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ORGANIC AMENDMENTS ENHANCE SOIL MICRONUTRIENT DYNAMICS AND TRANSFORMATIONS, BY IMPROVING THE RESIDUAL EFFECT ON WHEAT CROP

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Abstract

Optimal nutrient balance is crucial for boosting crop yield and biomass. Unnecessary use of mineral nutrients can lead to soil mining, deteriorating productivity, and soil health. Replenishing indigenous soil nutrients by adding organic amendments and inorganic fertilizer application may enhance soil health and crop productivity. This study investigates the effects of long-term integrated use of organic and inorganic fertilizers on soil nutrient status and crop growth and development. Field trails were conducted for two consecutive years (2018 and 2019) at the research farm of the University of Agriculture Peshawar-Pakistan. The experiments were conducted using two factorials randomizing complete block design with three replications. Treatments were used, Half (H) NPK, Full NPK, Legume Residues (LR) @ 10 tons ha^{-1}, Humic Acid (HA) @ 5 kg ha^{-1}, Biochar (BC) @ 10 tons ha^{-1}, LR + HNPK, HA + HNPK, BC + HNPK, HLR +HHA+ HNPK, HLR + HBC + HNPK, HBC + HHA + HNPK and one control for comparison to investigate its impact on maize growth and yield and its residual effect on soil health and subsequent wheat crop Experiential findings revealed that maximum soil micronutrients Zn (0.10 mg/kg), Mn (2.5 mg/kg), Fe (6.9 mg/kg) concentration in soil and Cu (0.009 %), Mn (0.023 %), Fe (0.041 %) concentration in plants were recorded in HBC + HHA + HNPK treatment. As compared to control, significant highest Zn (0.064 %) contents in grain were recorded in plots where only BC + HNPK was applied. The highest Cu (0.020 mg/kg) concentration in soil was recorded in BC, Ha, HA + HNPK, while high Cu (0.030 %), Mn (0.023 %), Fe (0.040 %) concentration in grain were recorded with HLR + HBC + HNPK, whereas Zn (0.030 %) concentration in plants were recorded with HLR + HBC + HNPK treatment. Overall, the soil fertility of micronutrients was better in the 2nd year as compared to the 1st year. Thus, the application of both inorganic and organic amendments together provides a sustainable and economical method of maintaining soil fertility. Conclusively the results of the study indicated that soil fertility and crop yield and biomass under Maize-wheat cropping system may be increased more effectively by applying organic amendments and inorganic fertilizers together than by applying either organic or inorganic fertilizers alone.

Key words: Residual effect, Organic amendments, Wheat, Nutrients and Soil fertility.

Introduction

Utilizing combined chemical and organic fertilizers in combination with integrated plant nutrient management can be an effective way for preventing nutrient depletion and enhance sustainable crop yield (Selim, 2020) (Hussain & Shah, 2023). The production of crops and soil quality can both be improved by using an integrated plant nutrition management system (Silva *et al*., 2022). While using organic fertilizer instead of nutrients from minerals, the yield of crops responded just as well or even better. With integrated plant nutrition management systems, maize yield may be greatly boosted (Elhaissoufi *et al*., 2022). To increase yield and soil productivity while maintaining sustainability, improving the use of mineral nutrients is essential. It is important to continuously develop, implement, and evaluate fresh integrated plant nutrient management systems based on important biological resources (crops and microorganisms). (Bargaz *et al*., 2018).

Among the organic amendment application, biochar is getting attention and is known a rich carbon source that is created by pyrolyzing a variety of raw materials in an enclosed environment without the presence of air. It has biogeochemical properties that are advantageous for the secure and long-term storage of carbon in the earth as well as the potential to improve soil quality (Das *et al*., 2021). Changes in the status of soil nutrients brought on by biochar particularly changes in P and K cycling, may additionally impact plant development (Dai *et al*., 2021). Additionally, biochar has the capacity to improve rhizosphere physical conditions and boost crop yield (Hussain *et al*., 2017). The utilization of biochar as a cutting-edge technique for carbon sequestration, improving soil quality, and boosting crop yields is receiving much too much attention these days (Xiang *et al*., 2022). In China, commercial manufacturing of biochar-based compound fertilizers (BCF) and amendments has begun since it has been demonstrated to increase crop yields and alter soil characteristics (pH, nutrients, organic matter, structure, etc.). While the changes in soil characteristics caused by the addition of biochar are broadly recognized, research on the interactions in the rhizosphere is still in its infancy, despite the advantages to yield that extend beyond the simple changes in soil properties (Chew *et al*., 2020).

Humic substances are crucial for soil health and agricultural sustainability. Humic acid enhances nutrient uptake in agriculture productivity, primarily found in natural products like lignite coal) (Ampong *et al*., 2022). Low-rank coal (LRC) has declined in energy generation due to renewable sources and gas. However, its potential as a soil amendment for maintaining soil quality and productivity is worth recognizing. LRC, a heterogeneous material with high HS concentration, can restore soil's physicochemical, biological, and ecological functionality (Akimbekov *et al*., 2021). Recent studies highlight the positive effects of humic substances on plant growth and mineral nutrition, particularly in seed germination, seedling growth, root initiation, root growth, shoot development, and uptake of some macro (K, Ca, P) and microelements (Fe, Zn, Mn, Cu) (Karimi *et al*., 2020). Organic fertilization is one of the most important factors influencing the amount of humus in the soil. Humic substances (HS) are naturally produced organic chemicals that may be obtained from a variety of sources, including compost, manure, peat, and coals such as lignite and leonhardite along with soil(Huculak-Mączka *et al*., 2018). Results obtain from the application of humic acid suggests that there is a great potential to increase crop yield and biological and physio-chemical properties of soil (Azeem *et al*., 2021).

