International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

Crossref

IJEP March 2026, 13(2): 01-06

Article IJEP6839a

Full Research

Natural Resource Management

Doi: HTTPS://DOI.ORG/10.23910/2/2026.6839a

Effect of Foliar Application of Micronutrients on Growth and Yield of Rice (*Oryza sativa* L.) and Soil Quality under SRI system

Muneesh Pal[1], Archana Verma[1*], Avdhesh Pratap Singh[1] and Sirazuddin[2]

[1]Dept. of Agricultural Chemistry and Soil Science, [2]Dept. of Agronomy, Amar Singh College, Lakhaoti, (Bulandshahr), Uttar Pradesh (203 407), India

Corresponding Author

Archana Verma
e-mail: varchana976@gmail.com

Article History

Received on 27th November, 2025
Received in revised form on 17th February, 2026
Accepted in final form on 05th March, 2026
Published on 11th March, 2026

Abstract

A field experiment was conducted during the *kharif* season (June–August) of 2023 to assess the effect of solo and combined foliar application of micronutrients on growth, yield, and soil nutrient status of rice (*Oryza sativa* L.). Eight treatments i.e., T_1: Control RDF, T_2: RDF+Foliar application of Zinc 0.5% at 30 DAT, T_3: RDF+Foliar application of Zinc 0.5% at 60 DAT, T_4: RDF+Foliar application of Iron 1.0% at 30 DAT, T_5: RDF+Foliar application of Iron 1.0% at 60 DAT), T_6: RDF+Foliar application of Zinc 0.5% and Iron 1.0% at 30 DAT, T_7: RDF+Foliar application of Zinc 0.5% and Iron 1.0% at 60 DAT, T_8: RDF+Foliar application of Zinc 0.5% and Iron 1.0% at 30 and 60 DAT, were taken in RBD with three replications. Results indicated that combined foliar application of zinc and iron significantly improved growth, yield, and soil nutrient status of rice compared to the control and individual applications. Treatment T_8 recorded the highest grain yield (590 kg ha^{-1}), straw yield (89.3 q ha^{-1}), and biological yield (147.3 q ha^{-1}). Soil available nitrogen, phosphorus, potassium, zinc, and iron were also significantly higher under T_8. The study concludes that foliar application of Zn and Fe at critical growth stages, along with soil application of RDF, was an effective strategy for enhancing rice productivity and improving soil fertility.

Keywords: Rice, zinc, iron, growth, yield

1. Introduction

Rice accounts for about 59.5% of food grain production and 39.5% of cereal production in India. India produces 275.68 million tons of food grains, with rice contributing 110.15 mt (Anonymous, 2026). However, only about 59% of consumer demand is met through domestic production, resulting in a considerable gap, that is bridged through imports (Anonymous, 2026). In 2022, approximately 9.2 mt of milled rice were imported at a cost of $3.9 billion (Anonymous, 2026). The World Health Organization highlights that sustainable agriculture is essential for ensuring proper nutrition and human health (Athar et al., 2020). Rice cultivation is highly water-intensive, causing depletion of water resources in major rice-growing countries, particularly India and China. Rice is cultivated through broadcasting, dibbling, or transplanting methods (Zhao et al., 2026). Among these, the System of Rice Intensification (SRI) has emerged as an efficient and sustainable methodology aimed at increasing rice yield while reducing water use and environmental impacts. SRI promotes improved crop management practices that enhance plant growth under limited resources (Stanslaus, 2025). Continuous increases in productivity since the Green Revolution have resulted in the gradual depletion of soil micronutrient reserves (Ouma et al., 2024). Deficiency of even a single essential micronutrient such as B, Cu, Fe, Mn, Mo, Ni, Zn, or Cl can significantly reduce crop yield. Often, yield reduction due to micronutrient deficiency occurs before visible symptoms appear (Das, 2014); however, farmers generally apply micronutrients only after symptoms are observed. Among micronutrients, zinc (Zn) and iron (Fe) are of global importance due to their role in plant growth, yield formation, and human nutrition (Thompson et al., 2022). Studies have shown that zinc fertilization improves dry matter production and grain yield of rice (Syed et al., 2016; Shivay et al., 2015). Adequate availability of Zn and Fe is necessary for improved crop growth and productivity (Ramanjaneyulu et al., 2021). Micronutrient deficiencies, referred to as "hidden hunger," affect nearly two billion people worldwide and contribute to diet-related health problems (Prom-u-thai et al., 2020). Application of iron and zinc enhances their concentration in rice grains and increases overall yield. These micronutrients may act as limiting factors even in the absence of visible deficiency symptoms. According to the law of maximum yield, crop response improves as each limiting factor is corrected, emphasizing the importance of balanced nutrient management. Zinc and iron deficiencies affect more than half of the world's population, impairing growth, development, and immune system function (Sidhu et al., 2020). With increasing intensification of agriculture, micronutrient management has become increasingly important and farmers aiming for higher yields and quality must focus on iron and zinc nutrition (Rao et al., 2019). Zinc is essential for auxin synthesis, protein production, seed development, and proper crop maturation, thereby improving yield and quality (Ashis et al., 2021). Iron plays a key role in chlorophyll activation and in the synthesis of proteins such as cytochromes involved in plant metabolism (Yadav et al., 2022). Improved agricultural practices focusing on nutritional balance further enhance productivity (Mauriya et al., 2024). Combined application of macro and micronutrients improves yield and crop quality (Venkatesh et al., 2021). Although iron and zinc deficiencies are difficult to correct through soil application, foliar application offers a rapid and effective alternative. Therefore, the present study aimed to evaluate the effect of foliar application of zinc and iron on the growth and yield of rice under the SRI System.

