**Assessment of Post-Harvest Soil Nutrient Status as Influenced by Sulphate Salts of Zinc, Iron and Copper in Wheat (*Triticum aestivum* L.)**

**ABSTRACT**

A field experiment was conducted at SIF, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur for two consecutive *rabi* cropping seasons, 2022-23 and 2023-24 to study the influence of sulphate-based micronutrient fertilizers on nutrient status and post-harvest soil chemical properties. Results revealed that soil application of Zn + Fe+ Cu through ZnSO4.7H2O @ 20 Kgha-1, FeSO4.7H2O @ 12 Kgha-1, CuSO4.5H2O @ 2.0 Kgha-1 (T8) significantly enhanced soil nutrient availability, recording the highest values for available N (172.67 kg ha⁻¹), P (17.51 kg ha⁻¹), K (307.79 kg ha⁻¹), S (21.12 mg kg⁻¹), Zn (2.15 mg kg⁻¹), Fe (8.49 mg kg⁻¹), and Cu (1.81 mg kg⁻¹). Soil pH showed slight acidification under T8 (7.02), while electrical conductivity (EC) increased moderately (0.55 dSm⁻¹). Organic carbon remained relatively stable, with minor improvements under T7 (foliar spray of Zn + Fe as 1.0% ZnSO4.7H2O and 1.5% FeSO4.7H2O at Tillering and Booting Stages) and T9 (foliar application of Zn + Fe + Cu as 1.0% ZnSO4.7H2O, 1.5% FeSO4.7H2O and 0.1% CuSO4.5H2O at Tillering and Booting Stages). Varietal influence was minimal, whereas nutrient management treatments had a significant impact on most parameters. The results underscore the importance of balanced micronutrient application for improving soil fertility and sustaining nutrient availability in wheat-based cropping systems.

**Keywords:** cropping, fertilizers, acidification and sustaining.

**Introduction**

Micronutrients such as zinc (Zn), iron (Fe), and copper (Cu) play a vital role in plant metabolism and are essential for improving crop productivity and soil fertility. Their deficiency in Indian soils, particularly in intensive cereal-based systems like wheat (*Triticum aestivum* L.), is widely reported due to continuous nutrient mining and unbalanced fertilization (Singh *et al.*, 2010; Sharma *et al*., 2013; Suganya *et al*., 2020). The application of sulphate salts of Zn, Fe, and Cu not only enhances crop growth and yield but also influences soil nutrient dynamics post-harvest (El-Ramady, 2013). Understanding their residual effect on soil properties is crucial for developing sustainable nutrient management strategies. Post-harvest assessment of soil nutrient status provides insight into the nutrient availability and potential carry-over effects for succeeding crops.

Crop quality is an important aspect of agricultural production because it directly influences customer preference, market value, and overall sustainability. Micronutrients are important for plant nutrition because they affect the growth, development and quality of agricultural crops. Diverse factors, including pre- and post-harvest soil nutrient availability and physicochemical properties, affect the quality of agricultural crops (Thokar *et al*., 2022). Environmentally, elements such as climate, soil composition, and water availability also play an important role. Furthermore, cultural practices, including irrigation, fertilization, pruning, and harvesting techniques, also leave an indelible mark on crop quality (Ahmed *et al.*, 2024). Current agricultural systems are still mostly oriented toward achieving high crop yields rather than nutritional quality, thus enhancing the concentrations of mineral micronutrients has become a key task in agriculture production. However, it is challenging to simultaneously increase the production of food enriched with essential micronutrients which does not cause obvious negative symptoms for plants like, i.e., limiting growth and productivity. Micronutrient deficiencies are more common in humid temperate and tropical regions where the intense leaching associated with high precipitation is observed. Another cause is the use of plant species with a low ability to accumulate sufficient quantities of micronutrients in their edible parts (Szerement *et al.*, 2022). The present study explores the Post-Harvest Soil Nutrient Status as Influenced by Sulphate Salts of Zn, Fe and Cu in Wheat (*Triticum aestivum* L.).

