

Response of Wheat to Farmyard Manure and Zinc Application in a Vertisol of Central India

ABSTRACT

Zinc (Zn) deficiency is one of the major global nutrition concerns, particularly in regions where diets are cereal dominant. About 50% of soils poor in zinc have resulted in zinc deficiency in cereal grains. Farmyard manure (FYM) with Zn application is the way to meet the Zn needs of crops and to raise the Zn content of grain that is ultimately consumed by people. Therefore, a pot experiment was conducted at the Department of Soil Science and Agricultural Chemistry of JNKVV, Jabalpur, in the Rabi season of 2020-2021 with three levels of FYM (0, 5.0, and 10 t ha⁻¹) and three levels of zinc (0, 5 and 10 kg Zn ha⁻¹) through ZnSO₄.7H₂O in a completely randomized design (CRD). Results revealed that the addition of 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ produced significantly better results for the plant height compared to the control. The combined application of 10 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ showed the highest SPAD reading at 21 DAS, but it was the highest at the sole application of 10 t FYM ha⁻¹ at 45 DAS. Significant enhancements in spike length (7.65 cm), weight and number of grains per spike (23.90), and DMP of 7.12 g pot⁻¹ were recorded with the 5 kg Zn ha⁻¹ sole application. However, the highest grain weight (2.50 g pot⁻¹) was recorded with 5 t FYM ha⁻¹ + 5 kg Zn ha⁻¹, which was on par with 5 t FYM ha⁻¹, 5 kg Zn ha⁻¹, and 10 t FYM ha⁻¹ + 10 kg Zn ha⁻¹. The highest Zn content (48.95 mg kg⁻¹) in wheat grain was recorded with 10 kg Zn ha⁻¹, followed by 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ (44.45 mg kg⁻¹). The highest Zn uptake of 99.53 µg pot⁻¹ by grain of wheat was recorded with 5 t FYM ha⁻¹ + 5 kg Zn ha⁻¹, which was significantly superior to all the treatments but on par with 5 kg Zn ha⁻¹ (98.82 µg pot⁻¹). Combined application of 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ maintain extractable zinc in soil as compared to control.

Keywords: Farm yard manure (FYM), SPAD, Zinc, Wheat, Vertisol

1. INTRODUCTION

“Wheat (*Triticumaestivum*) is an important Rabi crop grown in Madhya Pradesh, India. It is a significant ingredient in the daily diet of millions of people. The approximate chemical composition of the wheat kernel is starch 63–71%; protein 10-12%; water 8–17%; cellulose 2-3%; fat 1.5–2%; sugar 2-3%; and mineral matter 1.5–2%” [1]. “It plays an imperative role in the human diet and also provides strong monetary support for the country” [2].

“In high-input agriculture, deficiency of micronutrients has become a major constraint on the productivity, stability, and sustainability of soils. These deficiencies appeared much faster, primarily due to the fast adoption of new agricultural technology, including the cultivation of high-yielding crop varieties, an increase in cropping intensity, the expansion of irrigation facilities, the more frequent use of high-analysis fertilizers, and poor-quality irrigation water”. [2] The imbalanced fertilizer application, coupled with zinc deficiency, is one of the factors responsible for the low productivity of crops. Zinc deficiency in coarse-textured, calcareous, alkaline soils with a high pH and low organic matter is generally low in available zinc. Therefore, zinc malnutrition has become a major health concern among resource-poor people.

“Among micronutrients, Zn is now being regarded as the third most limiting nutrient element in crop production after N and P. Cereal crops are inherently very low in grain Zn concentrations and growing them on potentially Zn-deficient soils further reduces Zn concentrations in grain” [3]. “To obtain high yields without deterioration of soil fertility, it is important to work out the optimal combination of fertilizers and manures in the cropping system” [4].

“In India, increasing the productivity of wheat has become a major way to overcome the unusual increase in population. In the literature, several workers showed the importance of farmyard manure in increasing cereal grain yield. The various physico-chemical processes also mediated the Zn availability in alkaline soils i.e., variation in chemical composition of salt-affected soils, precipitation-dissolution reactions, adsorption kinetics, transformations of nutrients, and crop responses to applied nutrients greatly varied” [5, 6, 7]. “Application of micronutrients determines the yield potential of crops in deficient soil with low carbon content” [8, 9]. “The use of FYM and other organic manures produces various types of organic acids during microbial decomposition and converts the plant nutrients from immobile to mobile in the soil solution” [10]. “Combined soil application of micronutrients with FYM significantly enhanced the mustard yield in normal soil” [11].

“Organic manures not only supply micronutrients but also influence the transformation of native micronutrients in soil, thereby enhancing their availability for crops” [12, 13]. “The contributions of soil organic matter to available pools of micronutrients are limited and, thus, prone to deficiency of one or more micronutrients in salt-affected soils” [14]. “Manures contribute to Zn accumulation through N supply and organic acids, decreasing soil pH and improving the mobilization of soil Zn in calcareous soils. Decomposition of organic materials releases fluvic and other organic acids that form complexes with inorganic Zn and increase its solubility and availability to plants” [15, 16].