Legumes residues address nutrients deficiencies, maintaining soil nutrient balance and yields, and have significant effects on crop growth and yields, according to studies (Rani *et al*., 2019). Legumes residues are increasingly used as alternative fossil fuels, as they contain essential plant nutrients and can be used as soil fertilizer. Ash, the oldest man-made mineral fertilizer, is also beneficial for soils(Chojnacka *et al*., 2020). Crop residues, byproducts of crop production, are valuable natural resources that can be managed to maximize input use efficiencies. Crop residue management is a key component of conservation agriculture. The shift from conventional to input-intensive practices often increases crop residue production, as growing more food for an increasing population increases residue generation (Sarkar *et al*., 2020). The study examines legume residue management, focusing on impacts, resource utilization, and strategies for improved farming systems, addressing environmental issues and addressing residue management in farming systems. Efficient crop residue management strategies maximize input use efficiency for food and environmental security, ensuring sustainable yield without compromising yield (Nenciu *et al*., 2022).

In this context current study was designed to investigate the use of organic and inorganic fertilizers in proper combination under maize-wheat cropping system to attained higher yield and plant biomass in succeeding crop (maize) as well as their residual effect on subsequent crop (wheat) and maintain higher soil fertility, than the sole application of either inorganic fertilizer or organic fertilizer.

Material and Methods

Study site: Two years of field experiments were conducted at Agriculture Research Farm, of The University of Agriculture Peshawar (Fig. 1).

The mean annual rainfall and average temperatures are shown in (Table 1). The soil of the study site sandy loam having sand 47.3%, silt 40%, clay 12.7%. Before and after the experiment, Soil samples from different parts of the experimental field were collected with a soil auger, homogenized, and stored in the lab for further analysis. Soil samples before and after treatment application were analyzed by standard procedures to determine soil nutrients concentration, soil bulk density, CEC, and many other physiochemical properties.

Table 1. Physical and chemical properties of experimental site.

Properties	Unit	Values
Textural class		Silt loam
Sand	%	47.3
Silt	%	40
Clay	%	12.7
Zn concentration in soil	mg kg^{-1}	0.03
Cu concentration in soil	mg kg^{-1}	0.004
Mn concentration in soil	mg kg^{-1}	0.8
Fe concentration in soil	mg kg^{-1}	2.5

Treatments and experimental design: The experiment was consist of two factors i.e., factor A was of maize variety Azam and hybrid CS 220 and factor B was fertilizer amendments (control, HNPK, full NPK, LR @ 10 ton ha^{-1}, BC @ 10 ton ha^{-1}, HA @ 5 kg ha^{-1}, LR + HNPK, BC + HNPK, HA + HNPK, HLR + HHA HNPK, HLR + HBC + HNPK, HBC + HHA + HNPK)which were applied before two weeks of sowing. The varieties were allotted to main plots and all the organic amendments were assigned to sub plots. The experiment was arranged in randomized complete block design (RCBD) with three replications, with a net plot size of 3.5 x 3 m^2. The experimental field was irrigated and ploughed before sowing maize, and a composite soil sample was taken for physical and chemical properties. Crops were harvested, and growth and yield parameters were recorded.

Soil sampling: Before and after experiment, soil samples were collected at random depths. The collected soil samples were brought to the laboratory, made dry and clean, and stored in plastic bags with proper labelling, bulked, air-dried, and processed through a 2mm sieved screen. Soil samples were prepared and analyzed for selected physicochemical properties according to reported standard protocols (Kamal *et al*., 2023).

Table 1. Displays the physio-chemical parameters of the experimental site before beginning field experiments.

Subsequent wheat crop: The subsequent wheat crop in year 1 (2018-19) was sown in the last week of November 2018 and harvested in first week of April 2019 while same procedure was followed in year 2 (2019-20) by following meticulous seed bed preparation. The process involved thorough land cultivation and soil conditioning to create an optimal environment for seed germination. No fertilizer was added during seed bed preparation for wheat to ensure the residual impact of organic and inorganic fertilizer combination for the robust germination, healthy crop establishment, and ultimately, a successful wheat cultivation cycle under maize-wheat cropping system.

Soil analysis: The soil samples prepared as described above well be analyzed for the following parameters.

