Archives of Current Research International

Volume 24, Issue 9, Page 347-355, 2024; Article no.ACRI.123831
ISSN: 2454-7077

Evaluation of Nano-Zn, Inorganic, and Organic Nutrient Management Strategies and Their Effects on Growth Indices in *Kharif* Maize (*Zea mays* L.)

Shikhar Verma [a++*], D. D. Yadav [a#], V. K. Verma [a#], M. Z. Siddiqui [a#], Ravindra Kumar [b#], Sarvesh Kumar [c#], Shravan Kumar Maurya [a++], Mandeep Kumar [a++] and Sunil Kumar Prajapati [d++]

[a] Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology Kanpur, Uttar Pradesh, India.
[b] Department of Soil Science & Agricultural Chemistry, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology Kanpur, Uttar Pradesh, India.
[c] Department of Soil Conservation and Water Management, Chandra Shekhar Azad University of Agriculture and Technology Kanpur, Uttar Pradesh, India.
[d] Division of Agronomy, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi-110012, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/acri/2024/v24i9899

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/123831

Original Research Article

Received: 22/07/2024
Accepted: 25/09/2024
Published: 26/09/2024

[++] Ph.D Scholar;
[#] Professor;
**Corresponding author: Email: shikharsaurabh@gmail.com;*

Cite as: *Verma, Shikhar, D. D. Yadav, V. K. Verma, M. Z. Siddiqui, Ravindra Kumar, Sarvesh Kumar, Shravan Kumar Maurya, Mandeep Kumar, and Sunil Kumar Prajapati. 2024. "Evaluation of Nano-Zn, Inorganic, and Organic Nutrient Management Strategies and Their Effects on Growth Indices in Kharif Maize (Zea Mays L.)". Archives of Current Research International 24 (9):347-55. https://doi.org/10.9734/acri/2024/v24i9899.*

ABSTRACT

The investigation was carried out during the *Kharif* seasons of 2022 and 2023 at the Students' Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. To assess the impact of various nutrient management strategies, including Nano-Zn, inorganic, and organic methods, on the growth and yield of *Kharif* maize. A Split-Plot Experimental design was employed, incorporating three replications. Organic manures-specifically a control, farmyard manure (FYM) applied at 10 t/ha, and vermicompost applied at 5 t/ha-were assigned to the main plots. Meanwhile, nutrient management treatments (including a control, 75% RDF, 75% RDF + $ZnSO_4$, 75% RDF + Nano-Zn, 100% RDF, 100% RDF + $ZnSO_4$, and 100% RDF + Nano-Zn) were allocated to the sub-plots. The maize variety chosen for the study was DKC-9144. The soil at the experimental site was characterized by a sandy loam texture, with a pH ranging from 7.72 to 7.67, a bulk density of 1.37 Mg/m^3, and organic carbon levels between 0.43% and 0.44%. The location of the site is within the Indo-Gangetic Plain, which is typified by a subtropical climate and an average annual rainfall of about 890 mm. Throughout the experiment, data were collected on key growth parameters such as the crop growth rate (CGR), relative growth rate (RGR), and absolute growth rate (AGR) at different stages of maize development (30-60 days after sowing, 60-90 days after sowing, and from 90 days after sowing until harvest). Results indicated that the treatment involving 100% RDF combined with Nano-Zn at 10 ml/litre produced the highest growth rates, while 100% RDF + $ZnSO_4$ also showed significant results. Among the organic treatments, vermicompost at 5 t/ha proved to be more effective than FYM, highlighting the superior role of Nano-Zn and advanced nutrient management practices in promoting the growth and yield of *Kharif* maize.

Keywords: Nano-zinc; vermicompost; FYM; nutrient; maize.