2. Materials and Methods

Field experiment was conducted during the *kharif* season (June–August) of 2023 at the research block of Amar Singh College, Lakhaoti (Bulandshahr), U.P. The experiment was laid out in a Randomized Block Design (RBD) keeping eight treatments i.e. T_1: Control, T_2: RDF+Foliar application of Zn 0.5% at 30 DAT, T_3: RDF+Foliar application of Zn 0.5% at 60 DAT, T_4: RDF+Foliar application of Fe 1.0% at 30 DAT, T_5: RDF+Foliar application of Fe 1.0% at 60 DAT, T_6: RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 DAT, T_7 : RDF+Foliar application of Zn 0.5% and Fe 1.0% at 60 DAT, T_8: RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 and 60 DAT and three replications. Twenty-five-day-old seedlings of rice variety PB1509 were transplanted at a spacing of 25 cm between rows and 25 cm within rows. Rice was fertilized with 120 kg N, 60 kg P_2O_5, 40 kg K_2O ha^{-1} through urea (46% N) as a source of nitrogen, di-ammonium phosphate (DAP) as a source of Phosphorus, and muriate of potash (60% K_2O) as a source of potassium, respectively. Full dose of Phosphorus and potassium and half dose of nitrogen was applied as a basal dose. The remaining half of the nitrogen was applied in two equal split doses at tillering and stem elongation stage. Foliar application of zinc sulphate as a source of zinc and ferrous sulphate as a source of iron were applied in different doses at 30, 60, and 90 days. Observations recorded on leaf area index, panicle length (cm), number of empty grains, number of filled grains, test weight (g), grain yield, straw yield, biological yield, and Harvest Index. The data were collected on five randomly selected plants the data were subjected to statistical analysis.

2.1. Soil characteristics

A composite soil sample from a depth of 15 cm, representing the soil of the experimental plot, was collected. The collected sample was subjected to chemical analysis to check initial nutrient status of soil (Table 1). Composite soil sample was subjected to mechanical analysis that showed the soil is sandy loam with 66.5% sand, 12,4% silt and 20.4% clay.

Table 1: Initial nutrient status of soil

Particulars	Value
pH	7.4
EC (ds m^{-2})	0.61
Organic carbon (%)	0.38
Available N (kg ha^{-1})	179.1
Available P (kg ha^{-1})	8.8
Available K (kg ha^{-1})	147.3
Available Zn (ppm)	1.56
Available Fe (ppm)	3.75
Bulk Density (g cc^{-1})	1.28

After harvesting of the crop, soil samples were collected from each plot then subjected to laboratory analysis following standard procedures after sample processing. The soil samples were analyzed for pH and EC in 1:2 soil-water suspension (Jackson, 1973). The organic carbon content was determined by procedure outlined by Walkley and Black, 1934. Available nitrogen in soil was estimated by alkaline $KMnO_4$ method. Available phosphorus in soil was estimated by the procedure outlined by Olsen et al., 1954. Available K in soil was estimated by the producer outlined by Hanway and Heidal, 1952, using flame photometer. Available zinc and iron in soil was extracted by DTPA reagent and estimated by atomic absorption spectrophotometer as outlined by Lindsay and Norwell (1978).

