Effect of Organic and Inorganic Sources of Nitrogen on Nutrient Content of Wheat and Soil Fertility in Inceptisol

ABSTRACT

A pot experiment was conductedduring the year 2020 at the Institute of Agricultural Sciences, BHU, Varanasi, to study the impact of organic and inorganic sources of nitrogen on nutrient content in wheat and soil physic-chemical properties of the Inceptisols of eastern Uttar Pradesh. The experiment was arranged in completely randomized design with 10 treatment combinations having3 replications. The experiment results indicated that use of 50% of the recommended nitrogen dose through urea along with 50% N through poultry manure in integration significantly enhanced the nitrogen, phosphorus and potassium content in grain and straw compared to the control. The T_5 treatment, in which combined use of 50% RDN and 50% poultry manure recorded highest micronutrient concentrations(*i.e.* Zn: 14.3 and 21.41 mg kg^{-1}, Cu: 37.83 and 20.66 mg kg^{-1}, Mn: 20.03 and 3.65 mg kg^{-1}, and Fe: 231.73 and 54.31 mg kg^{-1}) in both straw and grain, respectively as compared to control (T_1). The use of organic source with fertilizers also increased the post-harvest soil fertility as available N, P, and K, along with DTPA-extractable micronutrients. Overall, the treatment incorporating poultry manure @ 50% RDN and 50% PM (5.26 t ha^{-1}) provided best results among all treatments in term of nutrient content of wheat and soil fertility.

Keywords: Sustainability; Poultry Manure; Sewage Sludge; Farmyard Manure; Vermicompost

1. INTRODUCTION

Wheat is a crop sensitive to temperature and photoperiod, requiring long days for optimal growth. It thrives across various conditions, experiencing significant seasonal fluctuations in temperature and precipitation during its growing period[1]. In India, wheat production reached over 107 million metric tonnes from 31.6 million hectares in 2021, contributing around 37% to the total food grain production. Wheat is a cornerstone of the country's economy and food security, [2] its productivity increased dramatically after the Green Revolution as a result of the widespread use of plant protection measurs and the expansion of irrigated regions.

The use of imbalanced amount of chemical fertilisers negatively affected soil, human health, and overall production metrics. The mineral fertilizers are essential for plant growth; their prolonged use poses risks to both the environment and human health, including surface and groundwater pollution [3]. Therefore, effective nitrogen (N) management is crucial to enhance fertilizer efficiency, boost crop yields, and mitigate adverse effects associated with nitrogen use, which have become global challenges. Approximately 20% of the world's arable land is used for wheat cultivation, which covers 237 million hectares annually. The adoption of Green Revolution technology, such as fertilisers, has been substantially responsible for the significant increase in worldwide wheat yields between the 1960s and 2013, despite stable wheat production acreage. However, the impact of the Green Revolution on wheat production varied across regions [4]. Nitrogen serves as a crucial nutrient for crop development, enhancing both the quality and yield of agricultural produce. To meet the demands of global agriculture, substantial amounts of nitrogen are annually administered to the soil. Moreover, in non-fertilized agricultural settings, nitrogen emerges as the primary factor restricting crop yields [4]. However, despite the positive effect of N fertilizers on crops, there is an indirect negative effect on soil health in the absence of the proper use of N. Even with the extensive application of mineral nitrogen fertilizer, a considerable portion is lost or rendered inaccessible to plants within modern farming practices. Additionally, it exacerbates the degradation of soil physico-chemical and biological characteristics, as noted by [5]. Moreover, the overreliance on chemical fertilizers induces soil acidification and diminishes soil microbial biomass, ultimately impairing soil fertility, as highlighted in studies by [6]. Moreover, prolonged use of chemical fertilizers can compromise the soil's capacity to sustain healthy crop growth and productivity over time, as emphasized by [7]. Therefore, the persistent dependence on chemical fertilizers for crop cultivation is unsustainable. Currently, there is extensive research on utilizing organic manures, biochar, and crop residues either alone or in combination to enhance soil fertility, nutrient provision, and overall soil quality, thereby promoting long-term crop growth and health [8]. FYM is the most commonly used organic manure in wheat-based cropping systems in South Asia. It is generally applied to rice or maize grown in summer, but it leaves considerable residual effect in the following crop of wheat in winter but the rate of N mineralization from poultry manure is faster than from FYM because it contains high amount of uric acid and urea substances which readily release NH_4^-N. In a laboratory trial, PM showed faster rates of mineralization - 45% in 4 weeks as opposed to FYM's 12%. When it came to increasing rice yield and N uptake, PM-N was just as successful as urea-N, and its residual effect in wheat was equal to 40 kg N/ha. Furthermore, PM treatment improved soil health and wheat-soybean systems' resilience [9].Use of different manures in rice–wheat systems have been evidenced to increase the crop yield and DTPA-extractable micronutrient concentrations in soil in north-western India[8]. Organic manure offers a multitude of benefits, supplying both macro and micronutrients, enhancing soil microbial activity, and improving soil physical and chemical properties. Its gradual nitrogen release aids in achieving higher nitrogen use efficiency, rice yield, and quality. Additionally, it boosts soil organic carbon (SOC) levels and maintains nutrient availability for crop growth. The study presumed that combining organic and inorganic fertilizers could enhance soil quality, root development, and subsequently, positively impact nitrogen uptake, biomass, and grain yield. The research aimed to identify the most efficient and cost-effective organic-inorganic nitrogen fertilizer combination to enhance nutrient content and soil fertility.