A significant decrease of 80% in grain Zn concentration was observed in cereals grown on soils with low plant-available Zn. This decrease in grain Zn also reduces its bioavailability in humans and may contribute to Zn deficiency in susceptible human populations. The poor recovery of zinc by crops necessitates the adoption of improved techniques that are more effective in maintaining zinc in soil solutions.

The application of FYM is a potential bio-fortification approach to increase soil zinc availability to plants and thereby its accumulation in wheat grains. Poor soil organic matter usually results in lower availability of Zn in plants. Such a deficiency in zinc causes a significant decrease in the growth and yield of crops. However, information is limited in this aspect. Thus, the study was conducted to define the optimum dose and how the application of FYM in combination with Zn fertilizers in soils affects wheat yields.

2. MATERIAL AND METHODS

2.1 Location of experiment

Glass house of Jawaharlal Nehru KrishiVishwaVidyalaya, Jabalpur, India which situated at 23° 13' North latitude, 79° 57' East longitudes and elevation of 393 meter Above Mean Sea Level.

2.2 Soil of the experimental field

The soil of the experimental field belongs to Kheri series, taxonomically Fine, Montmorillonitic, Hyperthermic family of TypicHaplustert, clayey in texture. The soil of the experimental field was neutral in soil reaction, normal in EC, low in available N and medium in P and K.

2.3 Pot house experiment using wheat as a test crop

The test crop wheat GW-366 was sown manually as per the recommended practices. About 4 kg soil was placed in clean earthen Pot and mix it with three FYM levels and three zinc levels. Samples were collected from all treatments and analyzed for available zinc. There were viz., different FYM levels that is 0, 5 and 10 kg ha⁻¹ treatments having different zinc levels that is 0, 5 and 10 kg Zn ha⁻¹ with two replications to see the effectiveness FYM with zinc levels on growth, dry matter production and Zn composition of wheat.

2.4 Growth and yield attributes

Five plants per plot were tagged during both the year to measure the plant height, no. of tillers plant⁻¹, length of spikelet and number of grains spikelet⁻¹. The grain and straw yield of wheat was recorded at the time of threshing during both the year. A chlorophyll meter (SPAD-502, Minolta, Japan) was used to obtain readings estimating leaf chlorophyll concentration (SPAD value). Five plants per treatment were selected randomly and SPAD values were recorded from the fully matured leaves counted from the top of the plants, the youngest fully expanded leaf. The observations were recorded from each plot at crown root initiation (CRI) (21 DAS) and tillering (45 DAS). The plants were harvested at maturity and grain and straw yield was recorded.

2.5 Soil and plant analysis:

Representative soil samples were collected using a core sampling tool from each pot to determine the nutrient status of the soil after the harvest of the crop. The samples were air dried, ground, and passed through a 2 mm sieve and analyzed for organic carbon by Walkley and Black's method (1934) [17] available N by the Alkaline permanganate method (Subbiah and Asija, 1956) [18], available P by the extraction of soil with 0.5 M NaHCO₃ (pH 8.5), and the color intensity spectrophotometrically (Olsen et al., 1954) [19], available K is extracted with 1N ammonium acetate (pH 7.0) and estimated by a flame photometer. "The available Zn status was analyzed in a suitable aliquot of DTPA extract with the help of an atomic absorption spectrophotometer (Varian AAS-240)" Lindsay and Norvell (1978) [20]. "Plant samples were collected at maturity for determination of the uptake of Zn. The oven-dried plant samples were finely ground in a stainless-steel Willey mill and digested with a HNO₃:HClO₄ (4:1) di-acid mixture for the determination of Zn content as per the procedure" given by Jackson (1973) [21].

2.6 Statistical analysis

In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analyzed as described by Panse and Sukhatme (1985) [22]. The critical differences were calculated to assess the significance of the treatment mean wherever the 'F' test was found significant at the 5 percent level of probability. To elucidate the nature and magnitude of treatment effects, summary tables along with SEm+ and CD (P = 0.05) were given.

3. Result and Discussions

3.1 Plant height

The result given in Table 1 revealed that the highest mean plant height (57.95 and 65.75 cm) was recorded with 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ application, which was significant over control (42.75 and 53.44 cm) while at par with sole application of 5 kg Zn ha⁻¹ (56.60 and 65.70 cm) at 45 and 60 DAS, respectively. Further, it is apparent from data that the plant height of 30.60 cm was recorded at sole application of 5 t FYM ha⁻¹ which was found statistically at par with combined application of 5 t FYM ha⁻¹ + 5 kg Zn ha⁻¹, 10 t FYM ha⁻¹ + 5 or 10 kg Zn ha⁻¹. Thus, it is obvious from the data that 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ is the most suitable one for growth point of view because contributing to additional growth compared to control and other treatments. The results are also in agreement with the findings of Malav and Patel [23].

