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# Importance of Zinc in Major Crops: An Indian Perspective

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Zinc (Zn) is an essential micronutrient critical for plant growth, development and metabolic processes. In India, widespread zinc deficiency in soils, driven by intensive farming, imbalanced fertilizer use and soil degradation, threatens crop productivity and nutritional security. Zinc plays a key role in enzyme function, hormone synthesis, stress resilience and nutrient absorption, directly influencing grain quality and agricultural output. This deficiency manifests in major crops such as rice, wheat, maize, pulses and oilseeds, causing disorders like stunted growth, chlorosis and poor yield. Sustainable solutions, including soil and foliar zinc application, biofortification and organic amendments, can enhance zinc availability and uptake. Addressing this micronutrient gap is vital for ensuring food security, improving crop resilience and supporting sustainable farming practices in India.

**Keywords:** Zinc deficiency, crop productivity, micronutrient management, soil health, sustainable farming, food security

## Introduction

Zinc (Zn) is an essential micronutrient required for the optimal growth, development and yield of crops. It is a vital component of various enzymatic and metabolic functions, playing a crucial role in plant growth, stress tolerance and productivity. In India, agriculture remains the backbone of the economy. With the rising demand for food production to meet the needs of a growing population, ensuring adequate nutrient availability to soils is imperative for sustaining agricultural productivity and enhancing food security and enhancing the economic well-being of farmers.

## Role of zinc in crop growth and development

- Enzyme activation: Zinc is a cofactor for many enzymes that regulate essential processes like photosynthesis, nitrogen metabolism and protein synthesis.
- Hormone production: It is vital for the synthesis of auxins, which are plant hormones necessary for growth and development.
- Stress tolerance: Zinc enhances plant resistance against environmental stresses such as drought and extreme temperatures.
- Nutrient uptake and utilization: It improves root development, ensuring better nutrient absorption and utilization.
- Grain quality and yield: Adequate zinc levels contribute to improved grain formation, leading to higher productivity and better nutritional quality.
- Cell membrane integrity: Zinc plays a role in maintaining cell membrane stability, protecting plants from oxidative damage.
- Chlorophyll formation: It aids in chlorophyll synthesis, which is crucial for efficient photosynthesis and energy production in plants.

## Zinc deficiency in Indian soils

A significant portion of Indian soils, particularly in the Indo-Gangetic Plains, Deccan Plateau and arid regions of Rajasthan and Gujarat, suffer from zinc deficiency (Shukla et al., 2021). Intensive farming, overuse of chemical fertilizers and soil erosion have further aggravated this issue. Zinc-deficient soils lead to poor crop yields, stunted growth and reduced resistance to diseases. The increasing incidence of zinc deficiency has led to a decline in both the quantity and quality of agricultural produce, making it a serious concern for farmers and policymakers.

## Impact of zinc on major Indian crops

**1. Paddy *(Oryza sativa):*** Rice is the staple food of India and zinc deficiency is a common problem in paddy fields. It causes symptoms like bronzing of leaves, poor tillering and reduced grain yield. The application of zinc sulphate through soil or foliar sprays significantly enhances productivity and grain quality. Zinc-deficient rice plants often exhibit delayed maturity, making them more susceptible to lodging and pest attacks.

**2. Wheat *(Triticum aestivum):*** Wheat is another major cereal crop in India that is highly affected by zinc deficiency. Symptoms include chlorosis, delayed maturity and poor grain formation. Zinc fertilization improves root growth, enhances protein content in grains and increases overall yield. Proper zinc nutrition in wheat improves seed germination and ensures uniform growth, reducing the risk of poor harvests.

**3. Maize *(Zea mays):*** Zinc plays a crucial role in maize growth, particularly in root development and enzyme activation. Deficiency results in interveinal chlorosis and stunted growth. Zinc supplementation ensures better pollination, kernel filling and resistance to environmental stresses. Proper zinc levels in maize improve cob development, leading to higher grain weight and better market value.

**4. *Pulses (Chickpea, Pigeon Pea, Lentils):*** Zinc deficiency in pulses leads to poor germination, reduced nodulation and weak plants. Zinc application improves nitrogen fixation, enhances pod formation and increases overall grain yield, which is essential for food security and soil fertility management in India. Pulses are a major protein source and zinc deficiency in these crops can negatively impact human nutrition.