1. INTRODUCTION

Maize (*Zea mays* L.), commonly referred to as corn, is one of the most widely cultivated and essential cereal crops globally, serving as a staple food for many regions. In India, particularly during the *Kharif* season when it is primarily grown under rainfed conditions, maize holds considerable importance in the agricultural economy. However, *maize* productivity faces significant challenges due to inadequate soil fertility and improper nutrient management practices. As the demand for sustainable agricultural methods continues to rise, there is increasing emphasis on enhancing crop productivity without compromising soil health, a focus that agronomists and researchers are committed to addressing [1]. Globally, maize is cultivated on approximately 207.25 million hectares, spread across 160 countries, with a total production of 1,217.30 million tonnes and an average global yield of 5.87 metric tonnes per hectare [2]. In India, maize is the third most significant cereal crop, following rice and wheat, grown over an area of 10.10 million hectares, yielding 33.60 million tonnes with an average yield of 3.33 metric tonnes per hectare [2]. Specifically in Uttar Pradesh, maize is cultivated on about 0.73 million hectares, resulting in 1.53 million tonnes of production with an average productivity rate of 2,095.8 kg per hectare [3].

Nutrient management is a critical factor in determining the growth and yield of *Kharif* maize. It can be categorized broadly into three main types: inorganic, organic, and nano-fertilizers. Inorganic fertilizers, such as the well-known NPK (Nitrogen, Phosphorus, and Potassium) combinations and zinc sulphate ($ZnSO_4$), have long been utilized in conventional agriculture due to their ability to supply essential nutrients that drive plant growth. However, the excessive application of inorganic fertilizers can lead to negative consequences such as soil degradation, loss of biodiversity, and environmental pollution. In contrast, organic nutrient sources like farmyard manure (FYM) and vermicompost provide a more sustainable approach to nutrient management [4]. These organic inputs not only enhance soil structure and promote microbial activity but also offer a slow-release mechanism for nutrients, leading to improved long-term soil fertility.

The advent of nanotechnology in agriculture has opened up new avenues for optimizing nutrient management, with nano-formulations, such as nano-zinc (Nano-Zn), representing one of the most promising advancements. Nano-Zn enhances the availability and uptake of zinc, which is an essential micronutrient playing a key role in enzyme function, protein synthesis, and the regulation of plant growth hormones [5]. The

use of Nano-Zn has demonstrated potential in improving nutrient use efficiency, reducing the overall need for fertilizers, and minimizing the environmental impacts of agricultural practices. A synergistic approach combining inorganic, organic, and nano-fertilizers holds significant promise for nutrient management [6]. By integrating these diverse sources of nutrients, farmers and researchers can achieve enhanced soil fertility, increased nutrient uptake efficiency, and better growth indices in maize, including improvements in plant height, leaf area, chlorophyll content, and biomass accumulation. However, the specific effects of various combinations of these nutrient management strategies on maize growth and yield during the *Kharif* season are not yet fully understood and remain an important area for future research.

