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Effect of Long-Term Fertilizer Application on Performance of Wheat Crop and Soil Properties in a Vertisol

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ABSTRACT

A field experiment was conducted in an ongoing Long-Term Fertilizer Experiment during 2017-18 and 2018-19 at the Research Farm, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur to study the effect of long-term fertilizer application on performance of wheat crop and soil properties. The experiment was conducted in a randomized block design with ten treatments in four replications. The treatments comprised were 50% NPK, 100% NPK, 150% NPK, 100% NPK+Hand weeding, 100% NPK+Zn, 100% NP, 100% N, 100% NPK+FYM, 100% NPK-S and Control. The wheat crop (cv. GW-366) was grown with recommended nutrient dose of 120:80:40 (N: P_2O_5: K_2O) in Rabi season. Field observations such as plant height and number of tillers were recorded at various growth stages and periodic intervals. The grain yield, straw yield and total biomass were recorded at crop harvest. The representative soil samples were collected from 0-15 cm depth and analyzed for different properties. The results revealed that, the wheat responded positively to the balanced nutrition as compared to no fertilization and imbalanced fertilization. Similarly, the application of balanced application of fertilizers showed higher soil organic carbon and nutrients as compared to the imbalanced nutrition.

Keywords: *Long term fertilizer addition, wheat, Crop performance, Vertisol, Soil properties*

INTRODUCTION

Fertilizers are the key inputs for increasing agricultural production but their continuous and imbalanced application deteriorates the soil health (NAAS, 2009). The effects of the balance fertilizers on the yield and quality parameters of wheat were studied by Horvat et al. (2006). Application of continuous and higher amount of chemical fertilizers increases the crop yield in initial years but influences the soil nutrient supply capacity and induces the deficiency of micro nutrients. The optimum crop yield has been limited by many factors such as quality of seed, irrigation water availability, weather, agronomic practices, type of soil, soil nutrient status etc.

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The loss of organic carbon content is one of the major reasons for loss of soil fertility and it can be prevented by balanced fertilizer application and external addition of organic carbon to the soil (Lin et al., 2015, & Aher et al., 2018). The contribution of long-term fertilizer experiment recommendations in recent agriculture development continues to be of great importance. Initially, the outcome generated by such experiments, unequivocally, the potential increase in production that may be attained as a result from the balance use of chemical fertilizers (Lopez-Bellido et al., 2001).

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops globally and is a staple food for about one third of the world's population. It occupies second position both in terms of area and production in the world (Evans & Wardlaw 1996). It is cultivated over an area of 29.86 million hectares with an annual production of 94.88 million tonnes and productivity of 3.18 Mt/ha in India, whereas in Madhya Pradesh, it is cultivated in 4.89 thousand hectares of land with an annual production of 12.69 million tonnes and productivity of 2.36 Mt/ha (Singh et al., 2010, & Krishnan et al., 2019). Wheat grains are comparatively better source of protein consumed in India. About 10-12% protein requirement is met by wheat. In this endeavour proper blend of organic manure and inorganic fertilizer is important not only for increasing yield but also for sustaining soil health (Kumar et al., 2013)

Long term experiments provide valuable information for formulating future strategies for maintain soil health (Hati et al., 2007). Changes in soil properties, soil health and nutrient supply capacity of soil are slow processes and hence require long-term monitoring. Long-term monitoring allows both the identification of current changes in the soil and prediction of future changes (Antil & Singh, 2007). Considering these facts, the present field experiment was carried out to study the response of wheat to long term fertilizer application and changes in soil properties. The integrated use of concentrate organic materials and inorganic fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favorable ecological conditions and helps to restore and sustain fertility and crop productivity on long-term basis (Kumar & Dey, 2007).

