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MORPHO-PHYSIOLOGICAL, BIOCHEMICAL AND YIELD RESPONSES OF WHEAT (*TRITICUM AESTIVUM* L.) TO VERMICOMPOST, SIMPLE COMPOST AND NP FERTILIZER APPLICATIONS

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Abstract

An experiment in the field was performed to assess the impacts of simple compost, vermicompost, and NP fertilizer application on the morpho-physiological, biochemical, and yield characteristics of wheat in order to optimize nutrient needs. All the estimation was performed relying on various parameters *viz.* plant height, leaf area, N, P, K contents of leaf, superoxide dismutase, peroxidase, membrane stability index, relative water contents, chlorophyll contents, photosynthetic rate, osmotic potential, water potential, canopy temperature, stomatal conductance, total tillers of crop, length of spike, per spike spikelets number, grains numbers per spike, weight of 1000 grains, economic yield, biological yield and harvest index of wheat. The vermicompost application alone increased growth and productivity, but combining vermicompost with chemical fertilizer is highly desirable for wheat production. It was concluded from this study that 50% vermicompost (produced from FYM, rice and wheat straw) mixed with 50% recommended fertilizers showed excellent results. While, 25% vermicompost (produced from rice straw, wheat straw and cow dung) and 25% compost (produced from cow manure, rice straw and wheat straw) mixed with 50% recommended fertilizers showed intermediate results whereas, compost (produced from cow manure, rice straw and wheat straw) and control (recommended fertilizers) showed minimum results in wheat crop and soil fertility decreased in T_0 treatment.

Key words: Compost, Growth, Inorganic fertilizers, Vermicompost, Wheat, Yield.

Introduction

Wheat is one of Pakistan's most valuable crop. It's total production is 24.95 million tons and currently grown on 8.83 million hectares. It contributes 1.7% to GDP and 8.7% to value addition in agriculture (GOP, 2020). Almost 50% of the total calorie intake by the population of Pakistan is provided by wheat. However, rural households' contribution is more significant because their dietary habits are strongly characterized by loaf and bread made from wheat flour (Hussain *et al*., 2014). According to supply and demand-based forecasts by IFPRI, demand for wheat in Pakistan is expected to grow by 30 million tons by 2030 (Nazli *et al*., 2012). Given the prospect of straight expansion or additional land under cultivation, any productivity gains must be realized promptly via careful management of all input resources (Singh & Biswas, 2000).

Poor soil fertility is the main problem that causes adversely decreased production in the agriculture sector in Pakistan. In particular, the most significant cause for low biomass production is a decline in soil fertility levels due to intensive agriculture involving exhaustive high-yielding cultivars that heavily deplete soil nutrients (Lal, 2018). Therefore, to enhance the quantity of nutrients required for optimum plant growth, the application of inorganic components to increase the fertility status of bad soil quality is inevitable. Production per unit area can be increased by improving soil fertility by fertilization (Singh & Biswas, 2000). Excessive use of synthetic fertilizers, on the other hand, causes environmental degradation and pollution in surface and deeper water, moreover to upsetting the physical, biotic, and nutritive aspects of soil (Han *et al*., 2006). Implementing integrated nutrient management strategies is the greatest approach to decrease production costs, boost nutrient usage efficiency, and increase output (Weber *et al*., 2007; Pullicinoa *et al*., 2009; Hammad *et al*., 2010). The appropriate admixture made of some organic and inorganic enhancers in fertilizing the soil, provokes crop yield and health of soil (Aslam *et al*., 2010; Avasthe *et al*., 2014).

Vermicomposting is a technology for handling organic waste that is low input, cheaper and environment friendly (Aira *et al*., 2002; Aslam *et al*., 2022; Bellitürk *et al*., 2020; Kilbacak *et al*., 2021). Plant and animal wastes in the soil are known as organic matter, and it improves the soil physically, chemically, and biologically (Bellitürk *et al*., 2019; Ahmad *et al*., 2021). Vermicompost is bio-oxidation and organic material stabilization that involves the total action of micro-organisms. During the vermicomposting process, earthworms play an important role in converting biodegradable organic matter into high quality manure. Earthworm gut microorganisms produce exoenzymes that help to degrade organic matter into forms of nutrients that are available for plant growth (Mathivanan *et al*., 2013; Ahmad *et al*., 2021). It contains more nitrate (NO_3), phosphorus (P), potassium (K), sulphur (S), and magnesium (Mg) than standard compost (Aslam *et al*., 2022; Ahmad *et al*., 2022), and may improve soil conditions, increase crop development, and yield with a fraction of the quantity of classic composting methods (Pezeshkpour *et al*., 2014). Compared to conventional composting, vermicompost improves soil conditions, encourages crop growth, and yields by applying in comparatively smaller quantities (Atiyeh *et al*., 2001; Aslam & Ahmad, 2020). According to Suthar (2008), if chemical fertilizers are used in the right proportions with vermicompost, it may be a good source of nutrients for field crops. Previous research has also shown that adding vermicompost to highly prolific legumes had a positive impact (Suthar, 2006; Aslam *et al*., 2020).

Simple composting is a waste stabilization process that produces stable compost that may be used as low-grade manure and soil conditioner under appropriate soil moisture and aeration conditions (Guar & Singh, 1993). Compost, as naturally created from waste products, may be a helpful and inexpensive as well as a source of nutrients for plants. It has been demonstrated in several studies to have a good influence on crop major organicity and water retention capacity (Wells, 2000; Shen & Shen, 2001; Jedidi, 2004; Odlare, 2008). Furthermore, compost fertilizer has good nutritious value owing to high nitrogen, phosphorous, and potassium concentrations, whereas heavy metal pollution and other hazardous elements are quite low (Ndegwa & Thompson, 2001). Compost and vermicompost may have various physical and chemical qualities as a result of their varied processing processes, impacting plant development and morphology in different ways. After vermicomposting, the organic material is generally pulverized to a more uniform scale, giving the finished substrate a distinct earthy look. After composting, the final material has a more diverse look (Tognetti, 2005; Sarwar *et al*., 2007). Compost and chemical fertilizer in combination has been demonstrated to boost crop biomass and grain production in previous experiments (Cheuk *et al*., 2003; Gopinath, 2008; Sarwar *et al*., 2008). Moreover, optimistic changes in wheat flour quality have been recorded, with the amount of gluten increased following compost treatment (Asghar *et al*., 2006; Aslam *et al*., 2020).