2. MATERIALS AND METHODS

2.1 Experimental Site

A pot experiment on wheat was carried out during 2020-2021 in the Net House of the department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between 25°18’ North latitude and 80°36’ East longitudes. Varanasi experiences a humid subtropical climate with a mean average rainfall of about 1100 mm and potential evapotranspiration of about 1525 mm. The maximum and minimum temperature varied from 17.5ºC to 34.5ºC and 7.5ºC to 20.7ºC during wheat cultivation (December to March). The maximum and minimum relative humidity varied between 64-96% and 34-71%, respectively.

2.2 Experimental Setup

The alluvial soils of Indo-Gangetic plains are clay to sandy-loam in texture, deep, well-drained with good water holding capacity and having low available nitrogen, phosphorus and potassium. The initial soil had sandy clay loam texture (sand 48.42%, silt 19.83%, clay 21.74%), slightly alkaline in reaction pH 7.3, normal in salinity (EC 0.29 dS m^{-1}), low in organic carbon content (0.29%) low in available nitrogen (208.4 kg ha^{-1}), medium in available P (24.8 kg ha^{-1})and medium in available K (148.6 kg ha^{-1}). The soil had DTPA-extractable concentrations of Zn, Cu, Fe, and Mn of 0.41,1.27,3.78, and 4.01, respectively. Wheat (HD-2967) was used as the test crop. The treatments details are mentioned in Table

1. For conducting the experiment, the soil sample was collected from the Agro farm, BHU. The soil was air dried, grounded to pass through 2-mm sieve, and filled in polythene lined pots. An experiment was conducted with four organic sources (FYM, PM, VC and SS) and RDF dose of nitrogen in combination of 50 % of RDF & 50% N through organic sources and 100% through organic sources alone along with 100% RDF and control(Table 1). The recommended dose of N, P_2O_5 and K_2O for wheat was applied @ 118.56, 170.43 and 45.45 mg kg^{-1}soil through Urea, SSP and MOP as a source of N, P, and K respectively. Recommended dose for the 100% of nitrogen through organic sources for wheat @ 126, 44.70, 47 and 66.5 gram of nitrogen from FYM, VC, PM and SS for 10 kg soil. Full dose of inorganic fertilizers was applied in solution form before sowing of wheat and organic sources of fertilizer were applied one week before sowing.

2.3 Soil and Plant Analyses

For laboratory analysis, all the three replicates of soil and plant samples were taken, and the mean of the three is given as final value. From every pot, post-harvest soil (PHS) was collected and the sample was processed by passing it through 2-mm and subsequently with 0.5-mm sieves and kept for chemical analysis. The moisture content was determined immediately by the gravimetric method. The soil samples were analyzed for pH by following the procedure as outlined in [10], and the same solution/sample was used for measurement of electrical conductivity (EC). Potassium dichromate (1N $K_2Cr_2O_7$) oxidizable organic carbon was determined by the method of [11], available N by alkaline potassium permanganate ($KMnO_4$) method [12], available P by extracting the soil with sodium bicarbonate ($NaHCO_3$), and available K using neutral normal ammonium acetate extraction method [13]. The micronutrient content in PHS was determined by DTPA extraction in 1:2 soil: extractant ratio [14] and analyzed by atomic absorption spectrophotometer (AAS), model Agilent 240FS-AA (Agilent Technologies, Santa Clara, USA). Dry plant tissue was finely grounded in a soil-processing lab and stored in zipped polythene bags. The nitrogen concentration was determined by digestion (H_2SO_4), distillation and titrimetric method, using a standard Kjeldahl autoanalyzer (Distyl-EM; Pelican) procedure. Total Phosphorus and potassium in plant were estimated by HNO_3: $HClO_4$(3:1) di-acid mixture as per the procedure of [13]. Finely grounded seed and straw samples were digested with di-acid mixture (HNO_3:$HClO_4$: 3:1, v/v) and analyzed for Zn, Cu, Fe, Mn, and Ni using AAS [15].