3.2 SPAD

The findings showed in Table 1 revealed that the highest mean SPAD (40.64) was recorded with 10 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ application which was significant over control (28.19) and rest of the treatments but at par with 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ (39.66) at 21 DAS. However, at 45 DAS, the SPAD value of 42.52 was recorded at sole application of 10 t FYM ha⁻¹ which was found statistically superior to all rest of the treatments. Thus, it is obvious from the data that 10 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ is the highest SPAD reading at 21 DAS, but it was not steady after wards (45 DAS). However, sole application of 10 t FYM ha⁻¹

¹ showed the highest SPAD reading indicated that the highest chlorophyll formation and FYM plays an important role in nitrogen metabolism and development of pigment biosynthesis.

Yield attributes

3.3 Spike length

The findings showed in Table 2 revealed that the highest mean spike length (7.65 cm) was recorded with 5 kg Zn ha⁻¹ which was significantly superior to all the treatments. Further, the application of 10 kg Zn ha⁻¹ gave 6.95 cm spike length. However, spike length (6.75 cm) was recorded at 10 t FYM ha⁻¹ +10 kg Zn ha⁻¹ which was found statistically on par with 5 t FYM ha⁻¹ and 10 t FYM ha⁻¹ with 5 and 10 kg Zn ha⁻¹. Thus, 5 kg Zn ha⁻¹ might improve the catalytic activity in anther of wheat that increased spike length. Similar findings were reported by Zia et al., (2007) [24] Shaheen et al., (2007) [25], Ziaeyan and Rajaeia, (2009) [26] and Abbas et al., (2009) [27].

3.4 Spike weight

Among the treatments, the highest mean spike weight was recorded with 5 kg Zn ha⁻¹ which was significantly superior to control and other rest of the treatments (Table 2). Further, the sole application of 5 t FYM ha⁻¹, significantly increased the spike weight (0.72 g) and equal with combined application of 5 t FYM ha⁻¹+5 kg Zn ha⁻¹ and 10 t FYM ha⁻¹ +10 kg Zn ha⁻¹ addition (0.72 and 0.69 g). Zn is required for the biosynthesis of plant growth regulator (IAA) and for carbohydrate and N metabolism which leads to high yield and yield components.

3.5 No. of grains per spike

The data in table 2 revealed that the highest mean number of grains per spike (23.90) was recorded with 5 kg Zn ha⁻¹ application which was significantly superior to all the treatments. Further, the sole application of 10 kg Zn ha⁻¹ and 5 t FYM ha⁻¹ and combined application of 10 t FYM ha⁻¹ +5 kg Zn ha⁻¹ (18.90, 18.25 and 18.50) enhanced significantly but found statistically on par each other except 5 t FYM ha⁻¹. Zn has a key role in increasing the activities of enzymes [28], helps in growth hormones production [29], formation of spike and assimilates translocation to seed.

Yield

3.6 Grain weight

The result in table 2 revealed that the highest mean grain weight (2.50 g pot⁻¹) was recorded with 5 t FYM ha⁻¹ +5 kg Zn ha⁻¹ which was at par with 5 t FYM ha⁻¹, 5 kg Zn ha⁻¹ and 10 t FYM ha⁻¹+10 kg Zn ha⁻¹ but significant superior to all the rest of treatments. The result showed that the use of FYM in combination with Zn produce the highest grain weight which might be due to the involvement of the Zn in activation of enzymes [30]. Harris et al. (2007) [31] and Karim et al. (2012) [32] also observed an increase in grains weight with each incremental level of Zn. These results are in accordance with the findings of Niyigaba et al. (2019) [33].

3.7 Dry matter production (DMP)

The highest DMP of 7.12 g pot⁻¹ was recorded with 5 kg Zn ha⁻¹ which was significantly superior to all the treatments (Table 2). Further, 5 t FYM ha⁻¹ application enhanced the DMP significantly (6.11 g pot⁻¹) but at par with 5 t FYM ha⁻¹ + 5 kg Zn ha⁻¹, 5 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ and 10 t FYM ha⁻¹ + 10 kg Zn ha⁻¹ addition (5.58, 5.60 and 5.58 g pot⁻¹). The combined application of FYM and Zn brings higher DMP of wheat than control which might be due to better absorption of water and nutrients from the soil and applied fertilizers [34]. These findings are supported by Duan et al. 2014 [35], Sheoran et al. 2017 [36] and Sultana et al. 201 [37].

