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Effects of Different Tillage and Nutrient Management Practices on Soil Physico-chemical Properties under Wheat (*Triticum aestivum* L.)

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ABSTRACT

Background: The field experiment aimed to investigate the effects of various tillage and nutrient management practices on soil physico-chemical properties under wheat (*Triticum aestivum* L.) during the two consecutive seasons of *Rabi* 2020-21 and 2021-22. The field experiment was conducted at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand.

Methods: The experiment was laid out in a split-plot design with three replications, the main plot included three tillage treatments: Zero tillage (ZT), reduced tillage (RT) and conventional tillage (CT). Under sub-plots consisted the five nutrient management practices: Recommended dose of fertilizer (RDF: N 120, P_2O_5 40, K_2O 60), RDF + Farmyard Manure (FYM) at 5 tonnes/ha, RDF + Zinc Sulphate at 25 kg/ha, 75% RDF + FYM at 10 tonnes/ha, 75% RDF + FYM at 5 tonnes/ha + Zinc Sulphate at 12.5 kg/ha. This setup resulted in 15 treatment combinations integrating different tillage practices and nutrient management practices.

Result: The results revealed that zero tillage and nutrient management did not show effect on soil pH, electrical conductivity (EC), organic carbon, available NPK and bulk density during both the years of experiment. However, 75% RDF + FYM at 5 tonnes/ha + Zinc Sulphate at 12.5 kg/ha exhibited higher values in all evaluated properties, with organic carbon showing a significantly higher as compared to NM_1 (RDF: 120:60:40), NM_2 (RDF + Zinc Sulphate at 25 kg/ha) and NM_3 (RDF + FYM at 5 tonnes/ha), but it was statistically at par with NM_4 (75% RDF + FYM at 10 tonnes/ha).

Key words: Conventional tillage (CT), FYM (Farm Yard Manure), Organic carbon, RDF (Recommended dose of Fertilizer), Reduced tillage (RT), Zero tillage (ZT).

INTRODUCION

In India, wheat plays a crucial role as a staple food and significant energy source. Over the past four decades, India has made remarkable progress in wheat production, becoming the second-largest global producer. The wheat production has shown remarkable growth, increasing from 6.60 million tonnes during the time of independence to 114 million tonnes in 2023-24 (GOI, 2024). Uttar Pradesh leads in both area and production, while Punjab excels in productivity. Wheat is a versatile crop, well-adapted to a wide range of climates and soils, making it suitable for cultivation in diverse geographical regions. Its adaptability and high nutritional value have made it a major source of dietary energy for billions of people worldwide. As a cereal grain, wheat serves as a primary ingredient in a myriad of food products, such as bread, pasta, cereals and pastries, contributing to the daily sustenance of millions.

The government-mandated minimum support prices for rice and wheat make this cropping sequence particularly profitable and dominant in the region. During the 1960s, the production of these crops surged due to an expansion in cultivation areas, the adoption of high-yielding semi-dwarf varieties, reliable irrigation and increased use of fertilizers. Despite these advancements significantly boosting food production over recent decades, food security faces ongoing challenges such as climate change, water scarcity, population growth and urbanization (Rama Rao *et al.*, 2019). Under conventional agricultural systems, the principal indicators of non-sustainability are soil erosion and the decline in soil organic matter, primarily caused by heavy field traffic that degrades soil structure and water and wind erosion, which reduce infiltration rates, cause surface crusting and lead to soil compaction. Poor recycling

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of organic materials and mono-cropping further exacerbate these challenges (Swaminathan *et al.*, 2022). Conversely, conservation agriculture practices, such as reduced tillage, alleviate soil compaction and enhance the activity of soil micro flora. These microorganisms enhance nutrient availability and release sticky organic compounds that improve soil structure, aeration and moisture retention. Additionally, they support the proliferation of earthworms and other beneficial soil biota, contributing to overall soil health (Subbulakshmi *et al.*, 2009; Selvakumar and Sivakumar, 2021). Nevertheless, the sustainability of traditional rice-wheat systems faces significant threats due to declining factor productivity, overexploitation of groundwater and deteriorating soil health (Kumar and Sharma, 2020). Moreover, intensive tillage, labour and energy constraints and improper residue management-including widespread residue burning-contribute to environmental degradation and disrupt ecosystem services (Downing *et al.*, 2022).