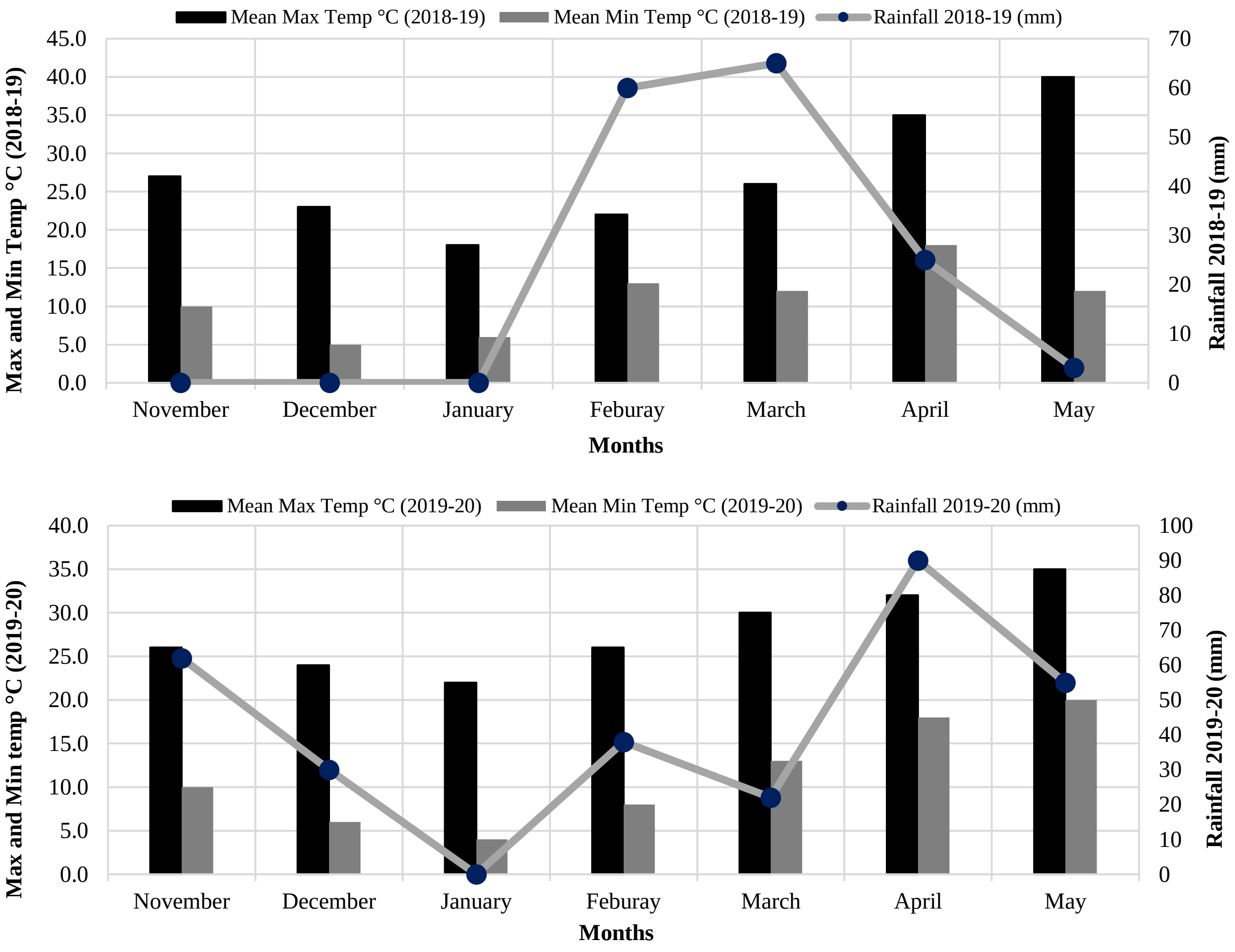

Fig. 1. Mean daily temperature and rainfall for 2018-19 and 2019-20 growing seasons from Pakistan Metrological Department Peshawar.

Extractable Zn, Cu, Fe, Mn (mg kg^{-1}): AB-DTPA extractable micro nutrients in soil sample were determined by procedure described by (Salam *et al*., 2022). In this procedure, 10g soil was taken with electric balance and added 20 mL AB-DTPA solution and shaking for 30 mints with horizontal shaker and then filtered. For determination, 1 mL aliquot, 4mL H_2O and 5 mL ascorbic acid mixed reagent was added and 25 mL volume was made. Then it was placed in a dark place for 30 mints to develop dark colour. Soil Zn, Cu, Fe, Mn was determined through atomic absorption spectrophotometer.

Plant Zn, Cu, Fe, Mn determination: The micro nutrients in plant was determined by the method of (Kumar *et al*., 2021). In a conical flask, 0.5 g of plant material was treated with 10 mL of HNO_3 and left overnight. Perchloric acid with 4 mL was then added and till the white fumes' appearance, digestion was done. The removal, cooling, and volume to 100 ML with distil water was done then. In a 25 ML was added with distilled water, volume up to 25 mL was made. For 15 mints in the dark, the sample was kept the development of colour. On atomic absorption spectrophotometer, standards of 0, 2, 6 and 8 ug and mL micronutrients were determined. Reading was obtained of Zn, Cu, Fe, Mn was determined through atomic absorption spectrophotometer.

Statistical Analysis

Statistical analysis of the data of field experiment was carried out using RCB design with split-split-plot arrangements following the principles described in (Parveen *et al*., 2020). Statistical package Statistix 8.1 was used for statistical analysis of the data of field experiment. LSD tests were used to determine statistical differences between treatments at 5% level of probability.

Results and Discussion

Zinc concentration in soil (mg/kg): The study examines the impact of fertilizer treatments and Previous varieties of maize on the Zn concentration in the soil of wheat crops show (Table 2). Data analysis using statistics showed that different fertilizer treatments resulting from different (organic and inorganic) additions still had some residual effects with various ratios and Previous varieties of maize significantly impacted the Zn concentration in the soil of wheat. The year was not determined to be a significant cause of variance. All interactions were determined to be nonsignificant. Wheat in the plot of previous maize Azam, a hybrid of maize so Wheat produced soil with higher Zn concentration (0.07 mg/kg), while wheat in the previous maize variety CS 220 produced soil with lower Zn concentration (0.06 mg/kg). The plots treated with HA + HNPK, HBC + HHA + HNPK, and BC 10 tons /ha produced the highest Zn concentration in soil for wheat (0.10 mg/kg), followed by BC 10 tons/ha, and lower Zn concentration in soil for the crop of wheat (0.03 mg/kg) was observed in treatment with HNPK and control. The study found that Zn concentration in wheat soil did not significantly differ between the experimental years.

Micronutrients like Zn are important nutrients for crop growth and production and play an important role in plant physiological process. Its bioavailability is strongly affected by soil pH and its availability is low at alkaline pH (Bindraban *et al*., 2020). Pakistani soil has alkaline pH and Zn availability is low. Therefore, organic amendments such as humic acid and legumes residues play an important role in bioavailability of Zn, and this may be due to its role in altering soil pH. These new varieties thus reduced the soil's supply of crucial micronutrients like Zn, which were already scarce (Saleem *et al*., 2023). Because of their varying mineralization, immobilization, and adsorption properties, organic additions require various management approaches and interaction with chemical fertilizers for the greatest advantages. Organic compounds also solubilize the metals by chelation and boost Zn availability to plants, (Rehman *et al*., 2018) in addition to releasing nutrients during decomposition.

Iron concentration in soil (mg/kg): The study examines the impact of various fertilizer treatments and maize varieties on soil Fe concentration presented in (Table 3). Analysis of the data revealed that varied fertilizer treatments (organic and inorganic) and previous maize varieties significantly impacted the Fe concentration in soil. Fe concentration in the soil of wheat crops was shown to be significantly affected by year as a cause of the variance. All potential interactions, with the exception of VS x FT and YS x FT, were found to be nonsignificant. In comparison to wheat in the previous different maize varieties, hybrid maize produced a lower Fe concentration in soil (4.6 (mg/kg) while maize Azam produced the highest Fe concentration in soil with a value of (4.7 mg kg-1) with no discernible difference between the two. The study found that wheat plots treated with HBC + HHA + HNPK had the highest Fe concentration in soil (6.9), followed by HBC + HHA + HNPK fertilizer, which was statistically equivalent. Control plots had lower Fe concentration (2.5) compared to those without fertilizers.