Many studies have proven that inorganic fertilizers and organic sources alone are insufficient for long-term productivity (Godara *et al*., 2012). Soil fertility is a potential technique to overcome soil fertility restrictions and contributing to high agricultural crop output via effective use of organic and inorganic fertilizers resource combinations (Singh *et al*., 2011). Compost and manure are examples of organic fertilizers that may provide soil organic matter (SOM) and nutrients for crop development and productivity. However, having adequate amounts of composts and manures to offer significant quantities of nutrients for crops in smallholder farmers' fields is problematic. To guarantee an adequate and balanced supply of nutrients to crops, it is advised that organic and inorganic fertilizers be used together. Chemical fertilizers may supply plants with easily accessible nutrients at an early stage using a collective nutrient management strategy, while organic fertilizers can boost yields (Kumar *et al*., 2015; Aslam *et al*., 2021). Using organic and inorganic fertilizers together improves fertilizer efficiency, maintains the provision of balanced nutrients to crops, and promotes soil sustainability, among other benefits. According to various researches, combining organic and inorganic nutrition sources provides several benefits over utilizing either type alone (Abedi *et al*., 2010; Mitiku *et al*., 2014; Sangiga & Woomer, 2009). However, there has been relatively little study into integrating vermicompost, conventional compost, and synthetic fertilizers as part of an integrated nutrient management plan to maximize the production potential of cereal crops like wheat. As a result of the previous discussion of the favorable benefits of each individual amendment, an experiment was undertaken to see how well vermicompost, basic compost, and chemical fertilizers worked together to improve wheat growth, yield, and nutrient absorption.

Material and Methods

During the Rabi season of 2019-20, the trial was conducted in the Plant and Microbial Ecology Laboratory and Student Research Farm, Department of Agronomy, Faculty of Agriculture, University of Agriculture, Faisalabad. Randomized Complete Block Design (RCBD) was used to lay out the study.

Physicochemical properties of soil: Standard procedures were applied to gather samples of soil before and after sowing and harvesting the crop, respectively. Three samples were obtained from the experimental site before planting and composited, and thirteen samples (one from each treatment) were taken after harvesting wheat from 0-15 cm and 15-30 cm depths using auger. The samples were sealed in polythene bags and sent to the Ayub Agricultural Research Institute's Soil and Water Testing Laboratory in Faisalabad. Table 1 summarizes the soil qualities. We measured pH, Ec, Ex. Na, organic matter, nitrogen, available P, and exchangeable K. By feel method clay loam textured soil at 0-15 cm and clay soil at 15-30 cm was collected for analysis.

Analysis of raw material, simple compost and vermicompost: Chemical and nutritional parameters of wheat straw, rice straw, cow dung, simple compost and vermicompost, were measured. The results are shown in the table below (Table 2). Heavy metals, including Cd (ppm), Ni (ppm), Pb (ppm), Hg (ppm), Cr (ppm), and Sn (ppm), were measured in the following wheat straw, rice straw, cow dung, simple compost, and vermicompost (Table 3).

Meteorological data: Weather data was collected during the crop's growing season from University of Agriculture's Faisalabad meteorological observatory during 2019-20. The meteorological conditions that prevailed during the growing season of the wheat crop are shown in (Fig. 1).

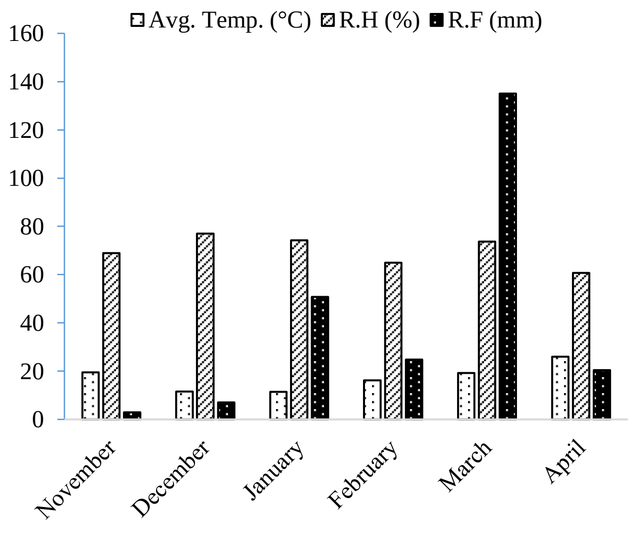

Fig. 1. Avg. Temp (Average temperature) [°C], R.H (Relative humidity) [%], R.F (Rainfall)[mm].

Table 1. The experimental site's pre-sowing and post-harvest soil physico-chemical characteristics.