MATERIALS AND METHODS

Experimental site, climate and soil characteristics

Present investigation was conducted in an ongoing scheme All India Coordinated Research Project (AICRP) on Long Term Fertilizers Experiment (LTFE) of Indian Council of Agricultural Research (ICAR). The LTFE is laid out on a permanent site at the Experimental field Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru krishi Vishwa Vidyalaya. Jabalpur (M.P.). The experimental site is situated in 'Kymore Plateau and Satpura Hills' agro climatic region of M.P. It falls on 23.9° N latitude and 79.6° E longitudes with an altitude of 411.8 m above the mean sea level. Jabalpur is situated in the semi-arid region having sub-tropical climate with hot dry summer, and cold winter. The average rainfall is about 1350 mm, which is mainly distributed from mid June to October. The maximum and minimum temperature ranges between 35.1°C and 5.3°C. The average annual relative humidity is 62%. The meteorological observations recorded during crop growth period are presented in Fig.1. Among them, decline in soil fertility due application of imbalanced chemical fertilizers has been identified as most important factor for lowering the crop productivity (Jarven et al., 2008, & Indoria et al., 2018).

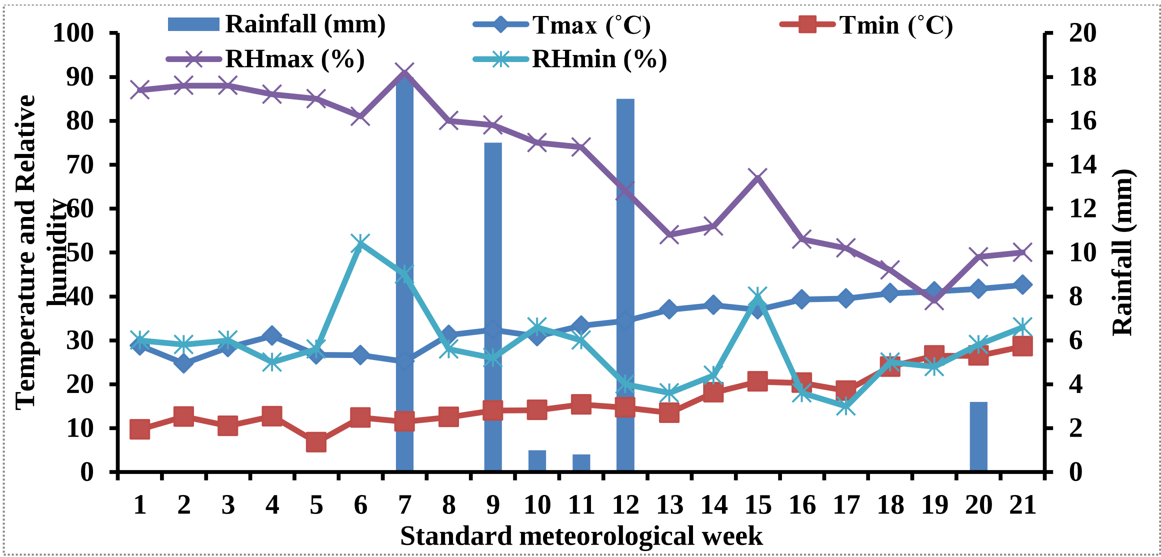

Fig. 1: Meteorological observations during experimental period

The experiment was started with maize fodder as the first crop in summer season of 1972; since then Soybean (Kharif)-Wheat (Rabi)-Maize fodder (summer) crop rotation was adopted till 1994. However, since 1994 the cultivation of maize fodder was left and presently the cropping sequence being followed is soybean (Kharif) and wheat (Rabi). The soil of the experimental field is medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic Haplustert. The characteristics of initial soil samples collected from experimental field are presented in Table 1.

Table 1: Initial characteristics of experimental soil

Soil properties	Value
pH (1:2.5)	7.60
EC (1:2.5) (dSm^{-1})	0.18
Soil organic carbon (%)	0.57
Available nitrogen (kg ha^{-1})	193
Available phosphorus (kg ha^{-1})	7.60
Available potassium (kg ha^{-1})	370
Available sulphur (kg ha^{-1})	7.80

Treatments detail

The experiment has been in continuance since 1972 with 10 different treatments. The details of the treatments are presented in Table 2. The 100% optimal NPK doses based on initial (1972) soil test values was 120:80:40 (N: P_2O_5: K_2O) for wheat. Nitrogen was applied through urea, phosphorus through single super phosphate and potassium was applied through murate of potash. The farm yard manure in FYM treatment was applied @ 5 ton ha^{-1} year^{-1} to soybean crop only. Due to build up of Zn content in soil, the application of Zn as $ZnSO_4$@ 20 Kg ha^{-1} in alternate year to wheat crop was discontinued since, 1987.