3. Results and Discussion

In the present study, foliar application of zinc (Zn) and iron (Fe) exhibited a significant impact on the growth and yield attributes of rice as well as soil health.

3.1. Effect on growth attributes

Growth attributes, *viz*. plant height, leaf area index, and number of tillers, and yield attributes, *viz.* panicle length, number of empty grains, and number of filled grains, were significantly affected by Zn and Fe application (Table 2 and Table 3).

The leaf area index at 30 DAT was found significantly higher under the effect of T_7 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 60 DAT), which was at par with T_3 (RDF+Foliar application of Zn 0.5% at 60 DAT), T_4 (RDF+Foliar application

Table 2: Effect of foliar application of zinc and iron on growth attributes of rice crop

Treatments	Plant height (cm)	Leaf area index (cm)	Number of tillers
T_1	107.5	3.0	15.4
T_2	102.8	3.3	20.3
T_3	100.8	3.5	15.9
T_4	104.4	3.2	18.6
T_5	105.6	3.6	21.3
T_6	105.2	4.3	18.5
T_7	103.4	4.2	19.2
T_8	110.5	4.5	21
SEm±	4.52	0.276	1.1
CD (*p*=0.05)	NS	0.846	3.4

of Fe 1.0% at 30 DAT), T_5 (RDF+Foliar application of Fe 1.0% at 60 DAT), T_6 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 DAT) and T_8 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 and 60 DAT). The panicle length after harvesting was found significantly higher under the effect of T_8 (RDF+Foliar application of Zinc 0.5% and Fe 1.0% at 30 and 60 DAT), while the minimum panicle length was recorded under T_1 (Control). The number of filled grains per panicle was found significantly higher under the effect of T_8 (RDF+Foliar application of Zinc 0.5% and Fe 1.0% at 30 and 60 DAT). The lowest straw yield was recorded under T_1 (Control). The test weight after harvesting was found significantly higher under the effect of T_5 (RDF+Foliar application of Fe 1.0% at 60 DAT), which was at par to T_4 (RDF+Foliar application of Zn 0.5% at 30 DAT) and T_8 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 and 60 DAT). The lowest test weight was recorded under T_2 (RDF+Foliar application of Zn 0.5% at 30 DAT). The improvement in crop growth in rice might had caused by an adequate supply of zinc, which in turn might had increased the availability and uptake of other essential nutrients. Foliar application significantly increased the concentration of Zn and Fe in rice seed, both in paddy and other crops. Similar results were also found in the previous studies, wherein foliar Zn application increased the Zn concentration in seed up to three times more than no Zn application (Zaman et al., 2018). Zinc played a significant role in mitigating water stress by influencing physiological and molecular mechanisms such as abscisic acid-regulated stomatal behavior and improved antioxidant defense systems. This further improved the yield of crop. Similar results were also found by Sattar et al., 2022. Zn and Fe also play very important role in regulating many cellular process like chlorophyll synthesis and deficiency of these nutrients further lead to decreased cellular metabolism which affect plant yield (Shoormij et al., 2022).

3.2. Effect on yield studies

3.3. Effect on soil nutrient status

The effect of foliar application of micronutrients on soil quality is presented in table 4. Treatment T_8 showed significantly higher organic carbon content (0.38 %), which was 22.5% higher than the control. Similarly, available nitrogen (N) was also found significantly higher under T_8 (155.3 kg ha^{-1}), while lower available N was recorded under T_1 (control). Available phosphorus (P) in the soil after harvesting was found to be significantly higher under T_8 (RDF+Foliar application of Zinc 0.5% and Fe 1.0% at 30 and 60 DAT), which was at par with T_6 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 DAT) and T_7 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 60 DAT). The lowest available phosphorus was recorded under T_1 (Control). Available potassium (K) in the soil after harvesting was found significantly higher under the effect of T_8, which was at par to T_4, T_5, T_6 and T_7. The lowest available potassium was recorded under T_1 (Control).