For the best results, organic inputs require different management strategies and interactions with chemical fertilizers due to their variable mineralization, immobilization, and adsorption capabilities. In addition to releasing nutrients during decomposition, organic compounds also solubilize the metals through chelation and increase Fe availability to plants (Dhaliwal *et al*., 2019). Nutrients that like Fe are crucial for crop development and production, and they also have a significant impact on physiological processes in plants (Ahmed *et al*., 2020). Its availability is limited at alkaline pH, and soil pH has a significant impact on its bioavailability. The soil in Pakistan has an alkaline pH and little Fe is available. Therefore, organic amendments like humic acid and residue from legumes play a significant role in the bioavailability of Fe, possibly as a result of their ability to change the pH of the soil. Thus, the availability of essential micronutrients like Fe, which were already scarce, was decreased by these new varieties (Moreno-Jiménez *et al*., 2019).

Manganese concentration in soil (mg/kg): The study examines the impact of various fertilizer treatments and maize varieties on soil Mn concentration showed (Table 4). Analysis of data using statistics revealed that the residual effects of diverse fertilizer treatments (organic and inorganic) combined with varied ratios and previous maize varieties significantly altered the Mn concentration in the soil. Mn concentration in wheat soil did not significantly differ between the experimental years. Also found to be nonsignificant was the combined impact of the treatments. For Mn concentration in soil, previous maize Azam and hybrid produced findings with a value of (1.5) that were comparable to other previous maize. The study found that LR with HNPK resulted in a higher Mn concentration in soil, followed by HBC + HHA + HNPK, while the lowest concentration was recorded with full NPK and control.

Peoples *et al*., (2017) observed the same findings, indicating that Mn concentration in soil increased as a result of the residual effects of legume residues. This rise may be attributable to improved soil structure and texture, which supply plants with all the necessary nutrients in an acceptable amount. The same investigation supported these findings as well (Meena *et al*., 2018).

Copper concentration in soil (mg/kg): The study examines the impact of various fertilizer treatments and maize varieties on soil Cu concentration presented in (Table 5). The results of the statistical analysis of the data demonstrated that the residual effect of various fertilizer treatments (organic and inorganic) and previous maize varieties greatly impacted the soil's Cu concentration. For the soil's Cu concentration, all possible effects of integration were found to be insignificant. The study also found that the Cu concentration in wheat soil did not significantly differ between the experimental years. Wheat from previous maize varieties Azam showed higher soil Cu concentration (0.014), while hybrid CS 220 had less Cu concentration (0.010). Plots were treated with BC @10 tons/ha and HA @5 kg/ha (0.020 mg/kg) to determine the residual impacts of various fertilizer treatments. The control plots, where no fertilizers were used, reported the lowest amount of copper in the soil (0.004 mg/kg) of maize.

The higher the Cu concentration in the soil, the more likely it is that the soil is providing adequate nutrients to the crops, resulting in better growth and development. The results are also available online (Moharana *et al*., 2017); (Joseph *et al*., 2021). Micronutrients, while only necessary in trace amounts, significantly increase nutrient availability and positively impact physiological cell processes, resulting in increased yield. The highest Cu levels in soil were found with Cu + humic acid, underscoring the importance of micronutrients in addressing economic and environmental concerns (Ramdan *et al*., 2023).

Table 2. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Zn concentration in soil (mg/kg) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.03	0.03	0.03g
HNPK (75:50:30)	0.03	0.03	0.03g
NPK (150: 100: 60)	0.06	0.05	0.05def
LR (10 ton/ha)	0.06	0.06	0.06cde
HA (5kg/ha)	0.04	0.04	0.04fg
BC (10ton/ha)	0.09	0.10	0.09ab
LR + HNPK	0.07	0.08	0.08bcd
HA + HNPK	0.10	0.11	0.10a
BC + HNPK	0.05	0.05	0.05efg
HLR + HHA + HNPK	0.07	0.07	0.07bcde
HLR + HBC + HNPK	0.07	0.09	0.08abc
HBC + HHA + HNPK	0.10	0.11	0.10a
LSD for FT	0.03	0.03	0.02
Wheat in the plot PMV			
Wheat in the plot of Azam	0.08	0.07	0.07a
Wheat in the plot Hybrid	0.05	0.06	0.06b
LSD for PMV	**ns**	**ns**	0.01
Years (YS)			
Y1: 2018-19			0.07a
Y2: 2019-20			0.07a
Significance level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**ns**
FT x PMV	**ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%.
*Previous maize varieties (PMV)

Table 3. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Fe concentration in soil (mg/kg) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	2.2	2.7	2.5f
HNPK (75:50:30)	3.5	3.4	3.5ef
NPK (150: 100: 60)	4.5	5.0	4.7cd
LR (10 ton/ha)	5.1	5.4	5.3bc
HA (5kg/ha)	4.1	4.4	4.3cde
BC (10ton/ha)	3.6	4.1	3.9de
LR + HNPK	4.5	4.9	4.7cd
HA + HNPK	3.8	4.6	4.2cde
BC + HNPK	3.4	4.6	4.0de
HLR + HHA + HNPK	6.4	5.7	6.1ab
HLR + HBC + HNPK	5.5	7.3	6.4ab
HBC + HHA + HNPK	6.6	7.2	6.9a
LSD for FT	1.9	1.6	1.2
Wheat in the plot PMV			
Wheat in the plot of Azam	4.6	4.9	4.7a
Wheat in the plot Hybrid	4.3	5.0	4.6a
LSD for PMV	**ns**	**ns**	**ns**
Years (YS)			
Y1: 2018-19			4.4b
Y2: 2019-20			4.9a
Significance level (SL)			NS
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**
FT x PMV	**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%.
*Previous maize varieties (PMV)

