shown in Fig. 1. The findings for spike length of our research were similar to the findings of Ahmad *et al*. (2008). According to El-Sobky. (2021), application of organic amendments with inorganic fertilizers significantly enhanced overall yield of wheat crop. These findings are in line with the results of Yu*et al.* (2023), Ranjan *et al.* (2023) and Albano *et al.* (2023). Rehim *et al.* (2020) &Khan *et al* (2013) in their findings also found that the use of farm yard manure with inorganic fertilizers like nitrogen and phosphorus also improved the number of grains per spike. A significant increase in growth, yield and grains weight was observed when the soil was amended with different organic manures (Tahir *et al*., 2011). Maqsood *et al*. (2001) also revealed that, the sufficient application of NPK increased number of tillers in wheat plant. Awan *et al*. (2011) stated that increased in spike length in those treatments which are the applied with both organic and inorganic fertilizers are may be due to the high availability of nutrients.

5. Conclusion and Recommendation:

Combined application of inorganic and organic fertilizers positively affected plant growth and yield attributes. Therefore, the study concluded that the application of organic amendments, in particular rice husk and poultry manure, significantly improved the physical and chemical properties of the soil, ultimately resulting in positive plant growth and yield. In addition, the study concluded that if rice husk is applied with a combination of recommended NPK, it proves to be a better substitute for nutrient availability compared to chemical fertilizers alone. Whereas it is a rich source of nutrients and is available cheaply, it must be applied in bulk quantities. Therefore, it is recommended that application of rice husk in combination with NPK not only affects plant growth and yield but also proves to be very beneficial economically.

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