Table 2: Treatment details of the field experiment

Treatment	Detail
T_1	50% NPK
T_2	100% NPK
T_3	150% NPK
T_4	100% NPK +Hand weeding
T_5	100% NPK + Zn
T_6	100% NP
T_7	100% N
T_8	100% NPK + FYM
T_9	100% NPK – S
T_{10}	Control

Crop culture and Agronomic observations

The wheat crop (cv. GW-366) was grown with nutrient dose of 120:80:40 (N: P_2O_5: K_2O) in rabi season of 2017-18 and 2018-19. The field experiment was laid in a randomized block design (RBD) with ten treatments in four replications. The crop was sown in last week of November and first week of December in rabi season of 2017-18 and 2018-19, respectively. Similarly, the crop was harvested at physiological maturity in April. Field observations were recorded at various growth stages and periodic intervals. The plant height was recorded at different growth stages of wheat such as crown root initiation (CRI), tillering stage (TS), flowering stage (FS), milking stage (MS) and at dough stage (DS). Similarly, the number of tillers was recorded at 45 DAS, 60 DAS, 90 DAS, 120 DAS and Harvest. The grain yield, straw yield and total biomass were recorded at the harvest.

Soil sampling and analysis

The representative soil samples were collected from 0-15 cm from each plot with the help of soil auger at crop harvest in each year. The composite soil samples were prepared by quartering technique. The composite soil samples were air dried, crushed by wooden pestle and mortar then passed through 2 mm sieve and finally the processed samples were used for analysis of different properties. The soil pH and electrical conductivity (EC) was measured by glass electrode pH meter and EC meter in 1:2.5 soil: water suspension(Jackson, 1958). For determination of the soil organic carbon, a suitable quantity of the soil was digested with chromic acid and sulphuric acid. Excess of chromic acid left over unreduced by the organic matter of the soil was determined by a titration with Ferrous Ammonium Sulphate solution using diphenylamine indicator (Walkley & Black, 1934). Available nitrogen in soil sample was determined by using alkaline permanganate method (Subbiah & Asija, 1956) in which soil was mixed with excess of alkaline permanganate and distilled. Organic matter present in soils was oxidized by the nascent oxygen liberated by $KMnO_4$ in the presence of NaOH and thus ammonia was released. The released ammonia was absorbed in the boric acid (2%) containing mixed indicator and converted to ammonium borate. The formed ammonium borate was back titrated with standard sulphuric acid. The soil available phosphorus content was estimated by extracting the soil with 0.5 M $NaHCO_3$ (pH 8.5) and determination was done by ascorbic acid method on spectrophotometer (Olsen et al., 1954). The available potassium in soil was extracted by neutral 1N ammonium acetate and it was estimated using flame photometer (Knudsen et al., 1965). Soil available sulphur was extracted with 0.15% solution of $CaCl_2$ and determined by turbidimetric method (Chesnin & Yien, 1951).

Statistical analysis

The data obtained was compiled and analyzed for its significance (*p=0.05*) by statistical procedure appropriate for randomized block design as outlined by Gomez and Gomez (Gomez & Gomez 1984).

RESULTS AND DISCUSSION

Plant height and tillering

The pooled data with respect plant height of wheat recorded at key growth stages during 2017-18 and 2018-19 is presented in Table 3. The data revealed that, the plant height of wheat was significantly influenced under various nutrient management practices. The plant height of wheat crop followed similar trend during both the years of investigation. The change in plant with respect to unfertilized control (T10) was observed between 9-29% under various treatments (T1-T9) under study. The highest change was observed for treatment receiving combined application of 100% and FYM @ 5t/ha i.e. T8 followed by T3 and T5. The change was found statistically significant. The enhancement in plant height in response of combined application of organic and inorganic manure is might be due to the rapid conversion of synthesized carbohydrates into protein and consequent to increase in the number and size of growing cells, resulting ultimately in increased plant height of wheat. These results are supported by the findings of Sarwer et al. (2008) who reported that the use of organic manures in combination with mineral fertilizers maximized the plant growth.