2.4 Statistical Analysis

The research data were analyzed using statistical software SPSS 16.0 for ANOVA (complete randomized design). Duncan multiple range test (DMRT) at $p \leq 0.05$ levels of significance was used to evaluate the significant differences among mean values [16].

Table 1.Treatment details of the experiment.

Treatments	Treatment details
T_1	Control
T_2	100% RDF
T_3	50%RDN + 50% FYM (14 t ha^{-1})
T_4	50%RDN + 50% VC(5 t ha^{-1})
T_5	50%RDN + 50%PM(5.26 t ha^{-1})
T_6	50%RDN + 50% SS (7.5 t ha^{-1})
T_7	100% FYM (28 t ha^{-1})
T_8	100% VC(10 t ha^{-1})
T_9	100% PM(10.53 t ha^{-1})
T_{10}	100% SS (15 t ha^{-1})

RDF*, recommended dose of fertilizer

RDN*, recommended dose of Nitrogen through urea

Recommended dose of fertilizer (RDF) for wheat crop, i.e., N, P_2O_5, and K_2O:120, 60 and 60 kg ha^{-1}, respectively

FYM (farmyard manure), VC (vermicompost), PM (poultry manure) and SS (sewage sludge)

3. Results and Discussion

3.1 Macronutrient and Micronutrient Content

The perusal data in table 2 revealed that there was significant difference in N concentration in straw and grain yield of wheat crop in relation to applied treatments. Straw has a nitrogen content ranging from 0.65 to 1.01%. The highest nitrogen concentration was found in T5, followed by T6, T4, T3, and T2 at 0.97, 0.92, and 0.91% respectively. This meant that the concentrations of nitrogen were significantly higher than the control at 55.38, 49.23, 41.53, 40, and 35%. Grain had nitrogen contents ranging from 1.16 to 2.46%. T5 showed the highest N content in grain yield, while T1, the control, showed the lowest. T5 was at par differ with T6 having nitrogen 2.32% followed by T4, T3 and T2. These values represent a considerable increase of 182.81, 112, 100, 87.06 and 61.2% over control. An examination of data given in table 2 indicated that although application of 50% organic and 50% inorganic fertilizer showed lower increase in P concentration than T2 (100% RDN through urea), it was at par to T5 treatment and significantly higher than the control. It happened because of the readily available P present in chemical fertilizer. The concentration of phosphorus in straw varied, with T5 (RDN50%PM50%) having the highest concentration and T1 control having the lowest value, ranging from 0.15 to 0.08. Following T2, which produced a statistically significant rise of 87.5, 50, and 37.5% over control, T5 and T6 differed statistically at par. The range of phosphorus levels in grain was 0.22 to 0.39, with T5 (RDN50%PM50%) exhibiting the highest concentration and T1 (control) exhibiting the lowest. This led to a significant increase above control of 77.27%. The data pertaining to Potassium concentration in wheat straw and grain have been presented in table 4. Straw has a considerably wide range of potassium concentrations, from 1.16 to 1.65%. The lowest concentration was found in T1 (control), which differs considerably from T5, and the largest concentration was found in T5. T5 is statistically not comparable to T6, which is considerably higher than control by 42.24 and 29.31%, respectively. The highest concentration was found in grain at 0.62 and the lowest in 0.27. The same pattern was found in straw at T5 (RDN50%PM50%) and the lowest in T1 (control). T5 and T6 differed statistically, leading to a significant increase of 129.6 and 92.59% over control. An interesting observation is that the nutrient content in wheat was significantly lower with the solitary application of inorganic fertilizers, but the combined application of organic and inorganic fertilizers enhanced the nutrient content in Table 2. It further endorses that organic fertilizer is a rich source of nutrients and might contribute to increasing crop yields. Many reports showed that different organic fertilizers are the source of N, P, and K that can improve soil fertility and increase the content of these nutrients in grain crops [17]. The continuous use of organic fertilizer along with inorganic fertilizer increased the nutrient content and nutrient use efficiency of major nutrients than did the inorganic fertilizers alone [17]. The nutrient uptake is a key component of fertilizer management. The higher amount of nutrient content not only maximizes the yield, but also increases the nutrient-use efficiency and, thus, reduces the potential for groundwater pollution. Nitrogen, phosphorus, and potassium are essential for plant growth. The organic fertilizers that were used in the present study (FYM, SS, PM and VC) were enriched with different macro- and micro-nutrients especially N, P, and K. The total amount of N, P, and K were high enough and a significant amount might become available from microbial decomposition over the growing season of crops. Wheat may uptake a high amount of these nutrients, even over their requirements for normal growth and development, which is normally treated as luxury consumption of nutrients. The content of nitrogen by wheat was high in Table 2, which may favour the higher content of P and K. Nitrogen can increase P content and its concentration in plants by increasing root and shoot growth. In most agricultural soils, NO_3^--N is the most usual form which may exceed cation uptake, and, in the mean-time, $OH^-$and HCO_3^- may be released from the roots to the soils [17], [18]. This increases the pH in the rhizosphere and, hence, would promote P availability which, in turn, influences the P uptake by plants.