To address these issues, conservation tillage practices such as no-till, strip-till, mulch-till and ridge-till have been advocated to minimize soil disturbance and provide agronomic, environmental and economic benefits (Bezboruah *et al.,* 2024). These approaches influence soil properties positively, stabilize yields and support ecosystem resilience. Conservation tillage mitigates problems such as erosion, greenhouse gas emissions and water loss, while preserving soil organic matter, enhancing biodiversity, suppressing weeds and improving both soil structure and biological functions (Gulaiya *et al.*, 2025). Overall, conservation agriculture presents a viable strategy to reduce production costs, conserve essential resources like water and nutrients, enhance yield potential, diversify cropping systems and foster environmental stewardship (Bhadu *et al.*, 2018). By minimizing soil disturbance and optimizing nutrient management, conservation agriculture significantly improves soil health and ensures the long-term economic and ecological sustainability of crop production systems.

Nutrient management is crucial, especially in intensive cropping, as Indian soils lack major plant nutrients like nitrogen, phosphorus, potash, sulphur, zinc, boron, iron, manganese, copper and molybdenum. Deficiencies in macro and micronutrients have grown due to excessive use of high-analysis fertilizers, lack of soil testing, high-yielding crop varieties and intensified cropping. This poses a major constraint on agricultural production and productivity. To sustainably manage soil productivity and fertility, nutrient management strategies should comprehensively address the physical, chemical and biological properties of the soil. This can be accomplished through the integrated use of organic manures and chemical fertilizers (Yaduvanshi and Sharma, 2016; Bhardwaj *et al.*, 2022). Integrated nutrient management (INM) focuses on preserving soil fertility, maintaining crop productivity and increasing farmers' net profit by efficiently and judiciously combining chemical fertilizers, organic manures and crop residues (Verma *et al.*, 2006, Bhardwaj *et al.*, 2019).

MATERIALS AND METHODS

Experimental location

During the *Rabi* seasons of 2020-21 and 2021-22, a field experiment was conducted in the D-2 block of Norman E. Borlaug Crop Research Centre at G.B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand. The research centre is located in the Tarai belt, 30 kilometers south of the Shivalik range of the Himalayas, at a latitude of 29°N and longitude of 79.3°E, with an elevation of 243.83 meters above mean sea level. The experiment was laid out in a split-plot design with three replications. It consisted of two factors: Different tillage practices and nutrient management practices. The main plot included three treatments: Zero tillage, reduced tillage and conventional tillage. The sub-plots consisted of five treatments: RDF (120:60:40 N: P_2O_5 kg/ha), RDF + FYM (5 tonnes/ha), RDF + Zinc sulphate (25 kg/ha), 75% RDF + FYM (10 tonnes/ha) and 75% RDF + FYM (5 tonnes/ha) + Zinc sulphate (12.5 kg/ha).

Chemical properties

A composite soil samples were taken from 0-15 cm depth and kept in polythene bags for analysis of various soil chemical properties. The soil chemical properties were measured before sowing and after the harvest of crop.

Soil pH

To analysis the soil pH 10 g soil was taken in a clean 50 ml beaker and dissolved in 25 ml of distilled water. The suspension was stirred intermittent for 30 minutes. The pH was recorded using a digital pH meter having glass electrode pH meter (Jackson, 1973).

Soil EC

Electrical conductivity (EC) was determined by the Conductivity Bridge as described by Jackson, (1973). For determination of EC, 10 g of soil was taken in 50 ml beaker, 25 ml of distilled water was added and the suspension was stirred intermittently for 30 minutes allowing the suspension to settle for about one hour to measure EC in the supernatant solution using EC meter.