Similarly, the data on active tillers (tillers with spike) under different treatments at harvest is presented in Fig 2. The various treatments under study (T1-T9) registered 8-77% higher number of tillers at harvest over unfertilized control (T10). The treatment receiving the combined application of 100% NPK and FYM @5t/ha showed highest number of tillers in wheat (Fig. 2). Tillering is closely related to the physical conditions of soil that were improved by addition of organic matter (Singh et al. 2011). The plant growth parameters are genetically as well as environmentally controlled and respond quickly to the nutrient management. The availability of soil nutrients required for crop growth and the ability of plant to remove the soil nutrients also influences the growth and different growth attributes (Ehdaie & Waines, 2001). The response of crop growth especially wheat (Aher, 2018), to various nutrient management in diverse soils has already been reported. The application of zinc with recommended dose of fertilizers also showed significantly higher plant height and tillering in wheat.

Table 3: Plant height of wheat under different treatments at various growth stages (Pooled data of 2 years)

Treatment	Plant height (cm)			
	CRI	TS	FS	MS
T1	23.4	34.2	47.0	73.3
T2	24.2	35.9	49.5	75.6
T3	25.2	38.4	51.2	82.0
T4	24.2	35.7	49.5	75.3
T5	24.4	36.6	50.9	76.7
T6	23.0	32.9	46.6	66.3
T7	21.6	31.9	40.7	63.8
T8	25.6	40.0	56.0	86.0
T9	23.8	35.1	48.9	73.8
T10	19.8	24.2	32.0	63.4
SEm(±)	0.59	1.25	1.01	0.51
CD($p=0.05$)	1.72	3.62	2.93	1.48

CRI-crown root initiation; TS-tillering stage; FS-flowering stage; MS-milking stage

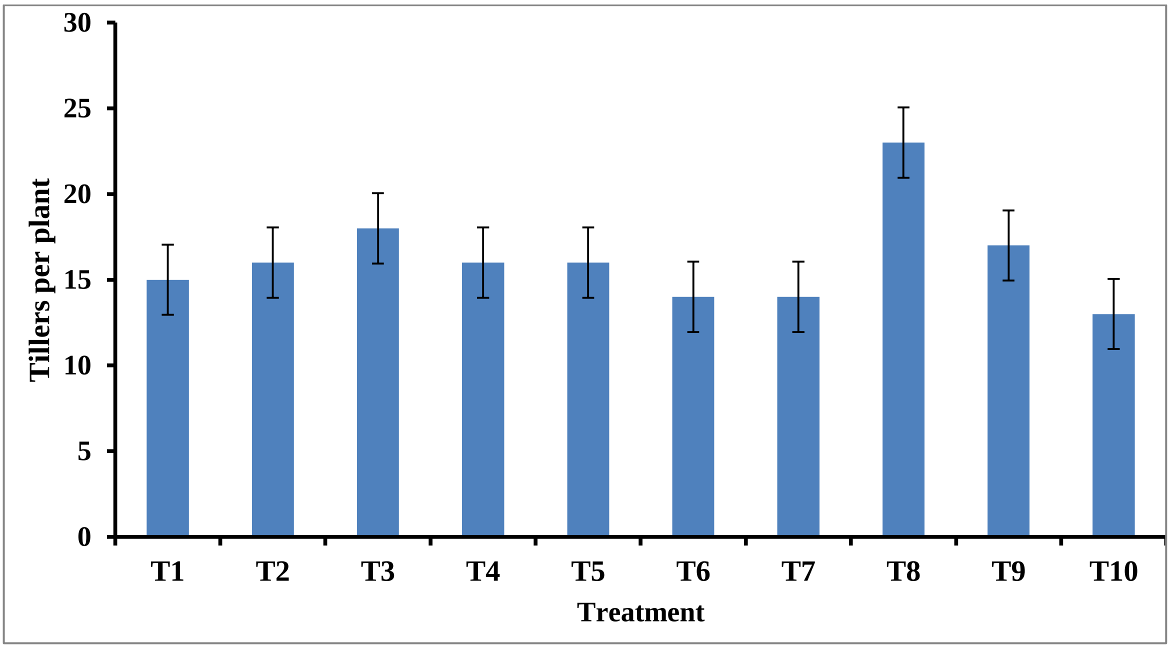

Fig. 2: Effective tillers in wheat at harvest under different treatments *(Pooled data of 2 years; Error bars indicate critical difference at 5% level of significance).*