Table 2. Effect of organic and inorganic sources of nitrogen on nitrogen, phosphorus and potassium concentration (%) in the straw and grain of wheat.(mean of 3 replications± standard error).

Treatments	Nitrogen concentration		Phosphorus concentration		Potassium concentration	
	straw	grain	straw	grain	straw	grain
T1	0.65 ± 0.02 e	1.16 ± 0.09 e	0.08 ± 0.02 e	0.22 ± 0.01 b	1.16 ± 0.01 e	0.27 ± 0.06 d
T2	0.88 ± 0.02 bc	1.87 ± 0.05 c	0.11 ± 0 bc	0.3 ± 0.01 ab	1.4 ± 0.01 c	0.44 ± 0.05 bc
T3	0.91 ± 0.02 abc	2.15 ± 0.03 b	0.11 ± 0 bc	0.3 ± 0.01 ab	1.44 ± 0.01 bc	0.47 ± 0.06 bc
T4	0.92 ± 0.01 abc	2.17 ± 0.05 b	0.11 ± 0 bc	0.3 ± 0.01 ab	1.45 ± 0.01 bc	0.47 ± 0.01 bc
T5	1.01 ± 0.05 a	2.46 ± 0.03 a	0.15 ± 0 a	0.39 ± 0.01 a	1.65 ± 0.02 a	0.62 ± 0.02 a
T6	0.97 ± 0.02 ab	2.32 ± 0.04 ab	0.12 ± 0 b	0.32 ± 0.06 ab	1.5 ± 0.01 b	0.52 ± 0.05 ab
T7	0.71 ± 0.03 de	1.5 ± 0.1 d	0.08 ± 0 e	0.22 ± 0.06 b	1.22 ± 0.01 de	0.34 ± 0.03 cd
T8	0.73 ± 0.08 de	1.63 ± 0.03 d	0.09 ± 0 de	0.24 ± 0.07 ab	1.26 ± 0.01 d	0.34 ± 0.02 cd
T9	0.83 ± 0.03 cd	1.86 ± 0.04 c	0.11 ± 0 bcd	0.28 ± 0.06 ab	1.28 ± 0.09 d	0.43 ± 0.01 bc
T10	0.81 ± 0.01 cd	1.84 ± 0.04 c	0.1 ± 0 cde	0.27 ± 0.02 ab	1.27 ± 0.02 d	0.35 ± 0.03 cd

Table 3. Effect of organic and inorganic sources of nitrogen on micronutrient concentration (mg kg^{-1}) in the grain of wheat.(mean of 3 replication± standard error).

Treatments	Fe	Zn	Mn	Cu
T1	30.72 ± 0.29 f	14.66 ± 0.91 d	1.24 ± 0.36 c	10.89 ± 1.15 c
T2	33.86 ± 0.03 e	19.83 ± 0.8 ab	2.1 ± 0.06 bc	14.54 ± 0.23 b
T3	197.27 ± 0.27 b	16.42 ± 0.14 cd	3.54 ± 0.29 a	19.76 ± 0.4 a
T4	42.01 ± 0.01 c	18.64 ± 1.12 bc	2.87 ± 0.44 ab	18.9 ± 0.58 a
T5	54.31 ± 0.43 a	21.41 ± 1.04 a	3.65 ± 0.46 a	20.66 ± 0.96 a
T6	46.99 ± 0.14 b	20.1 ± 0.04 ab	3.52 ± 0.03 a	19.37 ± 0.71 a
T7	39.48 ± 0.24 d	15.05 ± 1.19 d	2.71 ± 0.29 ab	11.5 ± 1.3 c
T8	34.01 ± 0.05 e	15.06 ± 0.03 d	1.94 ± 0.52 bc	14.54 ± 0.23 b
T9	39.8 ± 1.73 d	15.34 ± 1.35 d	2.79 ± 0.29 ab	16.06 ± 0.35 b
T10	35.14 ± 1.16 e	15.31 ± 0.06 d	2.16 ± 0.1 bc	15.23 ± 0.49 b

Table 4. Effect of organic and inorganic sources of nitrogen on micronutrient concentration (mg kg^{-1}) in the straw of wheat mean of 3 replication± standard error).