Characteristics	Pre-sowing analysis			Post-harvest analysis												
	Depth (cm)	Values		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
pH (1:25)	0-15	Quantity	8.80	8.80	8.20	8.30	8.25	8.60	8.70	8.65	8.50	8.60	8.63	8.62	8.50	8.61
		Status	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
	15-30	Quantity	8.00	8.10	7.80	7.85	7.83	7.90	7.93	7.91	7.88	7.95	7.93	7.94	7.91	7.94
		Status	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic	Basic
EC (1:25) dsm^{-1}	0-15	Quantity	1.80	1.84	1.70	1.72	1.71	1.78	1.77	1.78	1.75	1.77	1.76	1.77	1.73	1.75
		Status	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
	15-30	Quantity	1.30	1.31	1.20	1.23	1.21	1.28	1.29	1.28	1.23	1.25	1.26	1.25	1.23	1.24
		Status	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Ex. Na (mmole/100 g)	0-15	Quantity	2.60	2.65	2.48	2.51	2.50	2.58	2.59	2.58	2.53	2.57	2.56	2.50	2.45	2.51
		Status	High	High	High	High	High	High	High	High	High	High	High	High	High	High
	15-30	Quantity	1.70	1.72	1.61	1.64	1.62	1.66	1.68	1.67	1.63	1.65	1.66	1.63	1.64	1.66
		Status	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high	Medium high
Organic matter (%)	0-15	Quantity	1.40	1.34	1.60	1.57	1.58	1.42	1.41	1.42	1.55	1.54	1.55	1.50	1.59	1.48
		Status	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	15-30	Quantity	0.95	0.91	1.00	0.98	0.99	0.96	0.95	0.96	0.99	0.97	0.96	0.98	1.00	0.98
		Status	Very low	Very low	low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
Nitrogen (%)	0-15	Quantity	0.07	0.07	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		Status	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
	15-30	Quantity	0.05	0.04	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Status	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
Available P (ppm)	0-15	Quantity	30	28	38	36	37	32	31	32	34	32	33	31	33	32
		Status	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
	15-30	Quantity	35	33	41	39	40	36	37	37	39	38	36	38	36	36
		Status	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
Exchangeable K (ppm)	0-15	Quantity	334	330	349	345	347	335	335	336	340	338	337	336	340	338
		Status	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high
	15-30	Quantity	305	303	318	316	317	307	306	308	310	309	307	306	311	310
		Status	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high	Very high

Table 2. Chemical analysis of raw material, simple compost and vermicompost.

Treatments	pH	EC (dS/m)	OM (%)	C/N	N (%)	P_2O_5 (%)	K_2O (%)	Ca (%)	Mg (%)	Fe (%)	S (%)
Wheat straw	6.70	4.25	74	12.00	0.30	0.18	0.22	1.20	0.14	0.09	0.12
Rice straw	6.90	4.96	80	12.90	0.45	0.27	0.30	1.40	0.28	0.13	0.16
Cow dung	7.10	6.00	70	11.00	0.57	0.34	0.33	1.80	0.35	0.17	0.19
Wheat straw compost	7.09	3.12	48	9.00	0.70	0.38	0.40	1.95	0.45	0.25	0.23
Rice straw compost	7.00	3.80	50	10.00	0.85	0.45	0.47	2.03	0.49	0.28	0.26
Cow dung compost	7.50	3.95	43	10.00	0.98	0.49	0.55	2.15	0.55	0.33	0.29
Wheat straw vermicompost	7.23	3.00	35	9.00	1.02	0.70	0.80	2.43	0.68	0.39	0.31
Rice straw vermicompost	7.30	2.80	34	9.00	1.23	0.91	1.00	2.80	0.75	0.42	0.36
Cow dung vermicompost	7.75	2.91	38	8.00	1.47	1.06	1.03	3.01	0.79	0.48	0.39

Table 3. Chemical analysis for heavy metals of raw material, simple compost and vermicompost.

Treatments	Cd (ppm)	Ni (ppm)	Pb (ppm)	Hg (ppm)	Cr (ppm)	Sn (ppm)
Wheat straw	0.79	12.00	58.00	2.00	17.00	0.21
Rice straw	0.88	15.00	65.00	2.05	14.00	0.22
Cow dung	0.75	11.00	51.00	1.50	9.00	0.09
Wheat straw compost	0.43	8.00	0.43	1.20	7.00	0.08
Rice straw compost	0.55	10.00	0.47	1.23	8.00	0.10
Cow dung compost	0.54	7.00	0.39	1.00	5.00	0.05
Wheat straw vermicompost	0.36	6.00	0.33	0.99	4.00	0.04
Rice straw vermicompost	0.36	6.00	0.36	1.05	4.00	0.02
Cow dung vermicompost	0.29	4.00	0.18	0.63	2.00	0.01

Organic and inorganic fertilizers: During 2018-19, the simple compost and vermicompost were collected from the Plant and Microbial Ecology Laboratory and Student Research Farm of the Department of Agronomy, Faculty of Agriculture, University of Agriculture, Faisalabad. Organic fertilizers that were prepared from different sources were analyzed before the application. Simple compost, vermicompost and chemical fertilizers (Fig. 2) were applied in combination and chemical fertilizers were applied alone in each respective plot and then mixed thoroughly. The treatments applied were as following:

T_0: Control (Recommended fertilizers) @110:55 NP kg ha^{-1}
T_1: 100% Vermicompost (FYM) @ 5 t/ha
T_2: 100% Vermicompost (Wheat straw) @ 6 t/ha
T_3: 100% Vermicompost (Rice straw) @ 5 t/ha
T_4: 100% Compost (FYM) @ 8 t/ha
T_5: 100% Compost (Wheat straw) @ 10 t/ha
T_6: 100% Compost (Rice straw) @ 8 t/ha
T_7: 50% Vermicompost (FYM) + 50% recommended fertilizers
T_8: 25% Vermicompost (FYM) + 25% compost (FYM) + 50% recommended fertilizers
T_9: 50% Vermicompost (Wheat straw) + 50% recommended fertilizers
T_{10}: 25% Vermicompost (Wheat straw) + 25% compost (Wheat straw) + 50% recommended fertilizers
T_{11}: 50% Vermicompost (Rice straw) + 50% recommended fertilizers
T_{12}: 25% Vermicompost (Rice straw) + 25% compost (Rice straw) + 50% recommended fertilizers

Crop husbandry: On November 30, 2019, the single row manual hand drill was used for sowing of wheat (Akbar-2019). The crop was sown maintaining a row to row distance 23 cm, with a seed rate of 125 kg ha^{-1}. The crop received its initial irrigation 24 days after sowing, and following irrigations were determined by the crop's needs. The crop received three irrigations in total, but it also received water from rainfall at different development phases. Crop harvesting was done on April 26, 2020.

(i). Plant height (cm): To estimate plant height, ten plants were picked from each sub-plot and measured with a meter rod from the soil base to the top of all plants and average was recorded.