3.8 Zn content and uptake

The findings showed in Table 3 revealed that the highest Zn content (48.95 mg kg^{-1}) in grain of wheat was recorded with 10 kg Zn ha^{-1} followed by $5 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$ (44.45 mg kg^{-1}) and both were significantly superior to all the treatments. Further, 5 kg Zn ha^{-1} application increased Zn (41.63 mg kg^{-1}) which was significantly superior to rest of the treatments but at par with $5 \text{ t FYM ha}^{-1} + 5 \text{ kg Zn ha}^{-1}$ (39.80 mg kg^{-1}).

The highest Zn uptake (99.53 and $98.82 \text{ } \mu\text{g pot}^{-1}$) by grain of wheat was recorded with $5 \text{ t ha}^{-1} \text{ FYM} + 5 \text{ kg Zn ha}^{-1}$ which was significantly superior to all the treatments but at par with 5 kg Zn ha^{-1} ($98.82 \text{ } \mu\text{g pot}^{-1}$). Combined application $5 \text{ t ha}^{-1} \text{ FYM} + 10 \text{ kg Zn ha}^{-1}$ showed $83.56 \text{ } \mu\text{g Zn pot}^{-1}$ uptake by grain which was significant superior to all the treatments but at par with $10 \text{ t ha}^{-1} \text{ FYM} + 10 \text{ kg Zn ha}^{-1}$ ($77.66 \text{ } \mu\text{g pot}^{-1}$). "The combined application of FYM and Zn might be due to intermediates/metabolites of decomposition of FYM that hold Zn in forms available to plants or release of Zn mobilizing compounds such as phytosiderophores from roots, and induction of polypeptides involved in Zn uptake and translocation to shoots" [15].

3.9 P content in grain

P content in grain was found to be non- significant (Table 3). However, the application of different treatments were found significant for P content in straw. The maximum P content in grain (0.37%) was found at $10 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$, followed by 5 kg Zn ha^{-1} , 10 kg Zn ha^{-1} and the minimum value found in control (0.32%). "With the application of FYM the pH of soil decreased, and it make the P available to the crops" [38]. "FYM and mineral P have significantly enhanced the available phosphorus portion of soil and soil fertility" [39, 40]. "FYM released P slowly and it will take up by the plant at the time of its need" [41].

3.10 Soil fertility status

The data (Table 4) indicated that the highest pH was noted at combined application of $5 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$ which was found statistically at par with $10 \text{ t FYM ha}^{-1} + 5 \text{ kg Zn ha}^{-1}$, $5 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$, $5 \text{ t FYM ha}^{-1} + 5 \text{ kg Zn ha}^{-1}$ and 10 t FYM ha^{-1} . The decrease in soil pH with addition of FYM is due to organic acids in the organic manures [42,43]. "The result was contradictory with combined application of FYM and Zn but the fact that the decomposition of organic matter resulted in the production of low molecular organic acid like humic and fluvic acids, acetic, formic, oxalic, lactic, propionic, malic, citric, and aconitic acids" [44]. "FYM have a better structure and may contain humic acid, growth hormones and high microbial population resulted into increased CO_2 concentration in soil arising from microbial activity and decomposition of native organic matter. The CO_2 in contact with water forms carbonic acid which creates acidity" [45]. The EC was significantly increased with $5 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$ application over control but at par with $5 \text{ t FYM ha}^{-1} + 5 \text{ kg Zn ha}^{-1}$. Addition of FYM increase the organic acids in the soil which react with the sparingly soluble salts already present converting them to soluble salts [45]. Similar findings were reported by Singh et al. 2016 [46] and Banerjee et al. 2011 [47].

The highest OC was recorded with $10 \text{ t ha}^{-1} \text{ FYM} + 5 \text{ kg Zn ha}^{-1}$ addition (11.88 g kg^{-1}) which was at par with $10 \text{ t ha}^{-1} \text{ FYM} + 5 \text{ kg Zn ha}^{-1}$. Further, the SOC content of 9.75 g kg^{-1} which was found in $5 \text{ t FYM ha}^{-1} + 5 \text{ kg Zn ha}^{-1}$ and $10 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$ and both were at par with 5 t FYM ha^{-1} and 10 kg Zn ha^{-1} application. The highest Olsen-P was analyzed at $5 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$ which was significantly over control but at par with $5 \text{ t FYM ha}^{-1} + 5 \text{ kg Zn ha}^{-1}$ application.