**MATERIALS AND METHODS**

**Experimental site**

The experiment was conducted in the Student’s Instructional Farm (SIF) of the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, India situated at a latitude of 26.493729° N and longitude of 80.294382° E, and an altitude of 125.9 meters above the mean sea level (MSL) during rabi for two consecutive years, 2022-23 and 2023-24. The climate of the site is sub-tropical having maximum and minimum temperature ranges from 45–4°C.

**Treatment details**

The experiment was laid out in a *Split Plot Design (SPD)* with three replications. The main plot consisted of two widely cultivated wheat varieties, namely DBW-222 (V1) and HD-2967 (V2). The sub-plot treatments included nutrient management strategies which are – control-RDF (T0); RDF + Soil application of Zn through ZnSO4.7H2O @ 20 Kgha-1 (T1); RDF + Foliar Spray of Zn as 1.0% ZnSO4.7H2O at Tillering and Booting Stages (T2); RDF + Soil application of Fe through FeSO4.7H2O @ 12 Kgha-1 (T3); RDF + Foliar Spray of Fe as 1.5% FeSO4.7H2O at Tillering and Booting Stages (T4); RDF + Soil application of Cu through CuSO4.5H2O @ 2.0 Kgha-1 (T5); RDF + Foliar Spray of Cu as 0.1 % CuSO4.7H2O at Tillering and Booting Stages (T6); RDF + Foliar Spray of (Zn + Fe) as 1.0% ZnSO4.7H2O and 1.5% FeSO4.7H2O at Tillering and Booting Stages (T7); RDF + Soil application of (Zn + Fe+ Cu) through ZnSO4.7H2O @ 20 Kgha-1, FeSO4.7H2O @ 12 Kgha-1, CuSO4.5H2O @ 2.0 Kgha-1 (T8); RDF + Foliar application of (Zn + Fe + Cu) as 1.0% ZnSO4.7H2O, 1.5% FeSO4.7H2O and 0.1% CuSO4.5H2O at Tillering and Booting Stages (T9).The crop was fertilized with the recommended dose of fertilizers (RDF) at the rate of 120:60:40 kg ha-1 of N, P₂O₅, and K₂O, respectively, applied as per standard agronomic practices.

**Fertilizers application**

Phosphorus was applied at 60 kg P2O5 ha-1 through di-ammonium phosphate (DAP). Nitrogen (N) was applied at the recommended dose of 120 kg ha-1. As DAP has supplied around 23.5 kg N ha-1, so remaining dose of N was supplied though urea (46% N) for completing recommended dose. N was applied in two equal splits i.e. half at the time of sowing and the remaining as top dressing. Muriate of potash (MOP) was applied at the time of sowing at the rate of 40 kg K2O ha-1. The soil application of zinc sulphate, iron sulphate and copper sulphate were done as per treatment before sowing, except in control. The foliar sprays of zinc sulphate, iron sulphate and copper sulphate were made as per the treatments by taking 300 Litre ha-1 spray volume. The foliar spray of the micronutrient fertilizers was done two times; 1st spray at tillering stage and 2nd spray at booting stage.

In the experiment, agricultural grade micronutrient fertilizers were used from reputed Indian manufacturers. Zinc Sulphate Heptahydrate (ZnSO4. 7H2O), manufactured by KRIBHCO, contained approximately 21% zinc (Zn) and 10% sulphur (S). Iron Sulphate Heptahydrate (FeSO4. 7H2O), procured from Prabhat Fertilizer and Chemical Works, provided about 19% iron (Fe) and 10% sulphur (S). Copper Sulphate Pentahydrate (CuSO4. 5H2O), also sourced from Prabhat Fertilizer and Chemical Works, contained approximately 24% copper (Cu).

**Chemical analysis of soil**

For the estimation of chemical properties and available nutrient concentration in soil, following methods were followed.