Table 4. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Mn concentration in soil (mg/kg) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.8	0.8	0.8e
HNPK (75:50:30)	0.8	0.8	0.8e
NPK (150: 100: 60)	0.7	0.7	0.7e
LR (10 ton/ha)	1.1	1.0	1.0d
HA (5kg/ha)	1.3	1.3	1.3bcd
BC (10ton/ha)	1.2	1.3	1.2cd
LR + HNPK	2.6	2.7	2.6a
HA + HNPK	1.6	2.2	1.9abc
BC + HNPK	1.8	2.3	2.0ab
HLR + HHA + NPK	1.0	0.8	0.9d
HLR + HBC + HNPK	1.1	1.4	1.2cd
HBC + HHA + NPK	3.2	1.8	2.5a
LSD for FT	1.2	0.9	0.8
Wheat in the plot PMV			
Wheat in the plot of Azam	1.6	1.3	1.5a
Wheat in the plot Hybrid	1.2	1.5	1.3b
LSD for PMV	**ns**	**Ns**	**ns**
Years (YS)			
Y1: 2018-19			1.4a
Y2: 2019-20			1.4a
Significance level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**ns**
FT x PMV	**ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%.
*Previous maize varieties (PMV)

Table 5. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Cu concentration in soil (mg/kg) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.004	0.004	0.004e
HNPK (75:50:30)	0.006	0.006	0.006de
NPK (150: 100: 60)	0.009	0.009	0.009cde
LR (10 ton/ha)	0.008	0.011	0.010cd
HA (5kg/ha)	0.015	0.021	0.018a
BC (10ton/ha)	0.021	0.020	0.020a
LR + HNPK	0.011	0.009	0.010cd
HA + HNPK	0.020	0.021	0.020a
BC + HNPK	0.007	0.005	0.006de
HLR + HHA + HNPK	0.014	0.008	0.011cd
HLR + HBC + HNPK	0.010	0.013	0.011bc
HBC + HHA + HNPK	0.017	0.017	0.017ab
LSD for FT	0.009	0.006	0.005
Wheat in the plot PMV			
Wheat in the plot of zam	0.014	0.013	0.014a
Wheat in the plot Hybrid	0.010	0.011	0.010b
LSD for PMV	0.003	**ns**	0.002
Years (YS)			
Y1: 2018-19			0.012a
Y2: 2019-20			0.012a
Significance level (SL)			**Ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**Ns**
FT x PMV	**ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%.
*Previous maize varieties (PMV)

Zinc concentration in grains (%): The study examines the impact of various fertilizer treatments and maize varieties on grain Fe concentration presented in (Table 6). A statistical investigation of the data revealed that varied fertilizer treatments (organic and inorganic) amendments combined with various ratios and previous maize varieties significantly impacted the Zn concentration of grains of wheat. The year wasn't found to be a significant cause of variability. All potential interactions were similarly determined to be insignificant. For Zn concentration in grains of wheat, residual effects of various maize varieties led to similar outcomes (0.040% and 0.034%) for maize Azam and hybrid CS220, respectively. Different fertilizer treatments of Zn in grain show that the plots treated with BC + HNPK at a rate of 10 tons/ha produced the highest zinc concentration in wheat grains (0.064%), followed by HBC + HHC+ HNPK treatments, while the lowest zinc concentration was recorded (0.012%) in control. The results showed no significant differences in zinc concentration between experimental years.

Under various organic treatments, the concentration of Zn, Cu, Fe, and Mn in grain increased to levels of 46.1%, 93.8% mg kg1, 53.7%, and 47.9%, respectively (Dhaliwal *et al*., 2023). Furthermore, similar variations were seen in stover's Zn, Cu, Fe, and Mn concentrations, which reached values of 38.9%, 133.3%, 63.4%, and 79.8%, respectively. Additionally, treatment T11 with farmyard manure + 75% RDN had the highest concentrations of Zn, Cu, Fe, and Mn in comparison to the other treatments (Thakur *et al*., 2023). Another study was found that the residual effects of various organic matter on the Zn concentration in grains have been enhanced, (Dhaliwal *et al*. 2019).The research reveals that because the soil has the right nutrients to support better growth and development, the combination of legume residues and NPK can increase the zinc concentration in wheat grains. The results may be found online as well (A. Kumar *et al*., 2021), According to the study, adding leftover legume residues considerably increased the zinc concentration of wheat grains.

Copper concentration in grains (%): The study examines the impact of various fertilizer treatments and maize varieties on Cu in grain concentration showed (Table 7). Data analysis using statistics showed that the lingering impacts of diverse used in combination with both inorganic and organic sources of previous maize varieties greatly impacted the Cu concentration in wheat grains. With the exception of YS x FT and PMV x FT, the interaction between YS x PMV x FT and YS x PMV was shown to be insignificant for the Cu concentration in wheat grains. Years were not shown to be a significant cause of variance for the copper concentration of wheat grains. In comparison to wheat in the plot of Azam, which produced greater (0.011%) Cu concentration in grains of wheat, the maize hybrid varieties produced less copper in grains of wheat, while statistically, they were statistically equivalent. The study found that plots treated with HLR + HBC+ HNPK significantly increased copper concentration in wheat grains (0.030%), while the minimum copper concentration in maize grains (0.003%) was achieved with humic acid applied at half in combination with NPK fertilizer.

The higher uptake of micronutrients with the application of organic manures and inorganic fertilizers may be due to the soil's increased bioavailability of micronutrients, which increased their absorption in wheat in comparison to control. (Saha *et al*., 2019). Through a number of mechanisms, nutrients are released during the breakdown of organic matter, increasing their soil availability (Kamal, 2023). Additionally, compared to solely using inorganic fertilizers, Due to the release of different acids, the addition of organic manures produces a decrease in soil pH, which Favors the increased bioavailability of micronutrients. Similar findings were made by (Dhaliwal *et al*., 2023), who found that when inorganic and organic fertilizers were used together to treat plots, micronutrient absorption was greater than when inorganic fertilizers were used alone or as a control.

Manganese concentration in grains (%): The study examines the impact of various fertilizer treatments and maize varieties on Mn in grain concentration presented in (Table 8). A statistical investigation of the data revealed that residual effects of various fertilizer treatments (organic and inorganic) and different combinations of varied ratios and previous maize varieties significantly impacted the Mn concentration in wheat grains. The year was not determined to be a significant cause of variance. Except for PMV x FT and YS x FT, the combined impact of treatments was likewise determined to be non-significant. Wheat in the plot produced comparable findings for Mn concentration in wheat grains with a value of (0.015%) for both previous hybrid maize and maize Azam. The study found that plots treated with HLR + HBC + HNPK had a higher Mn concentration in wheat grains (0.023%), followed by BC + HNPK, which were statistically similar, while the lowest Mn concentration (0.009%) was recorded in the control. Chen *et al*., (2022) and Liang *et al*., (2022) revealed the same findings from their investigation, which showed that the use of many different organic fertilizers in combination increased the Mn concentration in wheat grains. The identical results were also suggested by (Chagas *et al*., 2021). Biochar application did not significantly affect the micronutrient content in leafy greens, but it generally increased the total uptake of micronutrients into leaves in acidic soil, while decreasing it in neutral (Kumasi) soil, according to soil (Rodríguez-Vila *et al*., 2022).