The DTPA Zn in the control soil was 0.32 mg kg^{-1} and $10 \text{ kg applied Zn ha}^{-1}$ (0.63 mg kg^{-1}) and $5 \text{ t FYM ha}^{-1} + 10 \text{ kg Zn ha}^{-1}$ (0.67 mg kg^{-1}) was found at the end of the experiment. FYM forms multi-dentate complex which greatly enhances the Zn solubility (Stevenson and Cole 1999). "to affect the pH perturbations as happened in our case the soil

pH decreased with the addition of FYM resulting increase in Zn availability. As soil pH decreases, Zn must compete with the extra H^+ and Al^{3+} for positions on the exchange sites, solubility of Zn increases in the soil solution and a greater proportion is present as highly available free metal ions in the soil solution" [48, 49]. Almas et al. 2000 [50] observed "the addition of organic matter increased the solubility of Zn through the formation of soluble organo-metallic complexes". Catlett et al. 2002 [51] concluded that "binding of Zn^{2+} with OM has a significant positive impact on its solubility in fine silty neutral to alkaline calcareous soils. $CaCO_3$ in calcareous soils can lead to Zn precipitation as $ZnCO_3$, but $ZnCO_3$ is soluble, hence more available". According to Lindsay 1979 [52] "minerals like ZnO (zincite) and $ZnCO_3$ (smithsonite) are too soluble to persist in soils".

Conclusion

Zinc deficiency is a global human malnutrition problem that affects people whose diets are based on wheat. In conclusion, the application of 5 t FYM ha^{-1} +10 kg Zn ha^{-1} produced significantly better results for the plant height. The SPAD reading at 10 t FYM ha^{-1} +10 kg Zn ha^{-1} at 21 DAS afterward it was the highest at sole application of 10 t FYM ha^{-1} . However, 5 kg of Zn ha^{-1} application enhanced yields attributes 5 t FYM ha^{-1} + 5 kg Zn ha^{-1} showed the highest mean grain weight, and 10 kg Zn ha^{-1} application increased the Zn content (48.95 mg kg^{-1}) in grain of wheat while Zn uptake (99.53 $\mu g\ pot^{-1}$) by grain of wheat was recorded with 5 t ha^{-1} FYM + 5 kg Zn ha^{-1} application. Further it is recommended with 5 t FYM ha^{-1} +10 kg Zn ha^{-1} also maintain soil extractable zinc. Hence, the application of 5 kg Zn ha^{-1} + 5 t FYM ha^{-1} is recommended to the farmer for increasing the overall Zn content in grain and getting better production of the wheat crop in a Vertisol of central India.

Conference disclaimer:

Some part of this manuscript was previously presented in the following poster presentation: The 87th Annual Convention of ISSS Inaugurated dated 3rd October, 2023 at ICAR-IISS, Bhopal, India, Web Link of the proceeding: <http://www.iss-india.org/img/ListofAbstracts23.pdf>

Reference

- Anonymous (2021). Directorate of Economics and Statistics, Department of Agricultural and Corporation, New Delhi.
- S.K Singh, V.K Mishra, U.K. Srivastava and A Kumar (2012). Impact of irrigation levels on growth, yield and quality of wheat (*Triticumaestivum* L.). *Environ Ecol*, 30: 72-77.
- I Cakmak, WH Pfeiffer, B McClafferty (2010). Biofortification of durum wheat with zinc and iron. *Cereal Chem*, 87:10–20.
- D.S.Pullicino, L. Massaccesi, R.B. Dixon and G. Gigliottia, (2009). Organic matter dynamics in a compost- amended anthropogenic landfill capping-soil. *Europ J Soil Sci*, 61: 35-47.
- B.L. Meena, R.K. Rattan and S.P. Datta (2013). Efficacy of seed treatment in ameliorating iron deficiency in aerobic rice on a calcareous soil. *J. Indian Soc. Soil Sci.*, 61: 147-152.
- J.C. Katyal, and B.D. Sharma (1980). A new technique of plant analysis to resolve iron chlorosis. *Plant Soil*, 55: 105-119.
- S.P. Datta, Meena, B.L. R.K and Rattan (2013). Development of a computer program for calculating metal ion activity using Baker soil test. *J. Indian Soc. Soil Sci.*, 61: 47-50.

A.K Shukla, P.K. Tiwari and C. Prakash (2014). Micronutrients deficiencies vis-a-vis food and nutritional security of India. *Indian J. Fert.*, 10: 94-112.

P. Ray, B.L Meena and C.P. Nath (2014). Management of coastal soils for improving soil quality and productivity. *Pop. Kheti*, 2:95-99.

M.L. zDotaniya, S.C. Datta, D.R. Biswas, C.K. Dotaniya, B.L Meena, S. Rajendiran, K.L. Regar and L. Manju (2016). Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. *Int. J. Recycl. Org. Waste Agricult.*, 5: 185–194.

M.C. Meena, K.P. Patel and D.D. Rathod (2006). Effect of Zn and Fe enriched FYM on mustard yield and micronutrients availability in loamy sand soil of Anand. *J. Indian Soc. Soil Sci.*, 54: 495-499.

S. Pal, S.P Datta, R.K Rattan and A.K Singh(2008). Diagnosis and amelioration of iron deficiency under aerobic rice. *J. Plant Nutr.*, 31: 919-940.