(ii). Leaf nitrogen content (mg g^{-1}Dw): 0.1 g dry powdered leaf was placed in the digestive tube. 5 mL concentrated H_2SO_4 was added to each tube. It was incubated for 24 hours at room temperature. In the digesting tubes, 1 mL H_2O_2 (35%) was added. Before fumes developed, the tubes were inserted into the digestive system and the temperature was elevated to 350°C. Kept the temperature at the same level for 30 minutes. After that, the digesting tubes were taken out of the block and left to cool. Then another 1 ml of H_2O_2 was poured and the tubes were placed back to the digestion block. These steps were continued until the digested material had lost its colour and become colorless. The extract was prepared in volumetric flasks with a capacity of 50 mL. The extract was purified with filter paper and the Kjeldahl method was used for nitrogen content determination.

(iii). Leaf phosphorus content (mg g^{-1}Dw): A 5 mL aliquot was collected and put in a volumetric flask with a 50 mL capacity. After pouring 10 mL of Barton reagents, the distilled water was used to bring the volume up to the mark. Volumes of up to 10 mL of Barton reagents made from distilled water standards were prepared using KH_2PO_4. To produce colours, this sample was kept for several minutes. Spectrophotometer was used to calculate phosphorus at 420 nm using a standard curve.

(iv). Leaf potassium content (mg g^{-1}Dw): For digestion, the same procedure was used as discussed above in the leaf nitrogen determination. The potassium contents were evaluated using a flame photometer.

Antioxidant enzyme extraction: To extract the antioxidant enzyme, samples of 0.5 g of frozen leaves were subjected for grinding with the support of a pestle in an ice cold mortar in a 50 mM (pH 7.8) cooled phosphate buffer (5 ml) in an ice bath. At 4°C the homogenate was centrifuged for 15 minutes at 15000 rpm. The supernatant was used to assay enzyme activity.

Fig. 2. The visual difference of various organic and inorganic amendments on wheat crop (A). Vermicompost, (B). Simple compost, (C). Chemical fertilizers, (D). 50% Vermicompost+50% Chemical fertilizers.

(v). Superoxide dismutase (SOD) [µmol mg^{-1} protein]: The activity of superoxide dismutase (µmol mg^{-1} protein) was assessed by measuring its capability to restrict the photo reduction of nitroblue tetrazolium (NBT) according to the protocol of Giannopolitis & Ries (1977). The reaction solution (3 ml) included 75 nM EDTA, 13 mM methionine, 50 nM phosphate buffer, 1.3 µM riboflavin and 5 µM NBT.

(vi). Peroxidase (POD) [µmol mg^{-1} protein]: The POD activity assayed by guaiacol oxidation and defined as 0.01 absorbance change min^{-1} mg^{-1} protein. The reaction mixture was prepared by adding 400 µL guaiacol (20 mM), 500 µL H_2O_2 (40 mM) and 2 mL phosphate (50 mM) in 100 µL enzyme extract. The change in absorbance at 470 nm of the reaction mixture was observed every 20 s up to 5 min. The POD activity expressed as m. mol min^{-1} mg protein^{-1} (Chance & Maehly, 1955).

(vii). Membrane Stability Index (MSI) [%]: Premachandra *et al*., (1990) introduced the procedure for calculating leaf membrane stability index, which Sairam (1994) improved. In 10 ml double distilled water, a 0.1 g leaf sample was dissolved. There were two sets of this solution. The conductivity (C_1, C_2) of both sets was measured using a conductivity meter under different circumstances (one set for 30 minutes at 40°C, the other for 15 minutes at 100°C). Finally, using the equation below, the MSI was determined.

$$MSI = 1-(C_1/C_2) \times 100$$

(viii). Relative water contents (RWC) [%]: Schonfeld *et al*., (1988) method was used to determine relative water content. By cutting the flag leaf of the wheat plant's stem with a sharp blade, the relative water content of leaves were determined. The weight of freshly removed leaves was instantly recorded. To achieve the turgidity of the weighing leaf, each leaf was floated in distilled water in a sealed bucket. In the laboratory, the leaves were ingested overnight (24 hours) in a bucket under variable temperature settings. At the end of the imbibition, samples of the leaves were weighed again and reported as turgid weight (TW). Leaves samples were weighed after being dried for 72 hours at 70 degrees Celsius (DW). All measurements were done on an analytical scale with an accuracy of 0.0001 g. Using the values of FW, TW, and DW, the following equation was used to calculate RWC.

$$\text{RWC (\%)} = \frac{\text{(Fresh weight - Dry weight)}}{\text{(Turgid weight - Dry weight)}} \times 100$$

(ix). Chlorophyll contents (mg g^{-1}): Chlorophyll contents were determined as mentioned by the Arnon (1949). 0.5 g of the top fresh flag leaf was homogenized in 80 percent acetone with pestle and mortar and made up to 5 ml in volume and filtered. Using a picodrop spectrophotometer (Hitachi-U-2001, Japan) the filtrate absorbance was read at 645 and 663 nm for chlorophyll a and b, measurement respectively. The total chlorophyll were calculated by the method of Yoshida *et al*., (1976), as mentioned below;

$$\text{Chl. } a \text{ (mg/g)} = [12.7(\text{OD}663) - 2.69(\text{OD}645)] \times \text{V}/1000 \times \text{W}$$
$$\text{Chl. } b \text{ (mg/g)} = [22.9(\text{OD}645) - 4.68(\text{OD}663)] \times \text{V}/1000 \times \text{W}$$
$$\text{Total Chl. (mg/g)} = [20.2(\text{OD}645) + 8.02 (\text{OD}663)] \times \text{V}/1000 \times \text{W}$$

Where
V = Volume of the acetone used in extract
W = Weight of fresh leaf tissue

(x). Photosynthetic rate (*An*) [µmol m^{-2} s^{-1}]: The photosynthetic rate in plants was determined using an infrared gas analyzer (Singh *et al*., 2018; Rosolem *et al*., 2019). Non-destructive sampling was used to make this measurement (without excising leaf from the parent plant). For each of the three plants in one treatment, three readings were taken independently and then averaged. All other treatments followed the same technique.