**5. *Oilseeds (Groundnut, Mustard, Soybean):*** Oilseed crops require zinc for proper enzymatic functions and oil biosynthesis. Zinc deficiency results in low oil content and poor seed quality. Balanced fertilization with zinc enhances both yield and the nutritional value of oilseeds. In mustard and soybean, zinc also plays a role in flower initiation and seed setting, improving crop productivity.

**6. *Fruits and vegetables:*** Horticultural crops such as mango, banana, citrus fruits and leafy vegetables also exhibit zinc deficiency, leading to poor fruit set, low vitamin content and reduced market value. Zinc fertilization enhances fruit size, flavour and nutritional content, making it vital for improving productivity and farmers' income. Proper zinc application ensures better post-harvest shelf life of fruits and vegetables, reducing losses during transportation and storage.

## Classical disorders caused by zinc deficiency in crops

a) Rice: "Khaira disease" - Symptoms include bronzing of leaves, stunted growth and poor tillering (Fig. 1).
b) Maize: "White bud"- Causes short internodes, chlorosis and poor kernel development (Fig. 2).
c) Citrus Fruits: "Mottle leaf disease"- Leaves become small, mottled and show poor fruit development (Fig. 3).
d) Grapes: "Zinc-induced chlorosis" - Leads to yellowing of young leaves and poor vine growth.
e) Legumes: Poor nodulation, reduced nitrogen fixation and low yield.

**Fig. 1: Zinc deficiency in paddy (Khaira)**

**Fig. 2: Zinc deficiency in maize (White bud)**

**Fig. 3: Zinc deficiency in citrus (Mottle leaf)**

## Zinc management strategies

### 1. Soil application of zinc

**Zinc sulphate heptahydrate ($ZnSO_4 \cdot 7H_2O$)**: This is the most common and cost-effective source of zinc fertilizer due to its high solubility. It is typically applied as a basal dose to the soil before sowing or planting. The recommended rates of soil application vary depending on soil type and crop. For example, in a maize-wheat cropping system, continuous application of 5 kg Zn $ha^{-1}$ has been found to be very effective. In some highly sodic and flood plain soils, the application rate for rice can be as high as 22 kg Zn $ha^{-1}$.

### 2. Foliar application

Foliar application involves spraying a zinc solution directly onto the leaves. This method is particularly effective in cases of severe deficiency, high soil pH or when the soil's low zinc availability is a major barrier to uptake. Foliar sprays provide a quick and efficient way for plants to absorb the nutrient. A 0.5% solution of zinc sulphate ($ZnSO_4 \cdot 7H_2O$) is a common recommendation for foliar sprays. Foliar applications are often done at specific critical growth stages. For example, in rice, sprays are recommended at the booting and milking stages to enhance zinc accumulation in the grains. For maize, a foliar spray at the tasselling stage can significantly improve grain zinc concentration.

### 3. Combined soil and foliar application

This approach, which combines basal soil application with one or more foliar sprays, has been shown to be the most effective strategy for both increasing crop yield and grain zinc concentration. Studies have shown that this combined method can lead to a substantial increase in zinc concentration in grains, often more than what can be achieved with either method alone. For instance, in wheat, soil + foliar application can increase zinc content in grains by over 100% compared to a soil-only application (Zhao *et al.*, 2020).

### 4. Other management strategies

- ✓ **Organic matter application**: The use of organic manures can help improve zinc availability in the soil.
- ✓ **Nano-Fertilizers**: The use of nano-zinc fertilizers is an emerging strategy that has shown promise in improving zinc delivery to plants and enhancing biofortification.
- ✓ **Plant Growth-Promoting Bacteria (PGPB)**: Certain bacteria can help in solubilizing zinc in the soil and promoting its uptake by plants (Kushwaha *et al.*, 2020).
- ✓ **Water management**: In crops like rice, which are grown in waterlogged conditions, proper water management can influence zinc availability.

## Conclusion

Zinc is an indispensable micronutrient for Indian agriculture, influencing the productivity and quality of major crops. Addressing zinc deficiency through effective management strategies can significantly enhance food production, nutritional security and farmers' livelihoods. Improving zinc availability in Indian soils is crucial for long-term agricultural success. Farmers, researchers and policymakers must work together to promote zinc awareness and its role in enhancing soil health and crop productivity. Increased use of zinc-based fertilizers, along with modern agronomic practices, can pave the way for a more resilient and productive agricultural sector in India.

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