Available zinc of the soil after harvesting was found significantly

Table 3: Effect of foliar application of zinc and iron on yield attributes and yield

Treatments	Yield attributes			Yield studies			
	Panicle length (cm)	Number of filled grains	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	H.I. (%)
T_1	22.9	75.3	19.3	455.0	6.26	11.8	26.4
T_2	25.7	80.8	18.6	476.0	6.80	12.0	32.8
T_3	28.4	82.8	20.0	501.0	7.35	11.9	34.5
T_4	29.6	84.6	21.6	515.0	7.93	13.3	37.2
T_5	31.3	86.9	23.6	539.0	8.24	13.1	35.2
T_6	30.2	88.5	21.3	561.0	8.33	13.3	37.7
T_7	30.6	92.7	21.0	538.0	8.47	13.0	37.7
T_8	31.4	100.6	23.3	590.0	8.93	14.7	39.1
SEm±	0.91	1.456	0.6	0.971	0.515	2.97	1.373
CD (*p*=0.05)	2.788	4.46	2.0	2.97	1.579	9.107	4.204

Table 4: Effect of foliar application of zinc and iron on soil quality after harvest of rice

Treatments	Organic Carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available zinc (ppm)	Available Iron (ppm)
T_1	0.31	136.3	13.6	220.6	1.58	3.8
T_2	0.33	138.6	12.7	225.8	1.62	4.2
T_3	0.34	144.5	11.8	228.3	1.61	4.8
T_4	0.35	145.8	16.4	234.7	1.65	4.5
T_5	0.35	146.7	17.1	237.1	1.72	4.3
T_6	0.36	150.2	17.9	238.2	1.89	5.9
T_7	0.36	153.2	18.6	241.8	1.97	6.3
T_8	0.38	155.3	19.5	242.5	2.02	6.4
SEm±	0.005	0.432	0.611	2.899	0.057	0.164
CD (p=0.05)	0.015	1.324	1.872	8.878	0.174	0.502

higher under the effect of T_8 (2.02 ppm), which was at par with T_6 (1.89 ppm) and T_7 (1.97 ppm). The lowest available zinc was recorded under T_1 (1.58 ppm). Available iron in soil after harvesting was found to be significantly higher under T_8 (6.4 ppm), which was at par with T_6 (5.9 ppm) and T_7 (6.3 ppm). The lowest available zinc was recorded under T_1 (3.8 ppm).

Application of Zn and Fe significantly increased nitrogen and potassium content in soil compared to the control. This may had attributed to the combined effect of macronutrients and micronutrients. Due to the antagonistic interaction of Zn and P, treatments with foliar application zinc exhibited comparatively lower phosphorus availability in soil. These findings were in agreement with those reported by Wahane et al. (2022). Increase in N and K contents with foliar application of Zinc 0.5% and Fe 1.0% at 30 and 60 DAT might be due to higher microbial activity in those plots in comparison to the control, which further led to significant mineralization of applied and inherent nutrients, as well as due to the synergistic effect of Zn on nitrogen content in the soil. The application of iron significantly increased the available N content in soil due to its synergistic effect on soil nitrogen content. Some nitrogen as amino acids in soil, which further increased the nitrogen content of the soil. These findings were also aligned with the study done by Daphade et al. (2019). The higher Zn content of the soil in the zinc-enriched treatments was ascribed to the varying zinc fertilizer amounts, which may have added more Zn to the soil pool. The application of iron in the form of iron sulfate topically resulted in increased iron availability. Similar results were also found by Zaman et al. (2018), and Liu et al. (2023).

4. Conclusion

The combined foliar application of $ZnSO_4$+$FeSO_4$ in treatment T_8 (RDF+Foliar application of Zn 0.5% and Fe 1.0% at 30 and 60 DAT)was an effective practice for enhancing rice growth, yield, yield attributing parameters and soil nutrient status such as available N, P, K, Zn and Fe. These parameters showed significantly higher responses under the effect of foliar spray of Zn and Fe. However, as the conclusion is drawn from a one-year experiment, further multi-season and multi-location studies are required before making generalized recommendations.

6. Reference

Anonymous, 2026. Agriculture Statistics -At a Glance, Economics, Statistics and evaluation division, Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. Available at: https://desagri.gov.in/document-report-category/agriculture-statistics-at-a-glance// Accessed on 2nd February, 2026.

Anonymous, 2026. Semi-milled or wholly milled rice imports by country in 2022, World Integrated Trade Solution. Available at https://wits.worldbank.org/trade/comtrade/en/country/ALL/year/2022/tradeflow/Imports/partner/WLD/product/100630. Accessed on 2nd February, 2026.