Treatments	Fe	Zn	Mn	Cu
T1	124.5 ± 2.91 f	9.03 ± 0.47 e	10.17 ± 0.07 f	22.67 ± 0.88 e

T2	138.8 ± 0.5 e	12.8 ± 0.31 b	10.47 ± 0.09 f	28.33 ± 0.38 d
T3	197.27 ± 0.27 b	10.28 ± 0.03 d	13.87 ± 0.09 c	36.43 ± 1.22 ab
T4	175.93 ± 0.97 c	11.89 ± 0.05 c	12.53 ± 0.09 d	35.1 ± 0.12 b
T5	231.73 ± 10.23 a	14.3 ± 0.15 a	20.03 ± 0.12 a	37.83 ± 0.19 a
T6	198.47 ± 0.15 b	12.97 ± 0.02 b	18.73 ± 0.77 b	35.93 ± 0.38 b
T7	164.77 ± 0.3 d	9.17 ± 0.03 e	11.6 ± 0.12 e	23.63 ± 0.34 e
T8	139.27 ± 0.27 e	9.22 ± 0.05 e	10.33 ± 0.03 f	28.33 ± 0.38 d
T9	165.77 ± 0.9 d	9.5 ± 0.03 e	12.47 ± 0.24 d	30.7 ± 0.31 c
T10	144.63 ± 1.69 e	9.41 ± 0.07 e	11.37 ± 0.09 e	29.4 ± 0.35 cd

The data pertaining to the effect of organic and inorganic sources of Nitrogen on the quality of wheat crop on micronutrient (Zn, Fe, Mn and Cu) concentration in straw and grain of wheat has been presented in table 3 and 4. The Zn, Fe, Mn and Cu concentration in straw ranged from, 14.3 to 9.03, 231.73 to 124.5, 20.03 to 10.17 and 37.83 to 22.67 mg kg^{-1}. Similarly, in grain, the micronutrient concentration (Zn, Fe, Mn and Cu) varied from, 21.41 to 14.66, 54.31 to 30.72, 3.65 to 1.24 and 19.37 to 10.89 mg kg^{-1}. In straw and grain the Zn, Fe, Mn and Cu content were higher in T5 followed by T6, T4, T3 and T2. Micronutrient (Zn, Fe, Mn, and Cu) concentrations in straw and grain are highest in (14.3, 21.4), (231.73, 54.31), (20.03, 3.65) and (37.83, 20.66), with significant increases of 58.36 and 46.04%, 86.12 and 76.79%, 96.95 and 194.35%, and 66.87 and 77.86% over control being observed. The use of inorganic fertilisers and organic manures may have enhanced the uptake of micronutrients in wheat compared to the control because of the micronutrients' higher bioavailability in the soil [19].Through a variety of processes, the decomposition of organic waste releases nutrients, increasing the soil's availability of those nutrients. Furthermore, adding organic manures lowers the pH of the soil by releasing different acids, which promotes the increased bioavailability of micronutrients as compared to using only inorganic fertilisers. Comparable outcomes have been reported by [8], who found that the combination application of inorganic and organic fertilizer-treated plots resulted in higher micronutrient uptakes than control and inorganic fertiliser use alone.Additionally, synergistic application of both organic and inorganic fertilizer may provide a sufficient level of nutrition, which takes part in the biosynthesis of chlorophyll. The micronutrient uptake was also influenced by their interactions with other nutrients. This interaction among nutritional components was further influenced by the physicochemical qualities of the soil. The application of N and Zn has a positive relationship. Additionally, high N concentrations result in an increase in the number of Zn transporters and Zn chelating nitrogenous substances. More nitrogen fertilization increases Zn uptake and translocation in wheat roots and shoots by 300% resulting in increased Zn uptake in grain. Manganese also has a favourable interaction with N. Because nitrate has the ability to promote Mn availability, uptake of Mn in wheat rises when N fertilizers such as urea are applied. Moreover, the use of N fertilizers as nitrate (NO_3^{-}) enhances the rhizospheric pH, whereas ammonium ions (NH_4^{+}) lead to a higher uptake of Mn. Likewise, Cu and Fe uptake was increased significantly due to the combined use of organic and inorganic fertilizers[20].