2. MATERIALS AND METHODS

The experiment was carried out during the years 2022 and 2023 at the Students' Instructional Farm, under the Department of Agronomy at Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. A split-plot design was implemented, where organic manures were assigned to the main plots, and various nutrient management practices were assigned to the sub-plots. The geographical coordinates of the experimental site lie between 25°26' to 26°58' North latitude and 79°31' to 31°34' East longitude, situated at an altitude of 125.9 meters above sea level, within the alluvial Indo-Gangetic Plain region of central Uttar Pradesh. The soil texture was classified as silt loam, with sand content measuring 24.86% in 2022 and 24.88% in 2023, silt content at 53.94% and 53.97%, and clay content at 21.20% and 21.19%, respectively. The particle density was recorded as 2.56 Mg/m^3 in 2022 and 2.55 Mg/m^3 in 2023, with bulk densities of 1.37 Mg/m^3 and 1.36 Mg/m^3, respectively. The soil pH was slightly alkaline, measuring 7.72 in 2022 and 7.67 in 2023, and the organic carbon content was 0.43% in 2022 and 0.44% in 2023. Electrical conductivity was found to be 5.4 dSm^{-1} in 2022 and 5.3 dSm^{-1} in 2023. The available nitrogen content was 135.40 kg/ha and 138.25 kg/ha in the respective years, with phosphorus (P_2O_5) levels of 13.50 kg/ha and 14.28 kg/ha, potassium (K_2O) levels of 210.45 kg/ha and 214.25 kg/ha, and zinc levels of 77.01 g/ha and 78.32 g/ha. The region is characterized by a sub-tropical climate, with an average annual rainfall of approximately 890 mm, predominantly occurring from mid-June to September. During the crop-growing period, the seasons were marked by cold and dry winters, with occasional frost. Meteorological data indicated variations in mean weekly maximum and minimum temperatures, ranging from 29.3°C to 37.7°C and 16.0°C to 28.5°C in 2022, and 31.4°C to 35.6°C and 14.5°C to 28.9°C in 2023. The main plot treatments consisted of three organic manure applications: control (O1), farmyard manure (FYM) at 10 t/ha (O2), and vermicompost at 5 t/ha (O3). The sub-plots involved seven different nutrient management treatments: control (M1), 75% recommended dose of fertilizer (RDF) at 120:60:60 NPK kg/ha (M2), 75% RDF + $ZnSO_4$ at 25 kg/ha (M3), 75% RDF + Nano-Zinc at 10 ml/liter (M4), 100% RDF (M5), 100% RDF + $ZnSO_4$ at 25 kg/ha (M6), and 100% RDF + Nano-Zinc at 10 ml/liter (M7). The maize variety used in this experiment was DKC (DEKALB)-9144, a full maturity hybrid from Bayer Crop Science Ltd., which is suitable for both rainfed and irrigated conditions, with a yield potential of 74-86 q/ha and a maturity duration of 105-115 days. The estimation of Crop Growth Rate (CGR), Relative Growth Rate (RGR), and Absolute Growth Rate (AGR) for maize during the stages of 30-60 DAS, 60-90 DAS, and 90 DAS to harvest was carried out by collecting plant dry matter at each interval. CGR was calculated using the formula: $CGR = (W2 - W1) / (T2 - T1)$, where W1 and W2 represent the dry weights at times T1 and T2, respectively. RGR was determined using the formula: $RGR = (\ln W2 - \ln W1) / (T2 - T1)$, where W1 and W2 are the dry weights of plants at times T1 and T2. AGR was estimated by using the formula: $AGR = (W2 - W1) / (T2 - T1)$, reflecting the actual increase in biomass over time. These growth parameters were measured to assess the effect of nutrient treatments on maize performance.

3. RESULTS AND DISCUSSION

3.1 Crop Growth Rate

The results presented in (Table 1) illustrate the significant effects of Nano-Zn, inorganic, and organic nutrient management practices on the Crop Growth Rate (CGR) of Kharif maize during different growth stages in the 2022 and 2023 seasons. The organic manure treatments showed that vermicompost at 5 t/ha produced the highest CGR across all stages, with pooled values of 0.645 g/m^2/day at 30-60 DAS, 0.570 g/m^2/day at 60-90 DAS, and 0.263 g/m^2/day from 90 DAS to harvest, outperforming both FYM and the control. FYM at 10 t/ha also improved growth compared to the control, indicating the beneficial effects of organic matter in enhancing soil

fertility. Among the nutrient management treatments, 100% RDF combined with Nano-Zn at 10 ml/litre significantly outperformed other treatments, with pooled CGR values of 0.696 g/m²/day at 30-60 DAS, 0.582 g/m²/day at 60-90 DAS, and 0.287 g/m²/day from 90 DAS to harvest, demonstrating the superior efficiency of Nano-Zn in promoting nutrient uptake and growth. The next best performance was observed with 100% RDF + ZnSO4 at 25 kg/ha, with pooled values of 0.678 g/m²/day at 30-60 DAS and 0.574 g/m²/day at 60-90 DAS, showing that conventional ZnSO4 application also contributed positively to crop growth, though it was less effective than Nano-Zn. Control treatments consistently resulted in the lowest CGR, underscoring the critical role of nutrient supplementation in achieving optimal maize growth. Although both organic and inorganic nutrient management practices independently impacted growth, no significant interactions between them were observed. The study highlights that 100% RDF with Nano-Zn at 10 ml/litre was the most effective treatment for enhancing maize growth, and vermicompost at 5 t/ha proved to be the best organic manure for improving CGR, emphasizing the importance of integrated nutrient management in maximizing maize productivity [7,8,9,10].