**Table-1:** Methods applied in the analysis of soil

|  |  |  |  |
| --- | --- | --- | --- |
| **Test Name** | **Method Used** | **Instrument used** | **References** |
| **pH** | Soil-water suspension method (1: 2.5) | pH meter | Schofield and Taylor, 1955 |
| **EC** | Soil-water suspension method (1: 2) | Conductivity meter | Jackson, 1973 |
| **SOC** | Titration method & colorimetric method | Colorimeter | Walkley and Black, 1934; Datta *et al*., 1962  |
| **Macronutrients** |  |
| **N** | Alkaline KMnO4 method | Kjeldahl Unit | Subbiah and Asija, 1956 |
| **P** | Olsen’s method | Spectrophotometer | Olsen *et al*., 1954 |
| **K** | Ammonium acetate method | Flame photometer | Jackson, 1973 |
| **S** | CaCl2-extractable S | Spectrophotometer | Williams and Steinbergs, 1969 |
| **Micronutrients** |  |
| **Zn** | DTPA - CaCl2 - TEA extraction method | AAS | Lindsay and Norvell (1978) |
| **Fe** | DTPA - CaCl2 - TEA extraction method | AAS | Lindsay and Norvell (1978) |
| **Cu** | DTPA - CaCl2 - TEA extraction method | AAS | Lindsay and Norvell (1978) |

**RESULTS AND DISCUSSION**

**Post harvest soil available N, P, K and S**

The post-harvest available nitrogen content in soil was significantly influenced by both wheat varieties and nutrient management practices across the two years (2022–23 and 2023–24) as given in table-2 and fig-1. Among the varieties, V2 (HD-2967) recorded the highest pooled soil nitrogen value (161.94 kg ha⁻¹), followed closely by the variety DBW-222 (158.30 kg ha⁻¹). Among treatments, T8 (soil application of Zn + Fe + Cu through ZnSO4.7H2O @ 20 Kg ha-1, FeSO4.7H2O @ 12 Kgha-1, CuSO4. 5H2O @ 2.0 Kg ha-1) had the maximum pooled nitrogen value of 172.67 kg ha⁻¹, followed by T9 (167.74 kg ha⁻¹) and T7 (168.06 kg ha⁻¹). The control (T0) had the lowest pooled value (153.57 kg ha⁻¹). The interaction effect (V × T) recorded a pooled mean of 160.12 kg ha⁻¹, indicating synergistic impacts of variety and nutrient management. Similar findings were also reported by Jat *et al.*, (2022).

Available phosphorus (P) content after harvest, also varied across treatments and years as given in table-2. Variety DBW-222 showed a slightly higher pooled P value (16.83 kg ha⁻¹) than HD-2967 (16.55 kg ha⁻¹). Maximum post-harvest soil phosphorus content (17.51 kg ha⁻¹ pooled) was recorded in T8 (soil application of Zn + Fe + Cu through ZnSO4.7H2O @ 20 Kg ha-1, FeSO4.7H2O @ 12 Kgha-1, CuSO4. 5H2O @ 2.0 Kg ha-1) and T9 (foliar application of Zn + Fe + Cu as 1.0% ZnSO4.7H2O, 1.5% FeSO4.7H2O and 0.1% CuSO4.5H2O at Tillering and Booting Stages). The lowest phosphorus was found in T1 (14.99 kg ha⁻¹ pooled). The variety and interaction effects were found to be statistically non-significant. Similar findings were also reported by Jat *et al.*, (2022); Malav *et al.,* (2019).

It is evidence from table-1 that the post-harvest available potassium (K) content showed notable variation due to treatments and interaction effects. Variety V1 (DBW-222) had a slightly higher pooled K value (301.63 kg ha⁻¹) than the variety HD-2967 (300.37 kg ha⁻¹). Among nutrient management practices, T9 (foliar application of Zn + Fe + Cu as 1.0% ZnSO4.7H2O, 1.5% FeSO4.7H2O and 0.1% CuSO4.5H2O at Tillering and Booting Stages) recorded the highest pooled K content (317.05 kg ha⁻¹), followed by the treatment T8 (307.79 kg ha⁻¹). The lowest K content was observed in the control (T0) with 283.31 kg ha⁻¹. The interaction between variety and treatments was significant, with a pooled interaction mean of 301.00 kg ha⁻¹. Thus, nutrient application had a pronounced effect on soil potassium status.