(xi). Water potential (-MPa): The water potential of the leaf was estimated using a "water potential instrument named pressure chamber (Chas W. Cook & Sons. Birmingham B 42, ITT England)" as reported by Scholander *et al*., (1964). For this experiment, a larger flag leaf was removed from the parent plant and placed in the pressure chamber. The leaf was arranged in such a way that the surface of the excised leaf protruded from the chamber's aperture. The leaf was cut and exposed to cylinder pressure while holding pressurized gas until xylem sap emerged on the sliced surface. The balancing pressure was computed using the tension in the leaf's xylem sap at the moment of measurement, which was expected to be equal to the cells' water potential. Early morning (6:00-8:00 AM) samples were obtained to prevent evaporation losses. For all of the treatments, the same technique was followed.

(xii). Osmotic potential (-MPa): A calibrated osmometer (Cryoscopic osmometer, Osmomat 030-D, Genatec) was used to determine the leaf's osmotic potential. To extract the xylem sap, the leaf was frozen at -20°C and then thawed. The cell sap was extracted by pressing a thawed leaf through the slab. This xylem sap was collected in Eppendorf tubes and then used to estimate the osmotic potential using an osmometer.

(xiii). Canopy temperature (°C): The energy emitted by the plants was measured using infrared temperature sensors (IRIS). It describes how plants are metabolically active, their water consumption efficiency, and their water levels (Pettigrew, 2004; Singh *et al*., 2018).

(xiv). Stomatal conductance (mmol m^{-2} s^{-1}): The LCA-4 ADC analyzer of infrared gas was used to assess stomatal conductance since it is a portable and open equipment. Stomatal conductivity was measured using a fully inflated leaf. This process was carried out by keeping the leaf chamber temperature (Tch) at 25-28°C, the ambient CO_2 concentration (Cref) at 371 mol mol^{-1}, the ambient pressure (P) at 97.94 kPa, the PAR (Qleaf) at the leaf surface at 770 mol m/s, the gas volume of the leaf chamber (v) at 295 mL min^{-1} and the leaf surface area at 6.24 cm^2.

(xv). Number of total tillers m^{-2}: A quadrate of 1m^{-2} was used to count the total number of tillers m^{-2}. Droped it at random in each subplot. After counting the tillers, the average was calculated.

(xvi). Spike length (cm): The spike length of ten plants in each subplot was measured with a foot rod from the beginning to the top of the spike, and the mean was determined.

(xvii). Number of spikelets per spike: Ten plants were picked from each subplot, and the number of spikelets from each spike were counted. The average number of spikelets per spike were determined.

(xviii). Number of grains per spike: The quantity of grains per spike was calculated by randomly selecting 10 plants from each sub-plot. Their spikes were manually separated and threshed. Each spike's quantity of grains was counted and then averaged.

(xix). Weight of 1000 grains (g): During the threshing of grains, 1000 grains were counted and sorted. On the electronic balance, they were weighed. The weight was calculated in grams.

(xx). Economic yield (t/ha): From each sub plot, an area of one m^2 was selected and harvested. Threshed manually and took the weight of the grain by electronic balance, and the yield of the grain was converted to t ha^{-1}.

(xxi). Biological Yield (t/ha): From each sub-plot, a sample of plants covering 1 m^2 was taken. The biological yield was converted into t/ha by weighing it on an electronic weighing scale.

(xxii). Harvest index (%): Grain yield was divided by biological yield to calculate the harvest index.

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The recorded data of all the experiments were statistically evaluated by applying method of Fisher's analysis of variance (ANOVA). LSD test was used ($p \leq 0.05$) to compare significant treatments means using Statistic version 8.1 (Analytical Software ©, 1985-2005) according to Steel *et al*., (1997).

Results

Plant height at maturity (cm): Because the mix of organic and inorganic fertilizers had a substantial impact on plant development, T_7 had the highest plant height (90.33 cm). Minimum plant height (68.33 cm) was recorded in T_5 *i.e.* 100% compost prepared from wheat straw followed by T_0 (69.33cm) where only chemical fertilizers were used (Table 4).

Leaf Nitrogen contents (mg g^{-1}Dw): Maximum nitrogen contents (18.86 mg g^{-1}Dw) were recorded in T_7 while in T_0 (10 mg g^{-1}Dw) and T_5 (9 mg g^{-1}Dw) having minimum nitrogen contents and all other treatments were intermediate as shown in Table 4.

Leaf phosphorus contents (mg g^{-1}Dw): Maximum leaf phosphorus contents (6.10 mg g^{-1}Dw) were recorded in T_7 in contrast with T_5 which contained minimum leaf phosphorus contents (3.6 mg g^{-1}Dw). T_0 leaf phosphorus contents (3.75 mg g^{-1}Dw) were slightly higher (3.6 mg g^{-1}Dw) than T_5. All other treatments have an intermediate effect on leaf phosphorus contents (Table 4).

Leaf potassium contents (mg g^{-1}Dw): All treatments contained significantly more leaf potassium contents (2.67 mg g^{-1}Dw) as compared to T_5 which was assigned 100% compost from wheat straw @ 10 t/ha proceeded by T_0 (2.85 mg g^{-1}Dw). Maximum leaf potassium contents (4.03 mg g^{-1}Dw) were recorded in T_7 as depicted in Table 4.

Superoxide dismutase [µmol mg^{-1}protein]: Superoxide dismutase contents were significantly affected by all the treatments. However, T_7 showed maximum superoxide dismutase contents (125.67 µmol mg^{-1}protein) and those of T_5 were minimum (105.00 µmol mg^{-1}protein) while T_0 (106.67 µmol mg^{-1}protein) was close to T_5 but more than that of it as shown in Table 4. All other treatments were intermediate.