B.L.Meena, R. K. Fagodiya, K. Prajapat, M.L. Dotaniya, M. J. Kaledhonkar., P. C. Sharma, R.S. Meena, T. Mitran and S. Kumar (2018). Legume Green Manuring: An Option for Soil Sustainability. In: Meena R. et al., (eds) *Legumes for Soil Health and Sustainable Management*. Springer, Singapore, 387-408.

B.D. Sharma R. Kumar, B. Singh and M. Sethi (2009).Micronutrients distribution in salt-affected soils of the Punjab in relation to soil properties. *Arch. Agron. Soil Sci.*, 55: 367–377.

H Marschner (1995).Mineral nutrition of higher plants.Academic, San Diego, 889.

M. A. Maqsood, S. Hussain, T. Aziz and M Ashraf (2011). Wheat exuded organic acids influence zinc release from calcareous soils. *Pedosphere* 21:657–665.

A Walkley and CA Black (1934).Estimation of organic carbon by the chromic acid titration method.*Soil Science*. 47:29-38.

B Subbiah and G. L. Asija (1956).Alkaline Permanente method of available nitrogen determination. *Current Science*, 25: 259-260

S.R. Olsen, C.V. Cole, F.S. Watanabe, L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate.U.S. Department of Agriculture, Circular No 939, USA, 19p.

WL Lindsay and WA Norvell (1978).Development of DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci. Soc of Amer. J.*; 42:421-428.

M. L. Jackson (1973). *Soil Chemical Analysis*.Prentice Hall of India Pvt. Ltd., New Delhi.

Panse V.G. and P.V. Sukhatme (1985).*Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research Publication, 87-89.

J.K. Malav and V.R. Patel (2019). Effect of iron and zinc enriched FYM on growth, yield and quality of wheat (*Triticumaestivum* L) in salt affected soils. *International Journal of Current Microbiology and Applied Science*. 8(6): 2960-2969.

M.S. Zia, R. Khan, A.R. Gurmani and A.H. Gurmani (2007).Effect of Potassium application on crop yields under wheat-rice system.*Sarhad J. Agric.* 23 (2): 24-27.

R. Shaheen, M.K. Samin and R. Mahmud (2007). Effect of zinc on yield and zinc uptake by wheat on some soils of Bangladesh. *J. Soil Nat.*, 1(1): 07-14.

A.H. Ziaeyan and M. Rajaiea (2009).Combined effect of zinc and boron on yield and nutrients accumulation in corn. *J. Plant Prod.*, 3: 1735-8043.

G. Abbas, M.Q. Khan, M.J. Khan, F. Hussain and I. Hussain (2009). Effect of iron on the growth and yield contributing parameters of wheat (*Triticumaestivum* L.) *J. Anim. Plant Sci.*, 19(3): 135-139.

M. Bameri, R. Abdolshahi, G. Mohammadi-Ne jad, K. Yousefi and S.M. Tabatabaie. 2012. Effect of different microelement treatment on wheat (*Triticumaestivum* L.) growth and yield. *Int. Res. J. Appl. Basic Sci.*, 3 (1): 219 – 223.

B. Kholdebarin, and T. Islamzadeh (2012).*Mineral feeding of higher plants*.Trs., 1, Shiraz University Press, pp. 500.

M. Aown, S. Raza, M.F. Saleem, S.A. Anjum, T. Khaliq and M.A. Wahid (2012). Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticumaestivum* L.). *J. Anim. Plant Sci.*, 22 (2): 431 – 437.

A. Harris, G. Rashid, G. Miraj, M. Asif and H. Shah (2007). On-farm seed priming with zinc sulphate solution. A cost-effective way to increase the maize yield of resources of poor farmers. *Field Crop Res.*, 110: 119-127.

M.R. Karim, Y.Q. Zhang, R.R. Zhao, X.P. Chen, F.S. Zhang and C.Q. Zou (2012). Alleviation of drought stress in winter wheat by late foliar application of zinc, boron and manganese. *J. Plant Nutr.*, 175: 142 – 151. <https://doi.org/10.1002/jpln.201100141>

E. Niyigaba, A. Twizerimana, I. Mugenzi, W.A. Ngnadong, Y.P. Ye and B.M. Wu. (2019). Winter wheat grain quality, zinc and iron concentration affected by a combined foliar spray of zinc and iron fertilizers. *Agronomy*, 9(5): 250. <https://doi.org/10.3390/agronomy9050250>

B.S. Brar, J. Singh, G. Singh, G. Kaur (2015). Effects of long-term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. *Agronomy*, 5: 220–238.

Y.H. Duan, M.G. Xu, S.D. Gao, X.Y. Yang, S.M. Huang, H.B. Liu and B.R. Wang (2014). Nitrogen use efficiency in a wheat-corn cropping system from 15 years of manure and fertilizer applications. *Field Crops Research*, 157: 47–56.

S. Sheoran, D. Raj, R.S. Antil, V.S. Mor and D.S. Dahiya (2017). Productivity, seed quality and nutrient use efficiency of wheat (*Triticumaestivum*) under organic, inorganic and integrated nutrient management practices after twenty years of fertilization. *Cereal Research Communications*, 45: 315–325.