It is evidence from table-2 that the post-harvest soil available sulphur (S) was highly responsive to nutrient management. Variety DBW-222 had slightly more sulphur (16.71 mg kg⁻¹) than HD-2967 (16.25 mg kg⁻¹). The maximum sulphur content was observed in T8 (21.12 mg kg⁻¹), followed by T9 (17.36 mg kg⁻¹) and T1 (17.46 mg kg⁻¹), whereas the control (T0) recorded the lowest (14.05 mg kg⁻¹). However, interaction effect was found to be statistically significant. These results highlighted the beneficial role of sulphate-based micronutrients in improving soil S availability.

**Post harvest soil available Zn, Fe and Cu**

The data for available Zinc content in soil after harvest is given in table-3. Among treatments, the highest pooled Zn content (2.15 mg kg⁻¹) was recorded under soil application of Zn + Fe + Cu through ZnSO4.7H2O @ 20 Kg ha-1, FeSO4.7H2O @ 12 Kgha-1, CuSO4. 5H2O @ 2.0 Kg ha-1 (T8), enhancing residual Zn availability in the soil. In contrast, the control (T0) and treatments without zinc application (T2, T3, T4, T6) showed lower Zn values. This is because sulphate-based zinc fertilizers (like ZnSO₄·7H₂O) not only supply zinc directly but also improve Zn solubility in neutral to slightly alkaline soils due to the formation of more available Zn²⁺ ions. Similar findings were also reported by Jat *et al.*, (2022).

It is evident from table-3 that available iron content in soil showed a moderate increase under certain nutrient management treatments, with T8 (8.49 mg kg⁻¹) and T3 (8.41 mg kg⁻¹) showing the highest pooled values. The control (T0) and treatments like T1 and T4 showed relatively lower values. Iron availability was not significantly influenced by wheat variety, suggesting that the source and method of Fe application played a more prominent role. Iron sulphate (FeSO₄·7H₂O) increases DTPA-extractable Fe in soil. However, Fe is prone to oxidation and precipitation as Fe³⁺ in aerated and alkaline soils, leading to reduced availability. The observed increase in Fe content under T8 and T3 suggests either a higher or more efficiently absorbed Fe application or lower plant uptake, possibly due to varietal absorption differences or lower removal by biomass. Similar findings were also reported by Jat *et al.*, (2022).

It is evident from table-3 that Soil available copper also increased significantly under nutrient treatments, particularly T8 (1.81 mg kg⁻¹), followed by T9 (1.67 mg kg⁻¹) and T5 (1.66 mg kg⁻¹). The lowest Cu content was observed under the control (1.38 mg kg⁻¹). Varietal and interaction effects were non-significant. The copper increase in these treatments can be attributed to direct supplementation through CuSO₄ application, especially under T8 (soil application of Zn + Fe + Cu through ZnSO4.7H2O @ 20 Kg ha-1, FeSO4.7H2O @ 12 Kg ha-1, CuSO4. 5H2O @ 2.0 Kg ha-1), which likely received all three micronutrients. Copper in soils binds strongly to clay and organic matter. Soil-applied CuSO4 enhances DTPA-extractable Cu, and its residual effect is observable due to its low leaching and low plant removal. The significant increase under T8 reflects a cumulative effect of multi-micronutrient input enhancing the overall micronutrient pool.

**Soil pH**

The data for soil pH is given in table-4. The soil pH ranged from 6.87 to 7.52, with the lowest pH (6.87) recorded under the control treatment (T0) and the highest (7.52) under T2 (foliar Spray of Zn as 1.0% ZnSO4.7H2O at Tillering and Booting Stages) which was significantly at par with the treatment T4 (foliar Spray of Fe as 1.5% FeSO4.7H2O at Tillering and Booting Stages). Among varieties, DBW-222 exhibited a slightly higher pH (7.36) than HD-2967 (7.29), although the difference was statistically non-significant. Among nutrient treatments, significant differences were observed, with T2, T4, T6, and T9 registering relatively higher pH values (≥7.48), likely due to reduced acidification or buffering effects from micronutrient sulphates. Treatment T8, which included combined sulphate applications, showed a lower pH (7.02), suggesting slight soil acidification due to the residual effect of sulphate salts (ZnSO₄, FeSO₄, and CuSO₄). Sulphate-based fertilizers tend to release H⁺ ions during microbial oxidation of S, leading to a slight decrease in soil pH. Similar findings were also reported by Jat *et al.*, (2022).