Organic carbon content of soil

The organic carbon content in soil was determined by following modified Walkley and Black, (1934) method. Organic carbon is calculated by using the following formula:

$$\text{Organic carbon (\%)} = \frac{10\ (B - T \times 0.003 \times 100)}{B \times \text{weight of soil (g)}}$$

Where,

B= Volume (ml) of Ferrous ammonium sulphate needed for blank.

T= Volume (ml) of Ferrous ammonium sulphate needed for soil sample.

Available soil nitrogen

The alkaline potassium permanganate method was used to determine available nitrogen in soil (Subbiah and Asija, 1956). The following formula was used to calculate the available nitrogen:

$$\text{Available N (kg/ha)} = \frac{(T - B) \times N \times 0.0003 \times 10^6}{20} \times 2.24$$

$$= (T\text{-}B) \times 31.36$$

Where,

B= Volume (ml) of H_2SO_4 needed for blank.

T= Volume (ml) of H_2SO_4 needed for soil sample.

N= Normality of H_2SO_4.

Available soil phosphorus (P_2O_5)

The available phosphorus was extracted using sodium bi-carbonate (0.5 M $NaHCO_3$) adjusted to pH 8.5 according to the method of (Olsen *et al.,* 1954) The phosphorous concentration was calculated using a standard curve.

Soil available phosphorus (ka/ha) =

$$\frac{Q \times 2.24 \times 10^6}{A \times S \times 10^6} = \frac{Q \times V \times 2.24}{A \times S}$$

Where,

Q= Quantity of P in micro-gram read on X-axis against a sample reading.

V= Volume of extracting reagent used (ml).

A= Volume of aliquot used for colour development (ml).

S= Weight of soil sample (g).

Available soil potassium (K_2O)

Available potassium was determined by neutral ammonium acetate method outlined by Jackson, (1973). The concentration of potassium was worked out with the help of standard curve.

$$\text{Soil available potassium (kg/ha)} = C \times \frac{25}{5} 2.24 = C \times 11.2$$

Where,

C= Concentration (mg/L) of potassium in the soil sample filtrate obtained on X- axis, against the reading.

Physical properties

Bulk density

Bulk density and moisture content was determined by core sampler method (Blake and Hartge, 1986). Bulk density of the soil was determined at 0-15 cm after core sampling. Fresh weight of soil along with moisture box was taken to determine the moisture in soil at the time of sampling and then boxes were dried in oven at 105°C temperature till constant weight and then sample was weighted to obtained soil oven dry weight express the bulk density and moisture content by following formula:

$$\text{Bulk density of soil (Mg/m}^3\text{)} = \frac{\text{oven dry weight of soil (mg)}}{\text{Volume of soil (m}^3\text{)}}$$

Volume of soil = $\pi r^2 h$; π r and h where having the value of 3.14, 5 cm and 15 cm respectively.

RESULTS AND DISCUSSION

Effects of different tillage and nutrient management practices on soil physico-chemical properties

Soil pH and EC (dSm^{-1})

The data pertaining to soil pH, soil electrical conductivity and soil organic carbon are presenting in Table 1. In both the years of experiments, there was no significant difference found in soil pH and EC caused by different tillage practices. Zero tillage (7.1, 7.0 and 0.29, 0.28 dSm^{-1}) recorded the lowest soil pH followed by reduced (7.2, 7.1 and 0.29, 0.28 dSm^{-1}) and conventional (7.2, 7.1 and 0.30, 0.29 dSm^{-1}) tillage. In general, conventional tillage had the highest impact on soil pH and EC followed by reduced tillage and zero tillage. The effect of nutrient management practices on soil pH and EC was found to be non-significant during both the years. It is clear from data that the higher value of soil pH and EC was recorded when RDF use alone. The lower soil pH and EC recorded when application of FYM @ 10 t/ha or FYM @ 5 t/ha with 12.5 kg/ha $ZnSO_4$ with 75% RDF followed by FYM @ 5 t/ha or 25 kg/ha $ZnSO_4$ with RDF during both the years. The trend reveals that the combination of zinc sulphate and FYM is the best option to buffer the soil pH and EC where at even with 75% RDF dose. The interaction effect between tillage and nutrient management practices on soil pH and EC was found non-significant.