3.2 Relative Growth Rate

The results presented in the (Table 2) on the relative growth rate (RGR) of Kharif maize under different organic and inorganic nutrient management practices show noticeable trends across the two years of study, 2022 and 2023. Among the organic manure treatments, vermicompost at 5 t/ha consistently demonstrated slightly higher RGR values compared to the control and FYM treatments, although the differences between FYM and vermicompost were minimal. For instance, the pooled RGR at 30-60 DAS for vermicompost was 0.034 g/g/day, which was slightly higher than the control (0.032 g/g/day). This trend continued through the 60-90 DAS stage and from 90 DAS until harvest, where vermicompost and FYM produced higher RGR values than the control, highlighting the positive impact of organic manure on plant growth. Regarding the nutrient management treatments, 100% RDF combined with Nano-Zn at 10 ml/litre yielded the highest RGR values across all growth stages, with a pooled RGR of 0.035 g/g/day at 30-60 DAS, 0.008 g/g/day at 60-90 DAS, and 0.003 g/g/day from 90 DAS to harvest, outperforming all other treatments. The next best performer was 100% RDF + ZnSO4 at 25 kg/ha, showing that zinc supplementation whether in its nano or conventional form-enhanced growth over the control and 75% RDF treatments. The control treatments, both for organic manures and nutrient management, consistently recorded the lowest RGR values, particularly in the later growth stages, indicating the necessity of nutrient supplementation for optimal maize growth. While there were some variations between treatments, the application of 100% RDF with Nano-Zn was the most effective strategy for maximizing the relative growth rate of Kharif maize [11,12,13,14].

3.3 Absolute Growth Rate

The results of the study on the absolute growth rate (AGR) of Kharif maize reveal a significant impact of Nano-Zn, inorganic, and organic nutrient management practices during the 2022 and 2023 seasons (Table 3). Among the organic manure treatments, vermicompost at 5 t/ha consistently resulted in the highest AGR across all growth stages, with pooled values of 4.302 g/plant/day at 30-60 DAS, 3.797 g/plant/day at 60-90 DAS, and 1.753 g/plant/day from 90 DAS to harvest, outperforming the control and FYM treatments. FYM at 10 t/ha also significantly improved the AGR compared to the control, highlighting the positive effects of organic amendments on crop growth. In the case of nutrient management, 100% RDF combined with Nano-Zn at 10 ml/litre emerged as the most effective treatment, producing the highest AGR values, with pooled rates of 4.641 g/plant/day at 30-60 DAS, 3.882 g/plant/day at 60-90 DAS, and 1.916 g/plant/day from 90 DAS to harvest. This was followed by the treatment of 100% RDF + $ZnSO_4$ at 25 kg/ha, which also showed notable improvements in AGR, indicating the beneficial role of zinc supplementation, particularly in its nano form, in enhancing plant growth. Control treatments, both for organic manure and nutrient management, consistently resulted in the lowest AGR, especially during the later stages of growth, underscoring the critical importance of nutrient inputs for optimal crop performance. No significant interactions were observed between organic and nutrient management practices. The application of 100% RDF with Nano-Zn at 10 ml/litre proved to be the most effective for maximizing maize growth, followed closely by the combination of 100% RDF and $ZnSO_4$, while vermicompost was the most beneficial organic manure [15,16,17].