S. Sultana, H.M. Naser, N.C. Shil, S. Akhter and R.A. Begum (2016). Effect of foliar application of zinc on yield of wheat grown by avoiding irrigation at different growth stages. *Bangladesh J. Agric. Res.*, 41(2): 323 – 334. <https://doi.org/10.3329/bjar.v41i2.28234>

T.B. Roba, (2018) Review on: The effect of mixing organic and inorganic fertilizer on productivity and soil fertility. *Open Access Library Journal*, 5(6), 1.

M. Bodruzzaman, C.A. Meisner, M.A. Sadat and M.I. Hossain (2010). Long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern. In *Proceedings of the 19th World Congress of Soil Science*, (10-15).

G.K. Biratu, E. Elias, and P. Ntawuruhunga (2019). Soil fertility status of cassava fields treated by integrated application of manure and NPK fertilizer in Zambia. *Environ. Syst. Res.* 8(1), 1-13.

A. Mian, Y. Anwar, S. Khan, M. W. Muhammad, M. Mussarat, M. Tariq, A. Usman, B Khan, M. Adnan, K. Dawar, K. Ullah, J. Ali (2021). Integrated Influence of Phosphorus and Zinc Along with Farmyard Manure on the Yield and Nutrients Uptake in Spring Maize. *Egyptian Journal of Soil Science*. Egypt. *J. Soil. Sci.* 61 (2), 241-258.

M.D. Reddy, L.S. Rama, K.V. Rao, M Sitaramaya, G Padmaja, LT Raja (2006). Effect of long-term nutrient supply on soil chemical properties, nutrient uptake and yield of rice. *Indian Journal of Fertilizers*, 2:25-28.

O. Mulyani, E. Trinurani, R. Sudirja, B. Joy (2017). The Effect of Bio-fertilizer on Soil Chemical Properties of Sugarcane in PurwadadiSubang. 2nd International Conference on Sustainable Agriculture and Food Security: A Comprehensive Approach, *KnE Life Sciences*, 164-171.

R. Baziramakenga and R. R. Simrad (1998). Low molecular weight aliphatic acid contents of composted manure, *Journal of Environmental Quality* 27: 557–561. <https://doi.org/10.2134/jeq1998.00472425002700030012x>

S. Yadav, BL Yadav, A. K. Meena, A. Doodhwal, Poonam Kumari Yadav, P. C. Gurjar, Sunita Choudhary and Saroj Choudhary (2022). Effect of Zn and Fe enriched FYM on soil properties and yield attributes of cowpea [*Vigna unguiculata* (L.) Wilczek] under sodic water irrigation. *The Pharma Innovation Journal*, 11(2): 380-386.

Singh G, Walia SS, Singh S (2016). Interactive effect of organic and inorganic sources of nutrition on growth of baby corn and post-harvest soil properties. *Agricultural Research Journal*, 53:121-123.

A Banerjee, JK Datta, NK Mondal and T Chanda (2011). Influence of Integrated Nutrient Management on Soil Properties of Old Alluvial Soil under Mustard Cropping System. *Communications in Soil Science and Plant Analysis*, 42:2473–2492.

M. B. McBride (1982). Electron spins resonance investigation of Mn²⁺ complexation in natural and synthetic organics, *Soil Science Society of America Journal* 46: 1137–1143. <https://doi.org/10.2136/sssaj1982.03615995004600060004x>

S. Sauve, M. B McBride, W. A. Norvell and W. H. Hendershot (1997). Copper solubility and speciation of in situ contaminated soils: effects of copper level, pH and organic matter, *Water, Air, and Soil Pollution*, 100: 133–149. <https://doi.org/10.1023/A:1018312109677>

A. R. Almas, M. B. McBride and B. R. Singh (2000). Solubility and liability of cadmium and zinc in two soils treated with organic matter, *Soil Science* 165: 250–259. <https://doi.org/10.1097/00010694-200003000-00007>

K. M. Catlett, D. M. Heil and W. L Lindsay (2002). Ebinger MH. Soil chemical properties controlling zinc²⁺ activity in 18 Colorado soils, *Soil Science Society of America Journal* 66: 1182–1189. <https://doi.org/10.2136/sssaj2002.118>