Soil organic carbon

It is evident from the data that different tillage practices caused non-significant effect on soil organic carbon during both the years. The treatment, zero tillage (0.82 and 0.84) recorded highest soil organic carbon followed by reduced (0.80 and 0.82) and conventional (0.79 and 0.81) tillage during 2020-21 and 2021-22, respectively. Overall, the effect of tillage practices on soil organic carbon was in order of conventional > reduced > zero tillage. Similar result was found by Rahimzadeh and Navid, (2011) studied the high level of organic matter under no-tillage treatment and the effect of organic matter on increasing water-holding capacity in wheat-legumes rotation and Calegari *et al.* (2008) also reported that conservation tillage can sustain or increase soil organic carbon in winter crops, which was due to organic residue left, no soil disturbance and decreased contact with soil micro-organisms. The effect of nutrient management practices on soil organic carbon was found non-significant variation during both the years. It is clear from data that the lowest value of soil organic carbon was recorded when RDF use alone. The higher soil organic carbon recorded when application of FYM @ 10 t/ha or FYM @ 5 t/ha + 12.5 kg/ha $ZnSO_4$ with 75% RDF followed by FYM @ 5 t/ha or 25 kg/ha $ZnSO_4$ with RDF during both the years. The trend reveals that the combination of zinc sulphate and FYM is the best option to increase the soil organic carbon where at even 75% RDF dose.

There was an increase in organic carbon with the application of FYM. FYM played an important role in soil properties *i.e.*, microbial activity, maintaining soil EC, buffering soil pH and availability of nutrients, which ultimately increased soil organic carbon. Singh *et al.* (2011) reported that integrated nutrient treatments increased the amount of available N, P, K and S as well as organic carbon in the soil.

The interaction effect between tillage and nutrient management practices on soil organic carbon was found non-significant.

Soil available nitrogen, phosphorus and potassium

The data pertaining to soil available nitrogen, phosphorus and potassium are presented in Table 2.

It is evident from the data that different tillage practices caused non-significant effect on soil available nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) during both years. The treatment, zero tillage (263 and 265.8 and 19.6 and 20.7 and 182.0 and 182.5) recorded numerically higher available nitrogen, phosphorus and potassium followed by reduced (261.0 and 263.6 and 19.5 and 20.6 and 181.0 and 181.6) and conventional (259.4 and 261.8 and 19.3 and 20.5 and 179.6 and 180.2) tillage during 2020-21 and 2021-22, respectively. Overall, the effect of tillage practices on soil available nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) was in order of zero tillage > reduced > conventional tillage.

Table 1: Effect of tillage and nutrient management practices on soil pH, EC and organic carbon in soil after harvesting of wheat crop.

Treatments	pH		EC (dSm^{-1})		Organic carbon (%)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Tillage practice						
ZT : Zero tillage	7.1	7.0	0.29	0.28	0.82	0.84
RT : Reduced tillage	7.2	7.1	0.29	0.28	0.80	0.82
CT : Conventional tillage	7.2	7.1	0.30	0.29	0.79	0.81
SEm±	0.02	0.001	0.001	0.001	0.01	0.01
CD at 5%	NS	NS	NS	NS	NS	NS
Nutrient management practice						
NM1 : RDF (120:60:40)	7.2	7.2	0.30	0.29	0.78	0.80
NM2 : RDF + $ZnSO_4$ @25 kg/ha	7.1	7.3	0.29	0.28	0.79	0.81
NM3 : RDF + FYM @5 t/ha	7.1	7.0	0.29	0.28	0.82	0.84
NM4 : 75% RDF + FYM @10 t/ha	7.1	6.9	0.29	0.28	0.82	0.84
NM5 : 75% RDF + FYM @5 t/ha + $ZnSO_4$ @12.5 kg/ha	7.0	6.9	0.29	0.28	0.83	0.85
SEm±	0.1	0.1	0.001	0.001	0.01	0.01
CD at 5%	NS	NS	NS	NS	0.03	0.03

Table 2: Effect of tillage and nutrient management practices on available N, P, K and Bulk Density in soil after harvest of wheat crop.