Grain yield, straw yield and total biomass

The pooled grain yield, straw yield and total biomass of wheat recorded during 2017-18 and 2018-19 is presented in Fig. 3. The yield of wheat was found significantly influenced under various nutrient management practices. The grain yield, straw yield and total biomass of wheat crop followed similar trend during the period of investigation. The treatments under study recorded 26-338% higher grain yield with respect to unfertilized control (T10). The highest grain yield was observed under the treatment T8 receiving combined application of 100% NPK and FYM @5t/ha followed by T3 and T5 (Fig. 3). Organic manures and inorganic fertilizers with combinations, as increased the fertilizer use efficiency and improved the physical and chemical properties of soil hence making better utilization of nutrients might also be a reason towards increased yield. (Singh et al., 2009). Similar results were reported by Chuan et al. (2013). Similarly, 34-64% and 32-134% higher straw yield and total biomass of wheat respectively were observed under various treatments (T1-T9) over control. The straw yield and total biomass followed similar trend that was observed for grain yield. A significant decline in yield and biomass of wheat under the application of imbalanced fertilizers was observed (T7). The crop yield is proportional to the yield attributes of the crop and are ultimately governed and controlled by genetic and environmental factors. The crop growth and yield attributes responds positively to the nutrient management. The availability of soil nutrients required for crop growth and the ability of plant to remove the soil nutrients also influences the growth and different growth attributes (Ehdaie & Waines, 2001). Straw yield is a function of vegetative growth. The increase in growth and yield owing to the application of inorganic fertilizer may be attributed to the fact that this nutrient being important constituents of nucleotides, proteins, chlorophyll and enzymes, involves in various metabolic processes which have direct impact on vegetative and reproductive phase of plants. The data clearly indicated that under intensive cultivation addition of integrated application of fertilizer with FYM was found to be beneficial for maintain the fertility if the soil as well as subsequently improving the potential of soybean-wheat cropping system (Dubey & Dwivedi, 2015). These findings confirm those of (Sharma & Singh 2011); (Chuan et al., 2013).

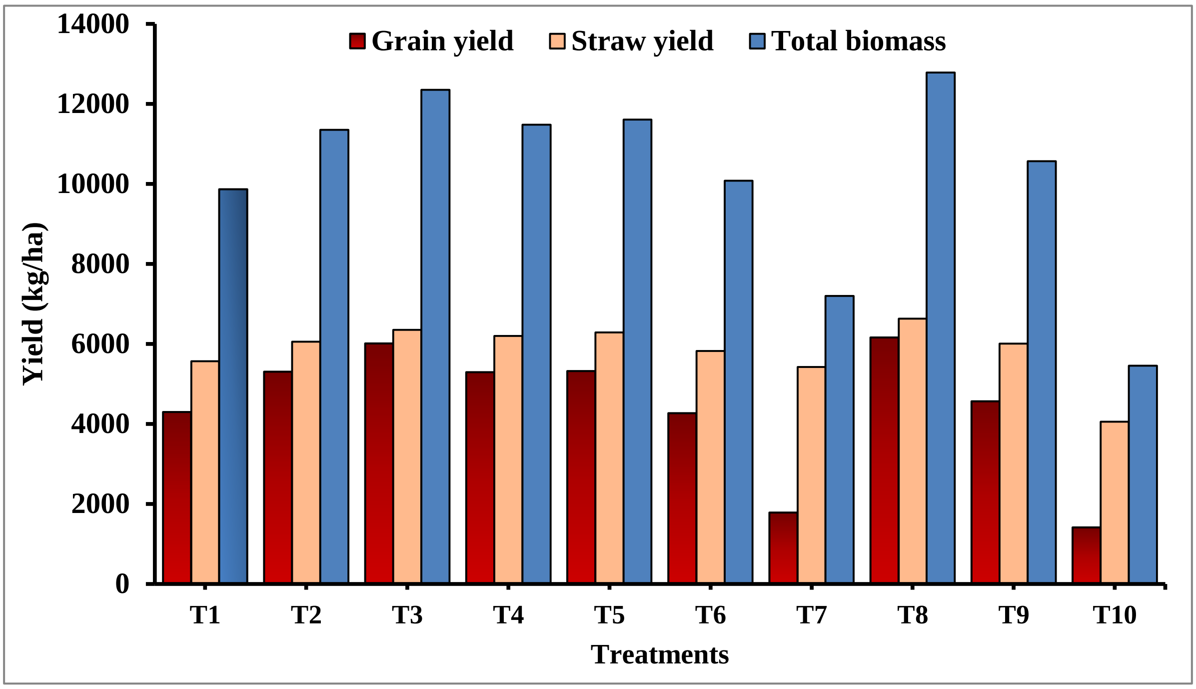

Fig. 3: Grain yield, straw yield and total biomass of wheat under different treatments *(Pooled data of 2 years).*