Table 5. Effects of organic and inorganic sources of nitrogen on pH, EC, nitrogen, phosphorus, potassium and DTPA extractable micronutrient content in the post-harvest soil (mean of 3 replications± standard error).

Treatments	**pH**	**EC**	**organic carbon**	**Nitrogen**	**Phosphorus**	**potassium**	**Zinc**	**Copper**	**Mn**	**Fe**
T1	7.5 ± 0.15 a	0.05 ± 0.01 b	0.31 ± 0 g	199.68 ± 0.95 g	8.98 ± 0.49 f	182.27 ± 0.58 h	0.56 ± 0.02 g	0.89 ± 0.04 e	2.3 ± 1.04 b	5.05 ± 0.6 c
T2	7.6 ± 0.06 a	0.09 ± 0 a	0.34 ± 0.01 f	258.16 ± 2.86 d	13.31 ± 0.31 cd	220.1 ± 0.59 d	0.64 ± 0.06 fg	1.58 ± 0.02 cd	3.76 ± 0.3 a	5.64 ± 0.73 bc
T3	7.67 ± 0.17 a	0.09 ± 0 a	0.35 ± 0 ef	260.64 ± 0.79 d	13.91 ± 0.18 c	220.27 ± 0.19 d	0.79 ± 0.02 cd	1.73 ± 0.05 bc	3.99 ± 0.51 a	6.63 ± 0.24 b
T4	7.63 ± 0.03 a	0.09 ± 0 a	0.36 ± 0 de	268.64 ± 0.63 c	13.98 ± 0.45 c	233.93 ± 0.71 c	0.87 ± 0.05 bc	1.58 ± 0.09 cd	3.92 ± 0.26 a	6.46 ± 0.11 b
T5	7.77 ± 0.03 a	0.1 ± 0 a	0.38 ± 0.01 c	300.51 ± 1.62 a	22.76 ± 0.51 a	300.33 ± 0.33 a	1.13 ± 0.01 a	2.02 ± 0.06 a	4.67 ± 0.11 a	8.48 ± 0.28 a
T6	7.77 ± 0.03 a	0.09 ± 0 a	0.37 ± 0.01 cd	278.12 ± 0.95 b	15.49 ± 0.32 b	266.87 ± 0.88 b	0.93 ± 0.05 b	1.95 ± 0.11 ab	4.24 ± 0.2 a	6.52 ± 0.14 b
T7	7.67 ± 0.17 a	0.08 ± 0.02 a	0.44 ± 0.01 ab	246.35 ± 0.66 f	10.35 ± 0.36 e	182.6 ± 0.95 h	0.73 ± 0.02 def	1.45 ± 0.06 d	3.9 ± 0.38 a	6.36 ± 0.18 bc
T8	7.67 ± 0.17 a	0.08 ± 0 a	0.43 ± 0.01 b	251.68 ± 0.24 e	10.97 ± 0.12 e	187.67 ± 0.64 g	0.74 ± 0.01 def	1.43 ± 0.14 d	3.71 ± 0.13 a	5.87 ± 0.55 bc
T9	7.7 ± 0 a	0.09 ± 0 a	0.46 ± 0.01 a	254.25 ± 0.5 e	12.61 ± 0.31 d	197.87 ± 0.37 e	0.67 ± 0.04 ef	1.49 ± 0.01 d	3.79 ± 0.25 a	6.14 ± 0 bc
T10	7.73 ± 0.03 a	0.08 ± 0 a	0.39 ± 0.01 c	253.59 ± 0.46 e	10.98 ± 0.42 e	194.13 ± 0.48 f	0.78 ± 0.02 de	1.49 ± 0.04 d	3.89 ± 0.61 a	6.05 ± 0.57 bc

3.2 Available Nutrient in Post-Harvest Soil:

The data regarding physicochemical properties of post-harvest soil, such as pH, EC, and OC, varied from 7.50 to 7.77, 0.054 to 0.098 ds m^{-1} 0.31% to (0.46%) respectively in table 5. The maximum pH (7.77) was recorded in T5 and T6 which was at par withT9, T10, T3, T8 and T7. However, the minimum pH was observed in control (7.5). The maximum EC (0.1 dS m^{-1}) was in T5 which was 3.6% higher than control (0.05 dS m^{-1}). The maximum