Ashis, M., Nilesh, G., Dinesh, B.K., Ananta, S., Prakash, P., 2021. Impact of zinc and boron foliar application on fruit yield, nutritional quality and quality and oil content of three pomegranate (*Punica granatum L. granatum* L.) cultivars. Journal of Plant Nutrition 14(13), 1841–1852. https://ui.adsabs.harvard.edu/link_gateway/2021JPlaN.44.1841M/doi:10.1080/01904167.2021.1884711.

Athar, T., Khan, M.K., Pandey, A., Yilmaz, F.G., Hamurcu, M., Hakki, E.E., Gezgin, S., 2020. Biofortification and the involved modern approaches. Journal of Elementology 25, 717–731. https://doi.org/10.5601/jelem.2020.25.1.1911.

Daphade, S.T., Hanwate, G.R., Gourkhede, P.H., 2019. Influence of Zn, Fe and B applications on nutrient availability in soil at critical growth stages of maize (*Zea mays*) in Vertisol of Marathawada region of Maharashtra, India. International Journal of Current Microbiology and Applied Sciences 8, 206–212. DOI: https://doi.org/10.20546/ijcmas.2019.801.022.

Das, S.K., 2014. Role of micronutrient in rice cultivation and management strategy in organic agriculture-a reappraisal. Agricultural Sciences 5(9), 765–769. DOI: 10.4236/as.2014.59080.

Hanway, J.J., Heidel, H., 1952. Soil analysis methods as used in the Iowa State College Soil Testing Laboratory. Iowa Agriculture 57, 1–31. DOI: 10.12691/ajwr-7-1-5.

Jackson, M.L., 1973. Soil chemical analysis. Verlag: Prentice Hall, Inc., Englewood Cliffs, NJ. 1958, 498 S. DM 39.40. 10.1002/JPLN.19590850311.

Lindsay, W.L., Norvell, W.A.W.A., 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Science Society of America Journal 42(3), 421–428. https://doi.org/10.2136/sssaj1978.03615995004200030009x.

Liu, L., Cong, W.F., Suter, B., Zhang, F., van der Werf, W., Stomph, T.J., 2023. How much can Zn or Fe fertilization contribute to Zn and Fe mass concentration in rice grain? A global meta-analysis. Field Crops Research 301, 109033. https://doi.org/10.1016/j.fcr.2023.109033.

Mauriya, A.K., Mohammad, H., Verma, R.B., Kumar, P., Kumari, M., Sahu, R., Verma, R.K., Maurya, V.K., 2025. Evaluation of *rabi* maize-based intercropping system for augmenting the productivity and profitability of rabi maize under irrigated conditions of Bihar. Indian Journal of Agricultural Research 59(7), 1131–1135. doi: 10.18805/IJARe.A-6213.

Olsen, S.R., Cole, C.V., Watanabe, F.S., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939, US Government Printing Office, Washington DC. OCLC no: 17316676. https://www.scirp.org/reference/referencespapers?referenceid=1117235.

Ouma, M.A., Ouma, L.O., Ombati, J.M., Onyango, C.A., 2024. A cost benefits analysis of the adoption of system of rice intensification: Evidence from smallholder rice farmers within an innovation platform in Oluch irrigation scheme, Kenya. PLOS ONE 19(11), e0314580. https://doi.org/10.1371/journal.pone.0314580.

Prom-u-thai, C., Rashid, A., Ram, H., Zou, C., Guilherme, L.R.G., Corguinha, A.P.B., Guo, S., Kaur, C., Naeem, A., Yamuangmorn, S., Ashraf, M.Y., Sohu, V.S., Zhang, Y., Martins, F.A.D., Jumrus, S., Tutus, Y., Yazici, M.A., Cakmak, I., 2020. Simultaneous biofortification of rice with zinc, iodine, iron and selenium through foliar treatment of a micronutrient cocktail in five countries. Front Plant Science 11, 589835. https://doi.org/10.3389/fpls.2020.589835.

Ramanjaneyulu, A.V., Kumar, M.V.N., Neelima, T.L., 2021. Response of rainfed castor to soil and foliar application of zinc and iron micronutrients. International Journal of Bio-resource and Stress Management 12(3), 158–164. https://doi.org/10.23910/1.2021.2196.