Treatment	Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)		Bulk density (Mg/m^3)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Tillage practice								
ZT : Zero tillage	263.0	265.8	19.6	20.7	182.0	182.6	1.32	1.30
RT : Reduced tillage	261.0	263.6	19.5	20.6	181.0	181.6	1.33	1.33
CT : Conventional tillage	259.4	261.8	19.3	20.5	179.6	180.2	1.34	1.35
SEm±	1.0	1.0	0.1	0.1	2.8	3.3	0.02	0.01
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management practice								
NM1 : RDF (120:60:40)	258.3	260.9	19.3	20.5	178.7	179.2	1.33	1.35
NM2 : RDF + $ZnSO_4$ @ 25 kg/ha	259.3	262.9	19.4	20.5	179.0	179.5	1.33	1.34
NM3 : RDF + FYM @ 5 t/ha	261.0	263.6	19.5	20.6	181.0	181.5	1.32	1.31
NM4 : 75% RDF + FYM @10 t/ha	262.3	264.9	19.5	20.7	182.7	183.2	1.31	1.30
NM5 : 75% RDF + FYM @ 5 t/ha + $ZnSO_4$@ 12.5 kg/ha	264.7	266.3	19.6	20.8	183.0	184.1	1.32	1.31
SEm±	2.1	2.1	0.1	0.1	1.8	3.0	0.03	0.01
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Similar result was found by Woniak *et al.* (2014) found that the RT and NT systems increased the amount of organic carbon, total nitrogen and available phosphorus in the soil. In comparison to the CT system, they also increased the quantity and size of earthworms in the soil. Feng *et al.* (2014) researchers also observed an increase in soil total nitrogen to a depth of 0-40 cm in no-tillage compared to other treatments.

The effect of nutrient management practices on soil available nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) was found non-significant variation during both the years. It is clear from data that the highest value of soil available nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) was recorded in NM5 (75% RDF + $ZnSO_4$ @12.5 kg/ha + FYM @ 5 t/ha). The highest soil available nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) recorded when application of FYM @ 10 t/ha or FYM @ 5 t/ha+12.5 kg/ha $ZnSO_4$ with 75% RDF followed by FYM @ 5 t/ha or 25 kg/ha $ZnSO_4$ with RDF during both the years. The trend reveals that the combination of zinc sulphate and FYM is the best option to increase the available nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) where at even with 75% RDF dose.

The increase in the available nitrogen, phosphorus and potassium of soil under integrated nutrient management might be due to the release of CO_2 and organic acids during decomposition which help in solubilizing the native nitrogen, phosphorus and potassium in soil solution. Similar result was found by Prasad *et al.* (2010) and Singh *et al.* (2013).

The interaction effect between tillage and nutrient management practices on available nitrogen, phosphorus and potassium were found non-significant.

Bulk density

The data pertaining on bulk density have been presented in Table 2. The different tillage practices caused non-significant effect on soil bulk density (Mg/m^3) during both the years. The treatment, zero tillage (1.32 and 1.30 Mg/m^3) recorded lowest soil bulk density followed by reduced (1.33 and 1.33 Mg/m^3) and conventional (1.34 and 1.35 Mg/m^3) tillage during 2020-21 and 2021-22, respectively. Overall, the effect of tillage practices on soil bulk density was in order of zero tillage>reduced>conventional tillage. During second year bulk density is lower compared with first year in zero tillage but it was increase in reduced and conventional tillage.