**Electrical Conductivity (EC)**

It is evident from the table-4 that the electrical conductivity of the soil, indicative of soluble salt content, was significantly affected by nutrient treatments. The pooled EC ranged from 0.48 to 0.55 dSm⁻¹, with the highest EC observed in T8 (0.55 dSm⁻¹). This treatment involved combined micronutrient applications that contributed to higher ionic concentration in soil solution. The lowest EC values were recorded under control (T0). Application of sulphate-based micronutrients increases soluble salt concentration, especially in surface soil, due to the ionic dissociation of metal sulphates into Zn²⁺, Fe²⁺, Cu²⁺ and SO₄²⁻, temporarily elevating EC post-harvest. Similar findings were also reported by Jat *et al.*, (2022).

**Soil Organic Carbon (SOC)**

It is evident from the table-4 that the soil organic carbon content varied slightly among treatments and varieties, ranging from 0.37% to 0.44% in pooled data. The highest SOC (0.44%) was recorded under T9 (Foliar application of (Zn + Fe + Cu) as 1.0% ZnSO4.7H2O, 1.5% FeSO4.7H2O and 0.1% CuSO4.5H2O at Tillering and Booting Stages) followed by the treatment T7 (0.43%), while the lowest (0.37%) was under T1. Variety DBW-222 exhibited a marginally higher organic carbon (0.42%) compared to HD-2967 (0.41%). Improved organic carbon levels under certain treatments can be attributed to enhanced biomass returns (roots, stubbles) and microbial activity stimulated by balanced micronutrient availability, which supports decomposition and humification processes in soil.

**CONCLUSION**

The application of sulphate-based micronutrients influenced soil chemical properties, particularly pH and EC, while organic carbon showed modest but consistent improvement under combined nutrient management treatments. However, the fertility status of soil (post-harvest) was also affected by the application of sulphate-based micronutrient fertilizers. It is suggested that combined application of Zinc sulphate, iron sulphate and copper sulphate is recommended to increase the availability of the nutrients.

**Competing Interests**

Authors have declared that no competing interests exist.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**REFERENCES**

Singh, B., Dheeravathu, S. N., & Usha, K. (2010). Micronutrient deficiency: A global challenge and physiological approach to improve grain productivity under low zinc availability. *Plant Stress*, *4*, 76-93.

Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, Vol. 25, 259-260.

Lindsay, W. L., & Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal*, *42*(3), 421-428.

Schofield, R. K., & Taylor, A. W. (1955). The measurement of soil pH. *Soil Science Society of America Journal*, *19*(2), 164-167.

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37*(1), 29-38.

Datta, N. P., Khera, M. S., & Saini, T. R. (1962). A rapid colorimetric procedure for the determination of organic carbon in soils. *Journal of the Indian Society of Soil Science*, *10*(1), 67-74.

Olsen, S. R., Watanabe, F. S., Cosper, H. R., Larson, W. E., & Nelson, L. B. (1954). Residual phosphorus availability in long-time rotations on calcareous soils. *Soil Science*, *78*(2), 141-152.

Jackson, M. L. (1973). Soil chemical analysis, pentice hall of India Pvt. *Ltd., New Delhi, India*, *498*, 151-154.

Williams, C. H., & Steinbergs, A. (1962). The evaluation of plant-available sulphur in soils: I. The chemical nature of sulphate in some Australian soils. *Plant and soil*, *17*, 279-294.

Jat, H., Yadav, K. K., & Singh, D. P. (2022). Effect of soil and foliar application of Zn and Fe on soil fertility after harvest of maize. In *Biological Forum–An International Journal* (Vol. 14, No. 1, pp. 637-40).

Malav, J. K., Salvi, N. N., Pavaya, R. P., Patel, J. K., Patel, V. R., Patel, B. T., & Jat, J. R. (2019). Soil Fertility Status after Harvest of Wheat (Triticum aestivum L) in Salt Affected Soils of Gujarat as Influenced by Iron and Zinc Enriched FYM. *Int. J. Curr. Microbiol. App. Sci*, *8*(6), 2949-2959.