W. Lindsay (1979). *Chemical equilibrium in soils*. New York, NY, USA: John Wiley and Sons.

Table-1 Growth and SPAD values of wheat as influenced by different treatments

Treatment	Plant height (cm)		SPAD	
	45DAS	60DAS	21DAS	45DAS
Control	42.75	53.44	28.19	30.42
5 t FYM ha ⁻¹	51.00	58.40	37.56	34.89
10 t FYM ha ⁻¹	46.15	48.10	36.88	42.52
5 kg Zn ha ⁻¹	56.60	65.70	32.32	34.57
10 kg Zn ha ⁻¹	51.00	59.25	31.61	32.80
5 t FYM ha ⁻¹ + 5 kg Zn ha ⁻¹	49.00	55.90	37.77	36.64
5 t FYM ha ⁻¹ + 10 kg Zn ha ⁻¹	57.95	65.75	39.66	34.95
10 t FYM ha ⁻¹ + 5 kg Zn	51.35	58.60	38.49	36.82
10 t FYM ha ⁻¹ + 10 kg Zn ha ⁻¹	51.90	59.60	40.64	36.71
SE(m)±	0.344	0.364	0.152	0.188
C.D. (P=0.05)	1.118	1.182	0.494	0.61

Table-2 Yield attributes and DMP as influenced by different treatments

Treatment	Yield attributes			Total DMP (g pot ⁻¹)	Grain wt (g pot ⁻¹)
	Spike Length (cm)	Spike Weight (g)	No of grains Spike ⁻¹		
Control	5.40	0.52	13.15	4.10	1.41
5 t FYM ha ⁻¹	6.40	0.72	18.90	6.11	2.40
10 t FYM ha ⁻¹	6.05	0.41	13.70	3.71	1.13
5 kg Zn ha ⁻¹	7.65	0.76	23.90	7.16	2.38
10 kg Zn ha ⁻¹	6.95	0.53	18.25	5.03	1.40
5 t FYM ha ⁻¹ + 5 kg Zn ha ⁻¹	6.90	0.72	12.85	5.58	2.50
5 t FYM ha ⁻¹ +10 kg Zn ha ⁻¹	6.15	0.54	16.55	5.60	1.88
10 t FYM ha ⁻¹ + 5 kg Zn	6.30	0.56	18.50	5.18	1.87
10 t FYM ha ⁻¹ +10 kg Zn ha ⁻¹	6.75	0.69	15.80	5.58	2.22
SE(m)±	0.143	0.01	0.1	0.129	0.077
C.D.(P=0.05)	0.465	0.031	0.32	0.42	0.251

Table-3 Zinc content in wheat as influenced by different treatments

Treatment	P (%)		Zn (mg kg ⁻¹)		Uptake of zinc (µg pot ⁻¹)	
	Grain	Straw	Grain	Straw	Grain	Straw
Control	0.32	0.04	27.35	3.80	49.02	8.65
5 t FYM ha ⁻¹	0.35	0.04	30.95	4.80	74.26	17.83
10 t FYM ha ⁻¹	0.34	0.09	33.98	10.03	60.66	34.55
5 kg Zn ha ⁻¹	0.37	0.07	41.63	10.28	98.82	49.21
10 kg Zn ha ⁻¹	0.37	0.05	48.95	9.35	68.30	33.99
5 t FYM ha ⁻¹ + 5 kg Zn ha ⁻¹	0.32	0.07	39.80	6.55	99.53	20.14
5 t FYM ha ⁻¹ +10 kg Zn ha ⁻¹	0.35	0.09	44.45	8.60	83.56	31.87
10 t FYM ha ⁻¹ + 5 kg Zn ha ⁻¹	0.36	0.08	35.75	7.63	66.67	25.29
10 t FYM ha ⁻¹ +10 kg Zn ha ⁻¹	0.37	0.09	35.10	5.58	77.66	18.77
SE(m)±	0.014	0.006	0.42	0.487	2.562	3.05
C.D.(P=0.05)	NS	0.021	1.362	1.58	8.312	9.896

Table-4. Soil fertility status as influenced by different treatments

Treatment	Physico chemical properties			Olsen-P (kg ha ⁻¹)	DTPA extractable Zn (mg kg ⁻¹)
	pH	EC	OC		

	(dSm ⁻¹)		(g kg ⁻¹)		
Control	7.40	0.32	5.88	16.84	0.32
5 t FYM ha ⁻¹	7.53	0.42	8.13	25.66	0.50
10 t FYM ha ⁻¹	7.42	0.35	7.88	22.98	0.40
5 kg Zn ha ⁻¹	7.70	0.41	8.75	27.17	0.38
10 kg Zn ha ⁻¹	7.74	0.42	7.88	21.15	0.63
5 t FYM ha ⁻¹ + 5 kg Zn ha ⁻¹	7.62	0.52	9.75	34.31	0.36
5 t FYM ha ⁻¹ + 10 kg Zn ha ⁻¹	7.75	0.53	11.63	35.19	0.67
10 t FYM ha ⁻¹ + 5 kg Zn ha ⁻¹	7.72	0.36	11.88	26.99	0.47
10 t FYM ha ⁻¹ + 10 kg Zn ha ⁻¹	7.69	0.32	9.75	27.09	0.44
SE(m)	0.028	0.03	0.574	2.1	0.034
C.D.	0.09	0.098	1.863	6.813	0.111