Rao, S., Immanuel, R., Ramesh, S., Baradhan, G.G., Kumar, S.M.S., 2019. Effect of zinc and iron fertilization on growthandgrowth and development of rice. Plant Archives 19(2), 1877–1880. Available at: https://www.researchgate.net/publication/337400030_effect_of_zinc_and_iron_fertilization_on_growth_and_development_of_rice.

Sattar, A., Wang, X., Ul-Allah, S., Sher, A., Ijaz, M., Irfan, M., Abbas, T., Hussain, S., Nawaz, F., Al-Hashimi, A., Al Munqedhi, B.M., Skalicky, M., 2022. Foliar application of zinc improves morpho-physiological and antioxidant defense mechanisms, and agronomic grain biofortification of wheat (*Triticum aestivum* L.) under water stress. Saudi Journal of Biological Sciences 29(3), 1699–1706. DOI: 10.1016/j.sjbs.2021.10.061.

Shivay, Y.S., Prasad, R., Singh R.K., Pal, M., 2015. Relative efficiency of zinc-coated urea and soil and foliar application of zinc sulphate on yield, nitrogen, phosphorus, potassium, zinc and iron biofortification in grains and uptake by basmati rice (*Oryza sativa* L.). Journal of Agricultural Science 7(2), 161–173. Available at: https://www.ccsenet.org/journal/index.php/jas/article/view/40999.

Shoormij, F., Mirlohi, A., Saeidi, G., Shirvani, M., 2022. Combined foliar application of Zn and Fe increases grain micronutrient concentrations and alleviates water stress across diverse wheat species and ploidal levels, Scientific Reports 12, 20328. https://doi.org/10.1038/s41598-022-24868-1.

Sidhu, M.K., Raturi, H.C., Singh, S.K., Bora, L., Shukla, Y., 2020. Effect of foliar application of boron, iron, and zinc on growth, yield, and economics of cucumber grown under naturally ventilated polyhouse conditions. Vegetable Science 47(01), 110–115. https://doi.org/10.61180/vegsci.2020.v47.i1.19.

Stanslaus, T.M., 2025. Comprehensive review of the system of rice intensification to enhance productivity and environmental sustainability in major rice producing countries. Discover Food 5, 358. https://doi.org/10.1007/s44187-025-00648-4.

Syed, T., Anwar, B.M., Ashaq, H., Ganai Manzoor, A., Teli, N.A., 2016. Effect of levels and sources of zinc on growth, yield and economics of rice (*Oryza sativa*) under temperate conditions. Indian Journal of Agronomy 61(2), 186–190. DOI: https://doi.org/10.59797/ija.v61i2.4367.

Thompson, S.M.D., Sayer, E.J., 2022. Micronutrients in food production: what can we learn from natural ecosystems? Soil System 6(1), 8. DOI: doi.org/10.3390/soilsystems6010008.

Venkatesh, U., Sharma, A., Ananthan, V.A., Subbiah, P., Durga, R., 2021. Micronutrient's deficiency in India: A systematic review and meta-analysis. Journal of Nutritional Science 10, e110. https://doi.org/10.1017/jns.2021.102.

Wahane, M.R., Bedse, T.J., Jondhale, D.G., Dodake, S.B., 2022. Effect of zinc application on yield, nutrients uptake and biochemical properties of rice under Inceptisols. ORYZA – An International Journal on Rice 59(4), 435–442. https://doi.org/10.35709/ory.2022.59.4.6.

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. http://dx.doi.org/10.1097/00010694-193401000-00003.

Yadav, D.K., Meena, Y.K., Deewan, P., Gupta, D., 2022. Effect of foliar application of micronutrients on yield and quality of pomegranate. International Journal of Bio-resource and Stress Management 13(9), 914–920. HTTPS://DOI.ORG/10.23910/1.2022.2733.

Zaman, Q., Aslam, Z., Yaseen, M., Ishan, M.Z., Khaliq, A., Fahad, S., Bashir, S., Ramzani, P.M.A., Naeem, M., 2018. Zinc biofortification in rice: leveraging agriculture to moderate hidden hungerinhunger in developing countries. Archives of Agronomy and Soil Science 64, 2, 147–161, DOI: 10.1080/03650340.2017.1338343.

Zhao, J., Wu, L., Wang, X., Yu, Y., Huang, K., 2026. High-resolution water footprints of major crops in China from cities to grids. Scientific Reports 16, 46. https://doi.org/10.1038/s41598-025-08906-2.