Ahmed, N., Zhang, B., Chachar, Z., Li, J., Xiao, G., Wang, Q., ... & Tu, P. (2024). Micronutrients and their effects on horticultural crop quality, productivity and sustainability. Scientia Horticulturae, 323, 112512.

Szerement, J., Szatanik-Kloc, A., Mokrzycki, J., & Mierzwa-Hersztek, M. (2022). Agronomic biofortification with Se, Zn, and Fe: An effective strategy to enhance crop nutritional quality and stress defense—A review. Journal of Soil Science and Plant Nutrition, 22(1), 1129-1159.

Thokar, N., Kattel, D., & Subedi, S. (2022). Effect of pre-harvest factors on postharvest quality of horticultural products. *Food Agri. Econ. Rev*, *2*, 92-95.

Sharma, A., Patni, B., Shankhdhar, D., & Shankhdhar, S. C. (2013). Zinc–an indispensable micronutrient. *Physiology and Molecular Biology of Plants*, *19*, 11-20.

Suganya, A., Saravanan, A., & Manivannan, N. (2020). Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (Zea mays L.) grains: An overview. *Commun. Soil Sci. Plant Anal*, *51*(15), 2001-2021.

El-Ramady, H. R. (2013). Integrated nutrient management and postharvest of crops. *Sustainable Agriculture Reviews: Volume 13*, 163-274.

**Figure 1:** Post harvest soil available N, P and K (kg ha-1)

**Table 2:** Post-harvest soil available Nitrogen, Phosphorus, Potassium and Sulphur

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Available N (kg ha-1)** | **Available P (kg ha-1)** | **Available K (kg ha-1)** | **Available S (mg kg-1)** |
| **Treatments** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Wheat Varieties** |  |  |  |  |  |  |  |  |  |  |  |  |
| V1 | 154.95 | 161.98 | 158.30 | 17.29 | 16.36 | 16.83 | 307.24 | 296.01 | 301.63 | 15.85 | 17.56 | 16.71 |
| V2 | 157.62 | 166.24 | 161.94 | 17.00 | 16.09 | 16.55 | 304.60 | 296.15 | 300.37 | 15.61 | 16.89 | 16.25 |
| **SE(m) ±** | **0.33** | **0.40** | **0.08** | **0.04** | **0.03** | **0.001** | **0.98** | **1.20** | **0.14** | **0.01** | **0.03** | **0.02** |
| **CD (P =0.05)** | **2.15** | **2.64** | **0.54** | **0.24** | **0.21** | **0.004** | NS | NS | **0.90** | **0.06** | **0.23** | **0.11** |
| **Nutrient Management** |   |   |   |   |   |   |   |   |   |   |   |   |
| T0 | 149.70 | 158.38 | 153.57 | 16.96 | 16.00 | 16.48 | 287.83 | 278.79 | 283.31 | 13.41 | 14.68 | 14.05 |
| T1 | 153.76 | 162.10 | 157.87 | 15.51 | 14.48 | 14.99 | 306.09 | 296.41 | 301.25 | 16.68 | 18.23 | 17.46 |
| T2 | 150.04 | 154.15 | 151.20 | 16.78 | 15.84 | 16.31 | 310.73 | 300.88 | 305.80 | 14.42 | 15.78 | 15.10 |
| T3 | 156.34 | 164.33 | 160.11 | 17.39 | 16.52 | 16.96 | 299.11 | 289.30 | 294.20 | 16.16 | 17.69 | 16.93 |
| T4 | 153.27 | 161.09 | 156.37 | 17.14 | 16.25 | 16.69 | 308.03 | 297.90 | 302.96 | 14.20 | 15.57 | 14.89 |
| T5 | 153.20 | 161.97 | 157.76 | 17.13 | 16.14 | 16.63 | 295.67 | 285.97 | 290.82 | 16.04 | 17.59 | 16.82 |
| T6 | 149.23 | 158.80 | 155.84 | 16.97 | 16.04 | 16.51 | 305.28 | 295.25 | 300.26 | 13.95 | 15.32 | 14.63 |
| T7 | 163.63 | 171.40 | 168.06 | 17.76 | 16.83 | 17.29 | 311.72 | 301.39 | 306.55 | 15.68 | 17.19 | 16.43 |
| T8 | 169.22 | 176.44 | 172.67 | 17.96 | 17.05 | 17.51 | 312.39 | 303.19 | 307.79 | 20.17 | 22.07 | 21.12 |
| T9 | 164.46 | 172.43 | 167.74 | 17.90 | 17.11 | 17.51 | 322.39 | 311.71 | 317.05 | 16.56 | 18.16 | 17.36 |
| **SE(m) ±** | **1.40** | **1.66** | **0.77** | **0.21** | **0.16** | **0.14** | **2.82** | **2.88** | **2.03** | **0.17** | **0.17** | **0.11** |
| **CD (P =0.05)** | **4.04** | **4.77** | **2.21** | **0.59** | **0.46** | **0.40** | **8.14** | **8.30** | **5.84** | **0.49** | **0.48** | **0.31** |
| **Interaction** |   |   |   |   |   |   |   |   |   |   |   |   |
| V x T | 156.28 | 164.11 | 160.12 | 17.15 | 16.22 | 16.69 | 305.92 | 296.07 | 301.00 | 15.73 | 17.23 | 16.48 |
| **SE(m) ±** | **1.04** | **1.27** | **0.26** | **0.12** | **0.10** | **0.002** | **3.11** | **3.79** | **0.44** | **0.03** | **0.11** | **0.05** |
| **CD (P =0.05)** | NS | NS | **3.15** | NS | NS | NS | **12.43** | **13.06** | **8.28** | NS | **0.71** | **0.44** |