OC was observed in T9 (0.46 g kg^{-1}) followed by T7, T8 and T10 which was significantly higher by 48.38, 41.93, 38.70 and 22.58% over control. Data on available N content in post-harvest soil has been presented in Table 5. It ranged from 199.68 to 300.51 kg ha^{-1}. The maximum N content (300.51 kg ha^{-1}) was obtained with T5 followed by 278kg ha^{-1}with T6, 268 kg ha^{-1} with T4, 260.64 kg ha^{-1} with T3and 258.16 kg ha^{-1} with T2 which resulted a significant increase of 50.58, 39.28, 34.53, 30.52 and % over control (199.68 kg ha^{-1}), respectively. The lowest N content was recorded in control (199.68 kg ha^{-1}). Data on available P content in post-harvest soil has been presented in Table 5. It ranged from 8.98 to 22.76 kg ha^{-1}. The maximum P content (22.76 kg ha^{-1}) was obtained with T5 followed by 15.49 kg ha^{-1}with T6, 13.98 kg ha^{-1} with T4,13.91 kg ha^{-1} with T3 and 13.31kg ha^{-1} with T2 which resulted a significant increase of 153.45, 72.49, 55.67, 54.89 and 48.21% over control (8.98 kg ha^{-1}), respectively. Data on available K content in post-harvest soil has been presented in Table 5. It ranged from 182.27 to 300.33 kg ha^{-1}. The maximum K content (300.33 kg ha^{-1}) was obtained with T5 followed by 266.87 kg ha^{-1}with T6, 233.93 kg ha^{-1} with T4, 220.27 kg ha $^{-1}$ with T3 and 220 kg ha^{-1} with T2 which resulted a significant increase of 64.77, 46.41, 28.34, 20.84 and 20.7% over control (182.27 kg ha^{-1}), respectively. The data pertaining to DTPA-extractable Fe, Mn, Cu and Zn content significant variation range from 8.48 to 5.05, 4.67 to 2.3, 2.02 to 0.89 and 1.13 to 0.56 mg kg^{-1}(Table 5). The maximum DTPA Fe content (8.48 mg kg^{-1}) was observed in T5 followed by T3 (6.63), T6 (6.52) and T4(6.46) which was significantly higher by 40.44, 31.28, 29.1 and 27.92% than control. The highest DTPA Mn content (4.67 mg kg^{-1}) was observed in T5 followed by T6 (4.24), T3(3.99) and T4(3.92) which significantly increased by 103, 84.34, 73.47 and 70.43% than control. The maximum DTPA Cu content (2.02 mg kg^{-1}) was in T5 followed by T6 (1.95), T3(1.73) and T4(1.58) which was significantly increased by 126.9, 119.1, 94.38 and 77.52% than control. The maximum DTPA Zn content (1.13 mg kg^{-1}) was in T5 followed by T6 (0.93 mgkg^{-1}), T4 (0.87 mg kg^{-1}) and T3 (0.79) with respective increase of 101.78, 66.07, 55.35 and 41.07% over control. Compared to the control treatment, the organic carbon content in the soil was increased by 10% when PM and VC were applied at the rate of 10 and 10.53 t ha^{-1}. Due to the high temperature and humid conditions in our tropical and sub-tropical climatic regions, microbial decomposition of organic materials in soils is very fast and, therefore, the resultant effect is a small increase in carbon content in soils even though farmers apply high amounts of organic matter. [21] Reported that animal manure is more effective in building soil C than straw is, possibly due to the presence of more humified and recalcitrant C forms in animal manure as compared to straw. Moreover, manure is more resistant to microbial decomposition than plant residues, thus, for the same C input, C storage is higher with manure application than with plant residues. These results are well corroborated with the findings of [22]. Poultry manure was found the most efficient in increasing soil pH to 6.25, which can be rated as slightly acidic. This is due to the higher calcium content in poultry diet which is attributed to poultry manure. Therefore, PM was found to increase soil pH, which was reported by many researchers [23]. Organic matter improved the soil pH status by increasing the soil buffering capacity. Organic fertilizers increase the cation exchange capacity, which contributes to a high base saturation of the soil. The nutrient availability in the soil is basically reliant on its better physicochemical and biological properties. The application of organic manure enhances the chemical properties of soil, for example, it increases OC, N, P, K, Ca, Mg, and S contents in soil [17]. The integrated organic and inorganic fertilizer treatment improved the soil structure and hence increased the macro-and micro-nutrient availability, resulting in enhanced crop yield [24]. The integrated treatment (organic and inorganic) gave higher values for soil N, P, K, and S contents whereas the sole inorganic treatment gave significantly lower values for those nutrients. In fact, the different organic manure increased the bacterial population in the soil, which may enhance the fertility status of soil. It can be explained in such a way that although the total P is higher with the higher rates of organic fertilizer application, its availability depends on the mineralization of these fertilizers which is a slow process where about 2–3% is mineralized in a year. It was reported that soil pH is important in controlling different available forms of P, as well as precipitation-dissolution and adsorption-desorption reactions, and thus P solubility and availability to plants[25]. Our results showed that soil pH under different organic treatments increased significantly in a favourable range for nutrient availability in soil; it might have a significant positive impact on the nutrient availability. Our results were also supported by many other researchers[26]& [27] who reported higher organic carbon, N, P, K, Ca, Mg, and S contents in post-harvest soils due to integrated organic and inorganic fertilizer treatment. It has also been reported that, in addition to the macro-nutrients, organic matter also contains micro-nutrients [24]which may promote and maintain the sustainable nutrients supply to the soil. The favourable effects of organic manure on soil N supply have already been documented [28]. In this investigation, the highest increase in available P under combined RDF, FYM, and PM treatment, as shown in Table 6, was very much expected under regular P addition through fertilizer, as cereal crops utilize only a fraction of the applied P [29]. Manure supplies a huge amount of P to soil, and decreases the fixation of applied P in the soil, resulting in increased competition of organic molecules with PO_4^{3-} ions for P retention sites under combined treatment, which could be another explanation for this finding[30]. The leaching loss of potassium (K) with percolating water is one of the major reasons for K removal from the rhizosphere, especially under irrigated ecology. The greater K fixing ability of illite-dominant soil is the main reason for the decrease in available K in soil [31]. On the other hand, the higher available K content under combined manure and mineral treatment in the current study may be ascribed to the release of organic acids during decomposition, which generates negative electron charges in the soil with a preference for di or trivalent cations, such as Al_3^+, Ca_2^+, and Mg_2^+, leaving K^+ to be absorbed by negatively-charged soil colloids[32]. This phenomenon might help to reduce K fixation and enhance its availability in soil. PM increased content of N, P, K, Ca, Mg, Zn, Fe and Cu by maize grown on an Alfisol in southwest Nigeria. This is consistent with the present study that PM enhanced nutrient status of maize in addition to increasing nutrient in soil [33].