Iron concentration in grains (%): The study examines the impact of various fertilizer treatments and maize varieties on Fe in grain concentration presented in (Table 9). Data analysis revealed that residual effects of various fertilizer treatments (organic and inorganic) amendments along with various ratios and previous maize varieties significantly impacted the Fe concentration in grains of wheat crops. Years is no significant variation in Fe concentration in wheat grains. All potential interactions were found to be nonsignificant, Except for PMV x FT and YS x FT. Wheat in the previous maize varieties that maize hybrid had less iron concentration in wheat grains (0.026%), while synthetic maize Azam produced higher iron concentration (0.028%) in wheat grains, which were statistically equivalent. The study found that plots treated with HLR + HHA + HNPK had the highest Fe concentration in wheat grains (0.40%), followed by plots treated with full BC + HNPK, which were statistically equivalent. The lowest Fe concentration was recorded with the incorporation of control.

Table 6. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Zn concentration in grain (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	**Y2: 2019-20**	**Average**
Control (C)	0.010	0.014	0.012d
HNPK (75:50:30)	0.014	0.017	0.015d
NPK (150: 100: 60)	0.025	0.035	0.030cd
LR (10 ton/ha)	0.042	0.052	0.047abc
HA (5kg/ha)	0.038	0.047	0.042abc
BC (10ton/ha)	0.028	0.025	0.026cd
LR + HNPK	0.030	0.025	0.027cd
HA + HNPK	0.042	0.058	0.050abc
BC + HNPK	0.061	0.066	0.064a
HLR + HHA + HNPK	0.044	0.038	0.041abc
HLR + HBC + HNPK	0.034	0.033	0.034bcd
HBC + HHA + HNPK	0.055	0.059	0.057ab
LSD for FT	0.023	0.016	0.014
Wheat in the plot PMV			
Wheat in the plot of Azam	0.033	0.046	0.040a
Wheat in the plot Hybrid	0.037	0.032	0.034a
LSD for PMV	**Ns**	0.021	**ns**
Years (YS)			
Y1: 2018-19			0.035a
Y2: 2019-20			0.039a
Significance level (SL)			NS
Interactions (IR)	SL	IR	SL
PMV x YS	**Ns**	YS x FT	**ns**
FT x PMV	**Ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 7. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Cu concentration in grain (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	**Y2: 2019-20**	**Average**
Control (C)	0.003	0.004	0.003f
HNPK (75:50:30)	0.004	0.006	0.005ef
NPK (150: 100: 60)	0.005	0.007	0.006ef
LR (10 ton/ha)	0.010	0.014	0.012cd
HA (5kg/ha)	0.007	0.012	0.010de
BC (10ton/ha)	0.008	0.009	0.009de
LR + HNPK	0.017	0.021	0.019b
HA + HNPK	0.006	0.005	0.006ef
BC + HNPK	0.005	0.008	0.007e
HLR + HHA + HNPK	0.014	0.017	0.016bc
HLR + HBC + HNPK	0.027	0.034	0.030a
HBC + HHA + HNPK	0.021	0.016	0.019b
LSD for FT	0.008	0.006	0.005
Wheat in the plot PMV			
Wheat in the plot of Azam	0.011	0.013	0.012a
Wheat in the plot Hybrid	0.010	0.013	0.011a
LSD for PMV	**ns**	**ns**	**ns**
Years (YS)			
Y1: 2018-19			0.011a
Y2: 2019-20			0.013a
Significance level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**
FT x PMV	**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 8. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Mn concentration in grain (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	**Y2: 2019-20**	**Average**
Control (C)	0.010	0.008	0.009ef
HNPK (75:50:30)	0.010	0.011	0.010ef
NPK (150: 100: 60)	0.011	0.013	0.012de
LR (10 ton/ha)	0.012	0.013	0.013de
HA (5kg/ha)	0.019	0.018	0.019b
BC (10ton/ha)	0.017	0.017	0.017bc
LR + HNPK	0.013	0.015	0.014cde
HA + HNPK	0.014	0.014	0.014cde
BC + HNPK	0.021	0.018	0.019ab
HLR + HHA + HNPK	0.016	0.017	0.016bc
HLR + HBC + HNPK	0.023	0.022	0.023a
HBC + HHA + HNPK	0.015	0.016	0.016bc
LSD for FT	0.004	0.007	0.004
Wheat in the plot PMV			
Wheat in the plot of Azam	0.017	0.014	0.015a
Wheat in the plot Hybrid	0.014	0.017	0.015a
LSD for PMV	**ns**	**ns**	**ns**
Years (YS)			
Y1: 2018-19			0.015a
Y2: 2019-20			0.015a
Significance level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**
FT x PMV	**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 9. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Fe concentration in grain (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	**Y2: 2019-20**	**Average**
Control (C)	0.020	0.018	0.019e
HNPK (75:50:30)	0.021	0.021	0.021de
NPK (150: 100: 60)	0.020	0.025	0.023cde
LR (10 ton/ha)	0.023	0.028	0.025bcde
HA (5kg/ha)	0.028	0.029	0.028bcd
BC (10ton/ha)	0.025	0.026	0.025bcde
LR + HNPK	0.031	0.031	0.031bc
HA + HNPK	0.020	0.026	0.023cde
BC + HNPK	0.030	0.036	0.033ab
HLR + HHA + HNPK	0.044	0.036	0.040a
HLR + HBC + HNPK	0.028	0.032	0.030bc
HBC + HHA + HNPK	0.030	0.027	0.028bcd
LSD for FT	**ns**	0.009	0.009
Wheat in the plot PMV			
Wheat in the plot of Azam	0.028	0.028	0.028a
Wheat in the plot Hybrid	0.025	0.027	0.026a
LSD for PMV	**ns**	**ns**	**ns**
Years (YS)			
Y1: 2018-19			0.027a
Y2: 2019-20			0.028a
Significance level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**
FT x PMV	**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at ($p \leq 0.05$) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 10. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Cu concentration in Stover (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.005	0.004	0.005b
HNPK (75:50:30)	0.006	0.005	0.006ab
NPK (150: 100: 60)	0.005	0.007	0.006ab
LR (10 ton/ha)	0.008	0.008	0.008a
HA (5kg/ha)	0.007	0.007	0.007ab
BC (10ton/ha)	0.007	0.011	0.009a
LR + HNPK	0.007	0.010	0.009a
HA + HNPK	0.008	0.010	0.009a
BC + HNPK	0.005	0.007	0.006ab
HLR + HHA + HNPK	0.007	0.009	0.008ab
HLR + HBC + HNPK	0.006	0.010	0.008ab
HBC + HHA + HNPK	0.009	0.010	0.009a
LSD for FT	**ns**	0.002	0.002
Wheat in the plot PMV			
Wheat in the plot of Azam	0.007	0.008	0.008 a
Wheat in the plot Hybrid	0.007	0.008	0.007 a
LSD for PMV	**ns**	**Ns**	**ns**
Years (YS)			
Y1: 2018-19			0.007 a
Y2: 2019-20			0.008 a
Significance level (SL)			**Ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**ns**
FT x PMV	**ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at (p≤0.05) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 11. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Zn concentration in Stover (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.010	0.008	0.009c
HNPK (75:50:30)	0.009	0.010	0.009c
NPK (150: 100: 60)	0.012	0.012	0.012bc
LR (10 ton/ha)	0.015	0.017	0.016abc
HA (5kg/ha)	0.014	0.019	0.017abc
BC (10ton/ha)	0.015	0.016	0.016abc
LR + HNPK	0.029	0.020	0.024abc
HA + HNPK	0.017	0.026	0.021abc
BC + HNPK	0.017	0.022	0.020abc
HLR + HHA + HNPK	0.020	0.032	0.026ab
HLR + HBC + HNPK	0.028	0.031	0.030a
HBC + HHA + HNPK	0.017	0.030	0.024abc
LSD for FT	NS	0.012	0.009
Wheat in the plot PMV			
Wheat in the plot of Azam	0.022	0.018	0.020a
Wheat in the plot Hybrid	0.012	0.022	0.017a
LSD for PMV	0.002	**ns**	**Ns**
Years (YS)			
Y1: 2018-19			0.017a
Y2: 2019-20			0.020a
Significance level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**Ns**
FT x PMV	**ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at (p≤0.05) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 12. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Mn concentration in Stover (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.005	0.008	0.007c
HNPK (75:50:30)	0.010	0.007	0.009bc
NPK (150: 100: 60)	0.009	0.013	0.011bc
LR (10 ton/ha)	0.015	0.021	0.018ab
HA (5kg/ha)	0.015	0.016	0.016abc
BC (10ton/ha)	0.013	0.020	0.017abc
LR + HNPK	0.012	0.018	0.015abc
HA + HNPK	0.012	0.020	0.016abc
BC + HNPK	0.012	0.018	0.015abc
HLR + HHA + HNPK	0.018	0.018	0.018ab
HLR + HBC + HNPK	0.013	0.021	0.017ab
HBC + HHA + HNPK	0.016	0.030	0.023a
LSD for FT	**ns**	0.009	0.006
Wheat in the plot PMV			
Wheat in the plot of Azam	0.012	0.020	0.016a
Wheat in the plot Hybrid	0.012	0.015	0.014a
LSD for PMV	**ns**	0.017	**ns**
Years (YS)			
Y1: 2018-19			0.012b
Y2: 2019-20			0.018a
Significance level (SL)			*
Interactions (IR)	SL	IR	SL
PMV x YS	**Ns**	YS x FT	**ns**
FT x PMV	**Ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at (p≤0.05) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Table 13. The residual influence of previous crop fertilizer treatments (organic and inorganic) impacts on the Fe concentration in Stover (%) of Wheat crops.