**Table 3:** Post-harvest soil available Zinc, Iron and Copper

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Available Zn (mg kg-1)** | **Available Fe (mg kg-1)** | **Available Cu (mg kg-1)** |
| **Treatments** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Wheat Varieties** |  |  |  |  |  |  |  |
| V1 | 1.63 | 1.81 | 1.72 | 7.75 | 8.16 | 7.95 | 1.43 | 1.57 | 1.50 |
| V2 | 1.61 | 1.76 | 1.68 | 7.84 | 8.02 | 7.93 | 1.45 | 1.59 | 1.52 |
| **SE(m) ±** | **0.003** | **0.006** | **0.003** | **0.06** | **0.03** | **0.04** | **0.02** | **0.003** | **0.01** |
| **CD (P =0.05)** | NS | **0.04** | **0.02** | NS | NS | NS | NS | NS | NS |
| **Nutrient Management** |     |   |   |   |   |   |   |
| T0 | 1.52 | 1.67 | 1.60 | 7.74 | 8.03 | 7.88 | 1.30 | 1.44 | 1.38 |
| T1 | 1.76 | 1.93 | 1.84 | 7.51 | 7.79 | 7.65 | 1.34 | 1.48 | 1.41 |
| T2 | 1.52 | 1.67 | 1.60 | 7.63 | 7.92 | 7.78 | 1.33 | 1.46 | 1.39 |
| T3 | 1.53 | 1.68 | 1.60 | 8.26 | 8.57 | 8.41 | 1.36 | 1.50 | 1.43 |
| T4 | 1.53 | 1.67 | 1.60 | 7.47 | 7.75 | 7.61 | 1.35 | 1.48 | 1.41 |
| T5 | 1.55 | 1.71 | 1.62 | 7.66 | 7.94 | 7.80 | 1.59 | 1.73 | 1.66 |
| T6 | 1.52 | 1.67 | 1.60 | 7.68 | 7.97 | 7.83 | 1.39 | 1.52 | 1.45 |
| T7 | 1.59 | 1.76 | 1.68 | 7.83 | 8.12 | 7.98 | 1.41 | 1.55 | 1.48 |
| T8 | 2.05 | 2.25 | 2.15 | 8.33 | 8.64 | 8.49 | 1.74 | 1.88 | 1.81 |
| T9 | 1.65 | 1.82 | 1.73 | 7.84 | 8.13 | 7.99 | 1.60 | 1.74 | 1.67 |
| **SE(m) ±** | **0.02** | **0.02** | **0.01** | **0.09** | **0.08** | **0.06** | **0.02** | **0.02** | **0.01** |
| **CD (P =0.05)** | **0.06** | **0.06** | **0.04** | **0.25** | **0.23** | **0.17** | **0.05** | **0.05** | **0.03** |
| **Interaction** |    |   |   |   |   |   |   |
| V x T | 1.62 | 1.78 | 1.70 | 7.80 | 8.09 | 7.94 | 1.44 | 1.58 | 1.51 |
| **SE(m) ±** | **0.01** | **0.02** | **0.01** | **0.18** | **0.11** | **0.14** | **0.05** | **0.01** | **0.03** |
| **CD (P =0.05)** | **0.080** | **0.093** | **0.061** | **0.441** | **0.357** | **0.307** | NS | NS | NS |