Table 1. Studies of Nano- Zn, inorganic and organic nutrient management practices on Crop Growth rate (g/m^2/day) of *kharif* Maize

Treatment	Crop Growth Rate at 30-60 DAS			Crop Growth Rate at 60-90 DAS			Crop Growth Rate 90 DAS - at Harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Organic Manures (Main plot)									
Control	0.476	0.491	0.484	0.533	0.523	0.528	0.195	0.206	0.201
FYM -10 t/ha	0.598	0.613	0.605	0.567	0.560	0.564	0.259	0.270	0.264
Vermi Compost- 5 t/ha	0.637	0.654	0.645	0.575	0.565	0.570	0.258	0.268	0.263
SE(d) ±	**0.007**	**0.007**	**0.007**	**0.005**	**0.005**	**0.005**	**0.004**	**0.004**	**0.004**
CD (P=0.05)	**0.019**	**0.019**	**0.019**	**0.014**	**0.014**	**0.014**	**0.010**	**0.010**	**0.010**
Nutrient Management (Sub plot)									
Control	0.425	0.44	0.433	0.527	0.517	0.522	0.108	0.122	0.115
75 % RDF (@120:60:60 NPK kg/ha)	0.49	0.502	0.496	0.537	0.53	0.534	0.212	0.227	0.219
75 % RDF + $ZnSO_4$ (@ 25 kg/ha)	0.549	0.564	0.556	0.551	0.543	0.547	0.256	0.268	0.262
75 % RDF + Nano- Zinc -(@ 10 ml/litre)	0.567	0.584	0.576	0.553	0.541	0.547	0.259	0.278	0.269
100 % RDF (@120:60:60 NPK kg/ha)	0.605	0.619	0.612	0.573	0.566	0.569	0.258	0.264	0.261
100 % RDF + $ZnSO_4$ (@ 25 kg/ha)	0.669	0.687	0.678	0.578	0.569	0.574	0.281	0.289	0.285
100 % RDF + Nano- Zinc - (@ 10 ml/litre)	0.687	0.706	0.696	0.587	0.578	0.582	0.286	0.289	0.287
SE(d) ±	**0.017**	**0.018**	**0.018**	**0.017**	**0.016**	**0.017**	**0.010**	**0.008**	**0.008**
CD (P=0.05)	**0.036**	**0.037**	**0.036**	**0.034**	**0.033**	**0.034**	**0.015**	**0.016**	**0.016**
Interaction (A x B)									
SE(d) ±	**0.029**	**0.030**	**0.029**	**0.027**	**0.027**	**0.027**	**0.013**	**0.013**	**0.013**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2. Studies of Nano- Zn, inorganic and organic nutrient management practices on Relative Growth rate (g/g/day) of *kharif* Maize

Treatments	Relative Growth Rate at 30-60 DAS			Relative Growth Rate at 60-90 DAS			Relative Growth Rate 90 DAS – at Harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Organic Manures (Main plot)									
Control	0.032	0.032	0.032	0.010	0.010	0.010	0.002	0.002	0.002
FYM -10 t/ha	0.034	0.034	0.034	0.009	0.009	0.009	0.003	0.003	0.003
Vermi Compost- 5 t/ha	0.034	0.035	0.034	0.009	0.009	0.009	0.003	0.003	0.003
SE(d) ±	0.000	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
CD (P=0.05)	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Nutrient Management (Sub plot)									
Control	0.031	0.031	0.031	0.011	0.01	0.011	0.001	0.002	0.002
75 % RDF (@120:60:60 NPK kg/ha)	0.032	0.033	0.032	0.01	0.01	0.01	0.003	0.003	0.003
75 % RDF + $ZnSO_4$ (@ 25 kg/ha)	0.033	0.033	0.033	0.009	0.009	0.009	0.003	0.003	0.003
75 % RDF + Nano- Zinc -(@ 10 ml/litre)	0.033	0.034	0.034	0.009	0.009	0.009	0.003	0.003	0.003
100 % RDF (@120:60:60 NPK kg/ha)	0.034	0.034	0.034	0.009	0.009	0.009	0.003	0.003	0.003
100 % RDF + $ZnSO_4$ (@ 25 kg/ha)	0.035	0.035	0.035	0.008	0.008	0.008	0.003	0.003	0.003
100 % RDF + Nano- Zinc - (@ 10 ml/litre)	0.035	0.035	0.035	0.008	0.008	0.008	0.003	0.003	0.003
SE(d) ±	0.001	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
CD (P=0.05)	**0.002**	**0.002**	**0.002**	**0.001**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**
Interaction (A x B)									
SE(d) ±	**0.002**	**0.002**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3. Studies of Nano- Zn, inorganic and organic nutrient management practices on Absolute Growth rate (g/plant/day) of *kharif* Maize