Fertilizer treatments (FT)	Years (Ys)		
	Y1: 2018-19	Y2: 2019-20	Average
Control (C)	0.022	0.015	0.018b
HNPK (75:50:30)	0.018	0.023	0.021b
NPK (150: 100: 60)	0.018	0.023	0.021b
LR (10 ton/ha)	0.019	0.031	0.025ab
HA (5kg/ha)	0.022	0.028	0.025ab
BC (10ton/ha)	0.028	0.025	0.026ab
LR + HNPK	0.026	0.030	0.028ab
HA + HNPK	0.022	0.029	0.025ab
BC + HNPK	0.024	0.026	0.025ab
HLR + HHA + HNPK	0.037	0.044	0.041a
HLR + HBC + HNPK	0.033	0.048	0.041a
HBC + HHA + HNPK	0.036	0.044	0.040a
LSD for FT	0.013	0.014	0.010
Wheat in the plot PMV			
Wheat in the plot of Azam	0.030	0.032	0.031a
Wheat in the plot Hybrid	0.020	0.029	0.025a
LSD for PMV	**ns**	**ns**	**ns**
Years (YS)			
Y1: 2018-19			0.025a
Y2: 2019-20			0.030a
Significance Level (SL)			**ns**
Interactions (IR)	SL	IR	SL
PMV x YS	**ns**	YS x FT	**ns**
FT x PMV	**ns**	YS x PMV x FT	**Ns**

This means using various alphabets within the same category are significantly different at (p≤0.05) "**ns**" = Non-significant, while "*", "**" and "***" indicate significance at levels of probability of 5, 1, and 0.1%. *Previous maize varieties (PMV)

Rashid *et al*., (2022)found that using LR combined with BC and NPK raised the Fe concentration in wheat grains; this may have happened as a consequence of providing the appropriate nutrients, this resulted in a higher Fe concentration in the grains Scientists also discovered that using organic biochar along with humic acid increased the amount of Fe in the grains. and legume residues significantly increased the Fe concentration in wheat grains (Chen *et al*., 2022) and (Irfan *et al*., 2021).