It might be due to adoption of zero tillage continuous two years which increase soil organic matter in soil, as well as the organic acid released by the decomposition of crop residue, aggregation and ultimately decreased bulk density of soil. Similar results were found by Hu *et al.* (2007) to study the effects of conservation tillage on soil aggregate characteristics. Soils were sampled from no tillage (NT), rotary tillage (RT) and conventional tillage (mold board tillage, CT) plots. They observed that no-tillage significantly increased the top soil (0-5 cm) bulk density, while reduced tillage maintained a lower bulk density than conventional. Therefore, no tillage increased the topsoil bulk density remarkably, which indicated that the soil compactness under no tillage was increased after 4 years.

The effect of nutrient management practices on soil bulk density was found non-significant variation during both the years. It is clear from data that the highest value of soil bulk density was recorded when RDF use alone. The lowest soil bulk density recorded when application of FYM @ 10 t/ha or FYM @ 5 t/ha+12.5 kg/ha $ZnSO_4$ with 75 % RDF followed by FYM @ 5t/ha or 25 kg/ha $ZnSO_4$ with RDF during both the years. The trend reveals that the combination of zinc sulphate and FYM is the best option to decrease the soil bulk density where at even with RDF and 75% RDF.

CONCLUSION

Based on the foregoing results and discussion it can be concluded that zero tillage with 75% RDF + FYM (5 tonnes/ha) + Zinc Sulphate (12.5 kg/ha) had a non-significant effect on soil pH, electrical conductivity, organic carbon, available NPK and bulk density. Nevertheless, this combination showed higher values in all measured parameters compared to other treatments. Specifically, the organic matter content was significantly higher with 75% RDF + FYM (5 tonnes/ha) + Zinc Sulphate (12.5 kg/ha) compared to NM_1 (RDF: 120:60:40), NM_2 (RDF + Zinc Sulphate at 25 kg/ha) and NM_3 (RDF + FYM at 5 tonnes/ha) and was comparable to NM_4 (75% RDF + FYM at 10 tonnes/ha). In conclusion of integrating zero tillage with reduced RDF and supplementary organic and micronutrient amendments (FYM and Zinc Sulphate) can enhance soil physicochemical properties, thus contributing to more sustainable wheat cultivation practices. These findings suggest that strategic nutrient management combined with conservation tillage can potentially improve soil health and crop productivity.

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The field experiment aimed to assess the impact of different tillage and nutrient management practices on soil physico-chemical properties under wheat during *Rabi* 2020-21 and 2021-22 it was conducted at the Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, the study used a split-plot design with three tillage treatments and five nutrient management practices, forming 15 treatment combinations. Results indicated that while tillage practices showed no significant effect, nutrient management involving 75% RDF + FYM at 5 tonnes/ha + Zinc Sulphate at 12.5 kg/ha improved soil properties, particularly organic carbon.

Disclaimers

The field experiment, conducted at the Norman E. Borlaug Crop Research Centre, G.B. Pant University, Pantnagar, during *Rabi* 2020-21 and 2021-22, studied the effects of tillage and nutrient management on soil physico-chemical

properties under wheat (*Triticum aestivum* L.). Using a split-plot design with three tillage treatments (zero, reduced and conventional tillage) and five nutrient management practices, including RDF and combinations with FYM and Zinc Sulphate, 15 treatment combinations were evaluated. Results showed no significant effect on soil pH, EC, organic carbon, available NPK, or bulk density. However, the combination of 75% RDF + FYM (5 t/ha) + Zinc Sulphate (12.5 kg/ha) consistently exhibited higher values, particularly in organic carbon, compared to other treatments, though it was at par with 75% RDF + FYM (10 t/ha).

Informed consent

The participants involved in this study were provided with detailed information about the research objectives, procedures, potential risks and benefits. They were assured that their participation was voluntary and that they could withdraw at any stage without any repercussions. Confidentiality of the data and personal information was maintained throughout the study. Written consent was obtained from all participants before initiating their involvement in the research.

Conflict of interest

The authors declare no conflict of interest regarding the research, authorship, or publication of this study.

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