Treatment	Absolute Growth Rate at 30-60 DAS			Absolute Growth Rate at 60-90 DAS			Absolute Growth Rate 90 DAS- at Harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Organic Manures (Main plot)									
Control	3.176	3.273	3.225	3.550	3.484	3.517	1.298	1.376	1.337
FYM -10 t/ha	3.985	4.084	4.034	3.780	3.736	3.758	1.728	1.797	1.763
Vermi Compost- 5 t/ha	4.244	4.360	4.302	3.831	3.764	3.797	1.718	1.788	1.753
SE(d) ±	**0.044**	**0.045**	**0.044**	**0.034**	**0.033**	**0.034**	**0.023**	**0.024**	**0.024**
CD (P=0.05)	**0.125**	**0.128**	**0.126**	**0.096**	**0.095**	**0.096**	**0.067**	**0.068**	**0.067**
Nutrient Management (Sub plot)									
Control	2.836	2.931	2.883	3.516	3.449	3.482	0.722	0.811	0.767
75 % RDF (@120:60:60 NPK kg/ha)	3.265	3.349	3.307	3.582	3.532	3.557	1.411	1.515	1.463
75 % RDF + $ZnSO_4$ (@ 25 kg/ha)	3.656	3.757	3.707	3.672	3.619	3.645	1.704	1.785	1.744
75 % RDF + Nano- Zinc -(@ 10 ml/litre)	3.782	3.891	3.836	3.688	3.606	3.647	1.729	1.853	1.791
100 % RDF (@120:60:60 NPK kg/ha)	4.033	4.127	4.08	3.817	3.774	3.796	1.717	1.759	1.738
100 % RDF + $ZnSO_4$ (@ 25 kg/ha)	4.462	4.58	4.521	3.856	3.796	3.826	1.876	1.93	1.903
100 % RDF + Nano- Zinc - (@ 10 ml/litre)	4.577	4.706	4.641	3.911	3.852	3.882	1.908	1.924	1.916
SE(d) ±	**0.117**	**0.120**	**0.118**	**0.111**	**0.110**	**0.110**	**0.050**	**0.052**	**0.051**
CD (P=0.05)	**0.237**	**0.244**	**0.240**	**0.227**	**0.223**	**0.225**	**0.102**	**0.106**	**0.104**
Interaction (A x B)									
SE(d) ±	**0.192**	**0.197**	**0.194**	**0.182**	**0.179**	**0.180**	**0.084**	**0.087**	**0.085**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4. CONCLUSION