Copper concentration in stover (%): Data regarding copper concentration in stover of wheat is shown in (Table 10) statistical analysis of the data showed that copper concentration in stover was significantly affected by residual effect of different fertilizer applications applied in combination from organic and inorganic sources of maize varieties. The interaction between YS x FT, MOV x FT, YS x MOV x FT was found non-significant for copper concentration in the stover of wheat. Years as a source of variation was found non-significant for copper concentration in stover of wheat Varieties of maize OPV Azam resulted in higher cupper concentration in stover (0.008) in comparison with hybrid CS-220 that produced less (0.007) Cu concentration in stover of wheat which had resulted statistically similar. In terms of residual effect of different fertilizer application, plots treated with HBC + HHA+ HNPK significantly produced higher copper concentration in grains of wheat (0.009) followed by HA applied with HNPK with value (0.009) which was statistically in line with each other. The minimum copper in stover of wheat stover (0.005) of maize was recorded by control plots where no fertilizers were applied. Ali *et al*. (2018) that K concentration in stover enhanced by residuals effect of different organic matters Taherymoosavi *et al*., (2018) also stated that combined use of biochar with NPK increased the Cu concentration in stover of wheat the reason may be due to appropriate nutrients supplied by the soil to the crops that leads to better growth and developments. The results are also online with Li *et al*., (2017); Munir *et al*., (2021).

Zinc concentration in stover (%): Zinc concentration in stover of wheat as influenced by residual effects of fertilizer application and maize varieties is shown in (Table 11). Statistical analysis of the data showed that zinc concentration in stover of wheat was noticeably affected by residuals effect of different fertilizer application applied from different organic and in organic amendments in combination with different ratios and maize varieties. Year as a source of variation were found non-significant. All the possible interactions were also found non-significant for zinc concentration in stover of wheat. Among different maize varieties, maize OPV Azam and hybrid CS 220 resulted same values that did not differ from each other for zinc concentration in stover of wheat with value (0.020 and 0.017), respectively. Among residual effect of different fertilizer applications, plots treated with HLR + HBC + HNPK followed by HLR, HHA, HNPK fertilizers produced maximum zinc concentration in stover of wheat (0.030 and 0.026), which was statistically similar with each other. The lowest zinc concentration in stover of wheat was recorded by control plots where no fertilizers were applied. For both experimental years similar values were observed that did not differ significantly for zinc concentration in grains of wheat. Sial *et al*., (2020); Dimpkpa *et al*., (2020) also stated that combined use of legumes residues with NPK increased the Zn concentration in stover of wheat the reason may be due to appropriate nutrients supplied by the soil to the crops that leads to better growth and developments. The results are also online with Imran *et al*., (2021) who reported from their study that Zn concentration in stover of wheat considerably enhanced by residual application of legumes residues.

Mn concentration in stover: Data presented (Table 12) showed the Mn concentration in stover of wheat crop. Analysis of the data showed significant results for nitrogen concentration in the stover of wheat in terms of residual effect of different fertilizer sources in ratios i.e. organic and in organic sources. Maize varieties did not significantly affect the Mn concentration in stover of wheat. Year as a source of variation was also found non-significant. All the possible interactions were found non-significant except VS x FT and YS x FT. Regarding residual effect of different fertilizers, plots treated with HBC + HHA + HNPK produced high Mn concentration in stover of wheat (0.023) followed by LR applied @ 10 tons/ha which was statistically at par with each other, respectively. Minimum Mn concentration in the store of wheat produced by control plots where no fertilizer was applied. Among varieties of maize, OPV Azam (0.016) vs Hybrids cs 220 (0.014) showed similar results that did not differ from each other. For both experimental years similar values were observed that did not differ significantly for Mn concentration in grains of wheat. Ma *et al*., (2019) and reported similar reports from their study that Mn concentration in stover of wheat crop could be increased by residual effect of biochar combined with other organic amendments and chemical fertilizer of NPK. The same study was also in accordance with Kimani *et al*., (2020) who stated that Mn concentration in wheat of stover significantly enhanced by application of different organic fertilizers, this may be due to more availability of nutrient s to the plants at an adequate amount.

Iron concentration in stover: Data pertaining iron concentration in stover of wheat as affected by residual effect of fertilizer application and maize varieties is shown in (Table 13). Statistical analysis of the data showed that iron concentration in stover was substantially influenced by residual effect of various fertilizer application, applied from different organic and in organic amendments in combination with different ratios and maize varieties. Year as a source of variation were found non-significant for iron concentration in stover. All the possible interactions were found non-significant except for iron concentration in stover of wheat. Regarding different maize varieties, maize Azam (0.031 %) and hybrid CS-220 (0.025 %) resulted in similar iron concentration in stover and did not show any residual effect on quality iron of wheat in stover. Among residual effect of different fertilizer applications, plots treated with HLR + HHA + HNPK, and HLR + HBC + HNPK produced maximum iron concentration in stover (0.041), followed by control plots HBC + HHA + HNPK, resulted in produced 0.040 iron concentration in stover of wheat crop which was statistically in line with each other. The lowest iron concentration in stover (0.119) was recorded in control. Similar values and no significant difference were observed among themselves. Liu *et al*., (2020) (Ali *et al*., 2019) and Medina *et al*., (2020) reported similar reports from their study that iron concentration in stover of wheat crop could be increased by residual effect of chemical fertilizer of NPK. The same study was also in accordance with Qaswar *et al*., (2020) who stated that iron concentration in wheat of stover significantly enhanced by chemical fertilization of NPK, this may be due to more availability of nutrient s to the plants at an adequate amount.

Conclusion

The use of organic fertilizers is an essential strategy for improving crop development while reducing the negative environmental effects of synthetic fertilizers. Organic amendments and synthetic fertilizers significantly increased Zn, Fe, Mn, and Cu levels, while higher amounts of organic amendments led to increased crop yields and nutrients. Surprisingly, all the organic additions increased the soil fertility and quality of growth. However, when compared with other amendment combinations across both years, the combined application of the biochar + humic acid + legumes residues + half of NPK treatment remained the top performer.

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