**Table 4:** Post-harvest soil pH, Electrical conductivity (EC) and Organic carbon (OC)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **pH** | **EC (dSm-1)** | **OC (%)** |
| **Treatments** | **2022-23** | **2022-23** | **2022-23** | **2022-23** | **2023-24** | **Pooled** | **2022-23** | **2023-24** | **Pooled** |
| **Wheat Varieties** |  |  |  |  |  |  |  |  |  |
| V1 | 7.36 | 7.36 | 7.36 | 0.49 | 0.51 | 0.50 | 0.41 | 0.43 | 0.42 |
| V2 | 7.29 | 7.29 | 7.29 | 0.52 | 0.51 | 0.51 | 0.40 | 0.41 | 0.41 |
| **SE(m) ±** | **0.01** | **0.01** | **0.01** | **0.003** | **0.004** | **0.002** | **0.002** | **0.002** | **0.002** |
| **CD (P =0.05)** | NS | NS | NS | **0.02** | NS | **0.01** | NS | **0.02** | **0.01** |
| **Nutrient Management** |  |  |  |   |   |   |   |   |   |
| T0 | 6.87 | 6.87 | 6.87 | 0.48 | 0.49 | 0.48 | 0.41 | 0.42 | 0.41 |
| T1 | 7.36 | 7.36 | 7.36 | 0.51 | 0.52 | 0.51 | 0.37 | 0.38 | 0.37 |
| T2 | 7.52 | 7.52 | 7.52 | 0.49 | 0.49 | 0.49 | 0.42 | 0.43 | 0.42 |
| T3 | 7.32 | 7.32 | 7.32 | 0.53 | 0.53 | 0.53 | 0.39 | 0.40 | 0.39 |
| T4 | 7.50 | 7.50 | 7.50 | 0.49 | 0.49 | 0.49 | 0.41 | 0.43 | 0.42 |
| T5 | 7.42 | 7.42 | 7.42 | 0.54 | 0.55 | 0.54 | 0.40 | 0.42 | 0.41 |
| T6 | 7.48 | 7.48 | 7.48 | 0.50 | 0.50 | 0.50 | 0.41 | 0.42 | 0.41 |
| T7 | 7.27 | 7.27 | 7.27 | 0.48 | 0.48 | 0.48 | 0.43 | 0.44 | 0.43 |
| T8 | 7.02 | 7.02 | 7.02 | 0.55 | 0.56 | 0.55 | 0.41 | 0.42 | 0.41 |
| T9 | 7.50 | 7.50 | 7.50 | 0.49 | 0.50 | 0.49 | 0.43 | 0.45 | 0.44 |
| **SE(m) ±** | **0.02** | **0.02** | **0.02** | **0.006** | **0.004** | **0.004** | **0.005** | **0.004** | **0.003** |
| **CD (P =0.05)** | **0.05** | **0.05** | **0.05** | **0.02** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** |
| **Interaction** |  |  |  |   |   |   |   |   |   |
| V x T | 7.30 | 7.30 | 7.30 | 0.50 | 0.51 | 0.51 | 0.41 | 0.42 | 0.41 |
| **SE(m) ±** | **0.03** | **0.03** | **0.03** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** | **0.01** |
| **CD (P =0.05)** | **0.09** | **0.09** | **0.09** | NS | NS | NS | NS | NS | NS |