Nutrient management practices significantly impact the growth and development of Kharif maize, with the combined application of 100% recommended dose of fertilizer (RDF) and Nano-Zn at 10 ml/litre yielding the highest crop growth and absolute growth rates across all stages. The inclusion of zinc in both its nano and conventional forms enhanced growth performance, though Nano-Zn proved to be more effective. Organic manure treatments, particularly vermicompost at 5 t/ha, also contributed positively to growth, outperforming FYM and control treatments. The control treatments exhibited the lowest growth rates, underscoring the importance of proper nutrient supplementation. Overall, the study highlights the benefits of integrating organic manures and advanced nutrient management practices, especially the use of Nano-Zn, for maximizing maize productivity and ensuring optimal plant growth.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Shah F, Wu W. Soil and crop management strategies to ensure higher crop productivity within sustainable environments. Sustainability. 2019;11(5): 1485.
2. USDA. World agriculture supply and demand estimate; 2021-22.
3. DAC & FW. Agricultural statistics division. Estimates of production of food grains for 2018-19. Directorate of economics and statistics; Department of agriculture, cooperation and farmers welfare; Ministry of Agriculture and Farmers Welfare, Government of India; 2018-19.
4. Verma BC, Pramanik P, Bhaduri D. Organic fertilizers for sustainable soil and environmental management. Nutrient Dynamics for Sustainable Crop Production. 2020;289-313.
5. Al Jabri H, Saleem MH, Rizwan M, Hussain I, Usman K, Alsafran M. Zinc oxide nanoparticles and their biosynthesis: overview. Life. 2022;12(4):594.
6. Shareef HJ, Al-Tememi IH, Abdi G. Foliar nutrition of date palm: advances and applications. A review. Folia Oecologica. 2021;48(1):82-99.
7. Nandini P, Laxminarayana P, Bhanu Rekha K, Anjaiah T. Growth and yield of maize as influenced by zinc enrichment through agronomic options. Inter. Jour. Chemi. Society. 2020;8(5):2087-2091.
8. Banerjee H, Sarkar S, Deb P, Chakraborty I, Sau S, Ray K. Zinc fertilization in potato: A physiological and bio-chemical study. International Journal of Plant & Soil Science. 2017;16(2):1-13.
9. Dhilipan K, Baradhan G, Kumar SS, Sathiyanarayanan G, Ramesh S. Evaluating the synergistic effects of integrated nutrient management and foliar application of zinc sulphate ($_{ZnSO4}$); 2017.
10. Mahato M, Biswas S, Dutta D. Effect of integrated nutrient management on growth, yield and economics of hybrid maize (*Zea mays* L.). Current Journal of Applied Science and Technology. 2020;39(3):78-86.
11. Mahato M, Biswas S, Dutta D. Effect of integrated nutrient management on growth, yield and economics of hybrid maize (*Zea mays* L.). Current Journal of Applied Science and Technology. 2020; 39(3):78-86.
12. Banerjee H, Sarkar S, Deb P, Chakraborty I, Sau S, Ray K. Zinc fertilization in potato: A physiological and bio-chemical study. International Journal of Plant & Soil Science. 2017;16(2):1-13.
13. Daphade ST, Hanwate GR, Gourkhede PH. Effect of Zn, Fe and B on yield, nutrient uptake and quality of kharif maize in Marathwada region of Maharashtra. Journal of Pharmacognosy and Phytochemistry. 2018;7(5):319-322.
14. Choudhary AK, Sood P, Rahi S, Yadav DS, Thakur OC, Siranta KR, Tyagi V. Rice productivity, Zn biofortification, and nutrient-use efficiency as influenced by Zn fertilization under conventional transplanted rice and the system of rice intensification. Frontiers in Environmental Science. 2022;10:869194.

15. Choudhary B, Sharma PK, Mandeewal RL, Verma BL, Dudwal M. Response of iron and zinc on yield attributes, yield and economics of wheat (*Triticum aestivum* L.). International Journal of Plant & Soil Science. 2021;33(16):29-35.
16. Sasalatti GN, Patil SB, Nandagavi RA, Yadahalli VG. Soil and foliar application of zinc increased pearl millet productivityin calcareous vertisols of Karnataka. Journal of Farm Sciences. 2023;36(01):26-32.
17. Galloway JN, Townsend AR, Erisman JW, Bekunda M, Cai Z, Freney JR. Higher production of high-quality grain (higher grain N content) requires higher application of fertilizer and greater uptake by crops. The maize was more responsive to fertilizer N than rice. Hence, fertilizer level must be optimized to balance grain yield, grain N content and profit. References. Extended Summaries. 2022;469.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/123831