Peroxidase [µmol mg^{-1}protein]: Peroxidase activity was significantly affected by all the treatments. However T_7 showed maximum peroxidase contents (19.25 µmol mg^{-1}protein) and those of T_5 were minimum (15.25 µmol mg^{-1}protein) while T_0 was greater (15.83 µmol mg^{-1}protein) to T_5 as shown in Table 4.

Membrane stability index (%): The membrane stability index was relatively higher (80.73%) in T_7 as compared to all other treatments. T_7 (80.73%) was followed by T_{11} (80.16%). T_5 shown a minimum membrane stability index (74.00%) while all other treatments were intermediate. Results are depicted in Table 4.

Leaf relative water content (%): Leaf water contents (85.40**%**) were significantly enhanced by T_7 followed by T_{11} (85.15**%**). Minimum leaf water contents (79.33**%**) were recorded in T_5. All other treatments were midway. Results are revealed in Table 5.

Chlorophyll contents (mg g^{-1}): The distribution of leaf chlorophyll contents among different treatments were significantly affected by various treatments. Maximum chlorophyll contents (4.02 mg g^{-1}) were exhibited by T_7 followed by T_{11} (3.96 mg g^{-1}). Minimum chlorophyll contents (3.10 mg g^{-1}) were executed by T_5. All other treatments were halfway. Results are displayed in Table 5.

Photosynthetic rate (µmol m^{-2} s^{-1}): The photosynthetic rate is affected by all treatments. Treatment T_7 had the most significant effect on photosynthetic rate (22.02 µmol m^{-2} s^{-1}) hence maximum photosynthetic rate (22.02 µmol m^{-2} s^{-1}) was noted in T_7. It was followed by T_{11} (21.76 µmol m^{-2} s^{-1}). Treatments T_9 (21.58 µmol m^{-2} s^{-1}) and T_8 (21.42 µmol m^{-2} s^{-1}) were close to each other. T_5 depicted minimum effect on photosynthetic rate (18.50 µmol m^{-2} s^{-1}). All of the other treatments were in the middle.

Water potential (-MPa): The effect of all treatments was clear on water potential. Treatment T_7 showed maximum water potential (-0.52MPa) as its value was less negative subsequently T_{11} (-0.53MPa) followed it. The value of the water potential (-0.72-MPa) of T_5 when compared to all other treatments, was the most unfavourable. All of the other treatments were in the middle. The results are shown in Table 5.

Osmotic potential (-MPa): The osmotic potential was affected by all of the treatments. The osmotic potential (-0.18 MPa) of T_7 was less negative thus having maximum osmotic potential. The osmotic potential of T_5 (-0.27MPa) and T_0 (-0.27MPa) was minimum and they possessed the same position. All other treatments were midway. The results are elucidated in Table 5.

Canopy temperature (°C): Maximum canopy temperature (18.33 °C) was recorded in T_5 followed by T_0 (17.66 °C). Canopy temperature of T_4 (17.33°C) and T_6 (17.33 °C) stood at the same temperature. Minimum canopy temperature (14.33 °C) was recorded in T_7. All other treatments were in-between. The results are elucidated in Table 5.

Stomatal conductance (mmol m^{-2} s^{-1}): Phenomenon of stomatal conductance was observed maximum in T_7 (76.33 mmol m^{-2} s^{-1}) followed by T_{11} (74.33 mmol m^{-2} s^{-1}). Minimum Stomatal conductance (58.66 mmol m^{-2} s^{-1}) was noted in T_5. Other variants of treatments were intermedial. The results are elucidated in (Table 5).

No. of total tillers m^{-2}: No. of total tillers m^{-2} were noticed maximum (355.67 tillers m^{-2}) in T_7 pursued by T_{11} (349.67 tillers m^{-2}). Minimum no. of total tillers m^{-2} were witnessed in T_5 (270.33 tillers m^{-2}). Other treatments were in between these treatments. Results are depicted in Table 6.

Table 4. Impacts of inorganic and organic amendments on morphological and biochemical attributes on wheat.

Treatment	Plant height (cm)	Leaf nitrogen content (mg g^{-1}Dw)	Leaf phosphorus contents (mg g^{-1}Dw)	Leaf potassium contents (mg g^{-1}Dw)	Superoxide dismutase [µmol mg^{-1}protein]	Peroxidase [µmol mg^{-1}protein]	Membrane stability index (%)
T_0	69.33 I	10.00 L	3.75 HI	2.85 J	106.67 KL	15.83 I	75.66 H
T_1	81.66 D	15.50 F	5.07 E	3.52 DE	117.33 EF	17.67 D	78.41 E
T_2	77.33 F	13.50 I	4.26 G	3.25 GH	112.00 HI	16.68 FG	77.00 FG
T_3	78.33 EF	14.08 H	4.68 F	3.36 FG	113.67 GH	16.94 EF	77.33 F
T_4	75.33 G	12.83 J	4.04 GH	3.12 HI	110.00 IJ	16.55 GH	76.58 G
T_5	68.33 I	9.00 M	3.60 I	2.67 K	105.00 L	15.25 J	74.00 I
T_6	72.66 H	11.33 K	3.93 HI	3.03 I	108.00 JK	16.30 H	76.00 H
T_7	90.33 A	18.86 A	6.10 A	4.03 A	125.67 A	19.25 A	80.73 A
T_8	84.33 C	16.83 D	5.40 CD	3.75 C	120.67 CD	18.35 BC	79.43 CD
T_9	86.33 B	17.56 C	5.55 BC	3.85 BC	121.67 BC	18.50 B	79.76 BC
T_{10}	79.33 E	14.66 G	4.85 EF	3.43 EF	115.33 FG	17.20 E	78.00 E
T_{11}	88.00 B	18.16 B	5.75 B	3.94 AB	123.67 AB	18.87 A	80.16 B
T_{12}	83.00 CD	16.33 E	5.16 DE	3.62 D	118.67 DE	18.01 CD	79.10 D
LSD value at $p < 0.05$	**1.25**	**1.90**	**4.14**	**2.35**	**1.04**	**1.28**	**0.42**

The means not sharing the common letter differ significantly

Table 5. Impacts of inorganic and organic amendments on physiological attributes on wheat.