In this study, we determined that an integrated application of PM, FYM, VC and SS with RDN was an effective approach to enhance nutrient content (straw and grain), physicochemical properties of wheat crop. RDN50PM50 (5.26 t ha^{-1}) treatment showed the best performance in terms of nutrient content in plant and soil of wheat crop. Therefore, organic manure, such as PM, which contains high total N (> 4%) and moderate P and K, is more compatible with EMN and should be integrated with 50%RDN through urea not only to improve yield but also to further reduce the amount of fertilizers applied for sustainable agriculture. Thus, the combined application of manures with chemical fertilizers over the sole application of inorganic fertilizers provides essential nutrients to the crop, which could be considered as an alternate way of enhancing nutritional security and sustaining crop productivity. Further evaluation pertaining to the interactive effect of manures and fertilizers on soil fertility build-up is required with respect to soil physical and soil biochemical properties.

4. CONCLUSION

In this study, we determined that an integrated application of PM, FYM, VC and SS with RDN was an effective approach to enhance the nutrient content (straw and grain), physicochemical properties of wheat crop. RDN50PM50 (5.26 t ha^{-1}) treatment showed the best performance in terms of nutrient content in plant and soil of wheat crop. Therefore, organic manure, such as PM, which contains high total N (> 4%) and moderate P and K, is more compatible with EMN and should be integrated with 50%RDN through urea not only to improve yield but also to further reduce the amount of fertilizers applied for sustainable agriculture. Thus, the combined application of manures with chemical fertilizers over the sole application of inorganic fertilizers provides essential nutrients to the crop, which could be considered as an alternate way of enhancing nutritional security and sustaining crop productivity. In the present study, the main emphasis has been given to recommended levels of N only by ignoring the other nutrients in different manures. Further evaluation pertaining to the interactive effect of manures and fertilizers on soil fertility build-up is required with respect to soil micronutrients and soil biochemical properties.

DISCLAIMER

The author(s) confirm that no generative AI technologies, including Large Language Models (such as ChatGPT, Copilot, etc.) or text-to-image generators, were utilized in the writing or editing of this manuscript.

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