Soil properties

The pooled data pertaining to the soil properties at crop harvest during both years are presented in Table 4. The pH of the soil was observed neutral to slightly alkaline (7.47-7.66) among different treatments. Similarly, the electrical conductivity was observed between 0.16 and 0.19 dSm^{-1} across the treatments. No significant impact of long-term fertilizers application and/or its combination was observed on soil pH and EC. The pH and electrical conductivity of soil are the basic properties and remains unchanged for longer period of time under regular nutriment management practice (Aher et al., 2019; & Mandale et al., 2018a). Application of fertilizer could be responsible for residual acidity might unable created a significant alteration in the pH values of the experimental soil (Patel, 2014). There were no appreciable changes in EC of the soil was found with continuous addition of fertilizers and manure. Similarly finding was observed by Dwivedi et al. 2007, Kadam, 2016 and Chouhan et al. (2017).

The soil organic carbon measured at crop harvest found 0.52-0.86% with highest in treatment T8 (100% NPK+FYM). The external application of organic carbon in the form of FYM might have increased the SOC level in treatment T8. Similarly, the balanced application of chemical fertilizers also showed higher SOC which is attributed to the increase in yield under these treatments and leftover stubbles and crop residues in soil. Application of balance nutrient and organic manure increase in productivity and overall growth of crop which proportionally adds more amount of carbon through root biomass and this biomass is responsible for increase in soil carbon (Singh & Wanjari, 2012 & Nagwanshi et al., 2018).

The soil available N, P, K and S also found higher under the sole application of balanced fertilization and its combined application with FYM. The long term fertilizer application with or without organic manure influences the soil nutrient status (Khandagle et al., 2019). The soil test based long term fertilizer application also proved beneficial for maintaining the sustainability of soil health (Raghuveer et al., 2017; & Rajput et al., 2016). The improvement in soil properties under the application of balanced fertilizers and/or combined application of balanced fertilizers with manures are mainly attributed to improvement in soil organic carbon. The enhanced soil organic carbon stimulates the soil microbial population and enzyme activities (Aher et al., 2018) and soil aggregation process (Aher et al., 2019). The enhanced soil microbial population results in mineralization (Mishra et al., 2014) of the native soil organic carbon and increases the nutrient availability.

Table 4: Soil properties at crop harvest under different treatments (2017-18 and 2018-19)

Treatment	pH	EC	SOC	N	P	K	S
T1	7.53	0.16	0.54	221.2	21.8	259.3	22.5
T2	7.61	0.18	0.66	288.3	33.9	298.3	31.6
T3	7.66	0.19	0.76	341.4	36.9	327.4	35.8
T4	7.52	0.18	0.66	285.3	34.0	294.3	30.6
T5	7.6	0.18	0.74	287.3	33.9	288.3	30.4
T6	7.61	0.19	0.62	250.3	29.2	249.3	29.8
T7	7.51	0.17	0.54	214.2	9.7	243.3	11.3
T8	7.47	0.16	0.86	346.4	37.8	349.4	38.6
T9	7.53	0.18	0.61	267.3	30.9	278.3	10.9
T10	7.52	0.16	0.52	177.2	9.4	244.3	10.5
SEm(±)	0.04	0.01	0.26	5.23	1.24	4.70	0.44
CD(P=0.05)	NS	NS	0.74	15.2	3.59	13.6	1.27

EC in dSm^{-1}; SOC in %; N, P, K and S in $Kgha^{-1}$

CONCLUSION

In the present research, the use of organic manure with inorganic fertilizers influenced the crop growth, productivity and fertility status of soil. The application of (100% NPK) balance fertilizer with FYM 5@t ha^{-1} with had significantly positive effect on most of growth and yield of wheat. long term fertilizer application under continuous cropping under balanced application of nutrient improve the soil fertility and sustainability of crop.

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