Treatment	Leaf relative water content (%)	Chlorophyll contents (mg g^{-1})	Photosynthetic rate [µmol m^{-2} s^{-1}]	Water potential (-MPa)	Osmotic potential (-MPa)	Canopy temperature (°C)	Stomatal conductance (mmol m^{-2} s^{-1})
T_0	81.00 H	3.19 J	18.86 HI	0.69 B	0.27 A	17.66 B	60.33 L
T_1	83.35 D	3.72 DE	20.93 CD	0.61 E	0.22 G	16.00 D	69.00 F
T_2	82.29 F	3.55 GH	19.83 FG	0.65 D	0.24 D	16.66 C	65.00 I
T_3	82.78 E	3.61 FG	20.26 EF	0.64 D	0.23 E	16.33 CD	67.00 H
T_4	81.93 FG	3.47 H	19.40 GH	0.67 C	0.25 C	17.33 B	63.00 J
T_5	79.33 I	3.10 J	18.50 I	0.72 A	0.27 A	18.33 A	58.66 M
T_6	81.74 G	3.35 I	19.12 H	0.68 BC	0.26 B	17.33 B	62.00 K
T_7	85.40 A	4.02 A	22.02 A	0.52 I	0.18 K	14.33 G	76.33 A
T_8	84.33 C	3.85 C	21.42 ABC	0.58 G	0.20 I	15.33 E	71.00 D
T_9	84.79 B	3.87 BC	21.58 AB	0.55 H	0.20 I	15.00 EF	72.33 C
T_{10}	83.00 DE	3.67 EF	20.76 DE	0.62 E	0.22 F	16.00 D	68.00 G
T_{11}	85.15 AB	3.96 AB	21.76 A	0.53 I	0.19 J	14.66 FG	74.33 B
T_{12}	83.90 C	3.79 CD	21.12 BCD	0.60 F	0.21 H	15.33 E	70.00 E
LSD value at $p < 0.05$	**0.32**	**1.57**	**1.75**	**1.44**	**1.43**	**2.04**	**0.69**

The means not sharing the common letter differ significantly

Table 6. Impacts of inorganic and organic amendments on physiological attributes on wheat.

Treatment	No of total tillers in m^{-2}	Spike length (cm)	No. of spikelets per spike	No of grains per spike	1000- grain weight (g)	Economic yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T_0	276.67KL	7.33 J	11.66 H	37.33 JK	27.33 J	2.71 I	9.48 KL	28.62 C
T_1	322.67 EF	11.66 EF	17.00 DE	47.33 E	38.00 DE	4.18 DE	13.24 EF	31.69 AB
T_2	299.67 HI	9.33 GH	13.667 G	43.00 GH	33.66 G	3.61 G	11.34 HI	32.00 A
T_3	308.33 GH	10.00 G	16.00 EF	44.33 FG	35.33 F	3.85 FG	12.08 GH	32.01 A
T_4	292.33 IJ	9.00 HI	15.00 FG	40.66 HI	31.66 H	3.28 H	10.75 IJ	30.66 ABC
T_5	270.33 L	6.66 J	11.66 H	36.33 K	26.00 J	2.58 I	8.95 L	28.89 BC
T_6	286.67 JK	8.33 I	13.66 G	39.33 IJ	30.00 I	3.08 H	9.96 JK	30.92 ABC
T_7	355.67 A	15.33 A	22.66 A	57.33 A	45.00 A	5.01 A	16.50 A	30.41 ABC
T_8	336.67 CD	13.00 CD	19.33 BC	52.00 CD	40.66 C	4.61 BC	14.33 CD	32.27 A
T_9	344.00 BC	13.33 C	20.00 B	53.33 BC	42.33 B	4.71 B	15.00 BC	31.49 ABC
T_{10}	314.67 FG	11.00 F	17.00 DE	46.00 EF	37.00 E	4.06 EF	12.58 FG	32.42 A
T_{11}	349.67 AB	14.33 B	21.00 AB	55.33 AB	43.33 B	4.87 AB	15.58 B	31.37 ABC
T_{12}	330.67 DE	12.33 DE	18.00 CD	50.33 D	39.33 CD	4.41 CD	13.92 DE	31.86 AB
LSD value at $p<0.05$	**1.98**	**5.07**	**6.09**	**3.03**	**2.71**	**4.08**	**4.02**	**5.75**

The means not sharing the common letter differ significantly

Spike length (cm): Treatments had notable effect on spike length. Spike length (15.33cm) was maximum in T_7 followed by T_{11} (14.33 cm). Shortest spike length (6.66 cm) was noted in T_5. All other treatments were in between. Results are outlined in Table 6.

No of spikelets per spike: The T_7 (22.66 spikelets per spike) had the maximum spikelets per spike followed by T_{11} (21.00 spikelets per spike). T_5 had the minimum number of spikelets per spike (11.66 spikelets per spike). The number of spikelets per spike is affected in a similar way by all other treatments. The outcomes are elucidated Table 6.

Number of grains per spike: T_7 (57.33 grains per spike) had the highest number of grains per spike, followed by T_{11} (55.33 grains per spike). T_5 had the minimum number of grains per spike (36.55 grains per spike). All of the other treatments were in the middle. The outcomes are calculated in Table 6.

1000-grain weight (g): All of the treatments had a significant impact on the weight of 1000 grains. T_7 had the highest 1000 grain weight (45.00 g), followed by T_{11} (43.33 g) while T_5 had a minimum 1000 grain weight (26.00 g). The outcomes are shown in Table 6.

Economic yield (t/ha): The economic yield was significantly affected by all treatments. T_7 had the highest economic yield (5.01 t/ha), followed by T_{11} (4.87 t/ha) while T5 had the lowest economic yield (2.58 t/ha). All other treatments had a moderate effect on economic yield. The outcomes are displayed in Table 6.

Biological yields (t/ha): All 13 treatments shown observable effects on yields. Maximum biological yield (16.50 t/ha) was recorded in T_7 followed by T_{11} (15.58). The Minimum Biological yield (8.95 t/ha) was recorded in T_5. All other treatments gave intermediate results in terms of biological yield. Results are shown in Table 6.

Harvest Index: All treatments shown notable effects on the harvest index. Harvest index was witnessed maximum (32.42%) in T_{10} subsequently followed by T_8 (32.27%). T0 recorded the harvest index's lowest value (28.62%). All of the other treatments were in the middle. The outcomes are shown in the (Table 6).

Discussion

Previous literature discovered that morphological, physiological, biochemical, yield and yield-related traits were statistically higher in wheat by the applying chemical fertilizer and organic manures. Balanced nutrients application enhanced the grain yield by 27% and grains per spike by 26% in wheat (Sadaf *et al.*, 2017). Cherif *et al.*, (2009) also found the same outcomes that chemical fertilizer and composts elevated all the morpho-physiological, biological and yield-related parameters of wheat. Compost application in wheat significantly improved the P, K and N contents and plant height compared to control (Ahmad *et al.*, 2008). Compost also modified the protein contents and other morphological parameters in wheat over control. Vermicompost applications significantly improved chlorophyll contents, number of tillers/ plant, number of spikes, plant height, 1000-grain weight, and biomass and grain yield of wheat per hectare compared with untreated soil. This increment in morphological attributes of wheat and its growth/ productivity might be due to higher nutrient contents and organic matter in vermicompost (Ding *et al*., 2021, Patil & Bhilare, 2000).

Vermicompost application caused improvements in NPK contents both in soils and plant (Xu *et al*., 2016; Aslam *et al*., 2021). Studies revealed that the sole application of vermicompost enhanced CATs, SODs and PODs contents in plants compared to NPK treatment. These are vital antioxidant enzymes produced in plants against abiotic stresses and scavenge the adverse effects of ROS (Hosseinzadeh *et al*., 2018). The combined use of chemical fertilizer and vermicompost regulated the proline contents of plant parts. When plants were supplied vermicompost, they had greater Ca^{2+}/Na^{+} and K^{+}/Na^{+} ratios in their aerial portions. The protein content of the roots and other plant components rose as a result of their combined application. However, more elevation in protein contents were seen in plants treated with sole application of vermicompost (Kizilkaya *et al*., 2012). The use of vermicompost in conjunction with fertilizers resulted in an increase in the number of effective tillers, grain/spike weight, and dry matter accumulation. This improvement might be owing to enhanced vegetative growth (vigorous root system, more dry matter accumulation and higher leaf area) of wheat due to prolonged/ adequate supply of required nutrients to wheat seedlings.

Further, the integration of organic and inorganic fertilizers also increased the grain/biological yields and improved the harvest index (Devi *et al*., 2011), and their co-application stimulated the plant height and chlorophyll contents in wheat leaves. Chlorophyll is the primary pigment that plays a significant role in photosynthesis. Vermicompost treated plots exhibited higher levels of chlorophylls in leaves increased the roots protein contents and increased CAT activity (Ajit *et al*., 2000). It was also seen that combined application of NPK fertilizer with vermicompost statistically enhanced soluble protein contents in ginger (*Zingiber officinale*), however, the greatest increment in soluble protein was noticed in ginger when these plants were supplied with vermicompost only (Xu *et al*., 2016). The literature showed when compared to other chemical and organic fertilizers, vermicompost had higher amounts of several macro and micro nutrients (N, P, K, Ca, Mg, Fe, Zn, Cu, and Mn). So vermicompost maintained the water levels in plants, modified water potential, stabilized the membrane and nutrients ultimately regulated the osmotic pressure. However, vermicompost application and simple organic compost caused more adjustment in osmotic pressure than its sole application (Hosseinzadeh *et al*., 2018). Due to presence of elevated levels of N in vermicompost, it increased the N uptake and N contents ultimately protein contents in plants (Hosseinzadeh *et al*., 2018).

As vermicompost is enriched with phytohormones (cytokinin etc.) and nutrients, vermicompost obliged as a virtuous source of nutrients uptake and helpful in water uptake even in water stress conditions (Lakhdar *et al*., 2009). Vermicompost stabilized the photosyhnthetic plant systems, decreased the stomatal closure and increased the photosynthesis process by supplying more CO_2 to plants. Because vermicompost enhanced the microbial activity and finally CO_2 in soil (Özenç, 2008). Under non-water conditions, transpiration enhanced significantly with respect to 20 and 30 w/w percent vermicompost treatments as associated to the control treatment. As vermicompost involved in maximum water absorption and preservation in roots of plants. So its application increased transpiration and decreased stomatal closure (Atiyeh *et al*., 2002). Researchers elaborated that activities of antioxidant enzymes (CAT, SOD, POD) increased by vermicompost application (Hosseinzadeh *et al*., 2018).

In short, combining organic and inorganic fertilizers improves the efficiency of inorganic fertilizer use that in turn decreases the amount of these chemical fertilizers (Demelash *et al*., 2014). Further organic fertilizer compensated the use of inorganic fertilizers, and provided a substitute to chemical fertilizers (Ibrahim *et al*., 2008; Ahmad *et al*., 2022).

Conclusion

It was concluded from this study that 50% vermicompost (produced from FYM, rice and wheat straw) mixed with 50% recommended fertilizers showed excellent results. While, 100% vermicompost (produced from wheat straw, rice straw, cow dung) and 25% vermicompost (produced from FYM, rice wheat straw) and 25% compost (produced from farm yard manure, rice straw and wheat straw) mixed with 50% recommended fertilizers showed intermediate results whereas, compost (produced from farm yard manure, rice straw and wheat straw) and control (recommended fertilizers) showed minimum results in wheat crop and soil fertility decreased in T_0 treatment. Vermicompost is a rich source of nutrients causes increment in availability of macro-and micro-nutrients and biocontrol agent for aphid and fungus attack, so it may be utilized in integration with inorganic fertilizers to decrease the recommended nutrient dose, further being an alternate nutritional source for biofortification.

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