Stories from the Global Call on Agricultural Innovation

Biofortification: A solution to malnutrition

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ABSTRACT

A field experiment was conducted to study the effect of Zn application methods on growth and yield parameters, Zn concentrations and Zn bioavailability in rice grains of two genotypes (NIA-Mehran and Shandar). The study revealed that zinc application had a positive impact on zinc bioavailability for humans by reducing phytic acid concentrations and affecting zinc bioavailability biomarkers in both polished and brown rice. Specifically, zinc application increased the number of productive tillers by 14%, grains per panicle by 88%, thousand grains weight by 10%, and grain yield by 30%. Zinc application also substantially increased zinc concentration by 244% and decreased phytic acid concentration by 44%.

Furthermore, it improved zinc bioavailability by reducing phytic acid to zinc molar ratios by 79% in polished rice and 69% in brown rice, while enhancing total absorbed zinc by 341% in polished rice and 217% in brown rice. Among the zinc treatments, foliar applications (twice or thrice) showed more significant improvements in grain production, zinc concentration, and bioavailability in both brown and polished rice compared to soil zinc application.

The study found that applying zinc three times via foliar application significantly improved productive tillers, grains per panicle, thousand grain weight, grain yield, zinc concentrations, and total daily absorbed zinc, while reducing phytic acid concentrations and its ratio to zinc. It was recommended that this method be used for NIA-Mehran and Shandar rice varieties to enhance yield, zinc concentration, and bioavailability. Additionally, the study suggests humans switch from polished rice to brown rice, which contains higher zinc and better bioavailability, to help combat widespread zinc deficiency.

TAPipedia Tags
grain production, malnutrition, wheat, Rice, biofortification,

Other keywords
Malnutrition; Biofortification; Foliar Application; Zn Nutrition

Context

Zinc deficiency affects a large portion of the global population, especially in Asian and African countries like Pakistan, where significant percentages of children and women lack adequate zinc levels. This deficiency leads to various health issues such as stunted growth, weakened immune systems, and learning difficulties. The problem is exacerbated in regions where staple foods like rice and wheat are consumed, often grown in zinc-deficient soils. Soil conditions like high pH, calcareousness, and submerged environments contribute to the reduced availability of zinc in these areas. Addressing zinc deficiency in humans can be done through supplementation, food fortification, and biofortification. Biofortification, specifically agronomic approaches involving the use of zinc fertilization, proves effective in enhancing zinc levels

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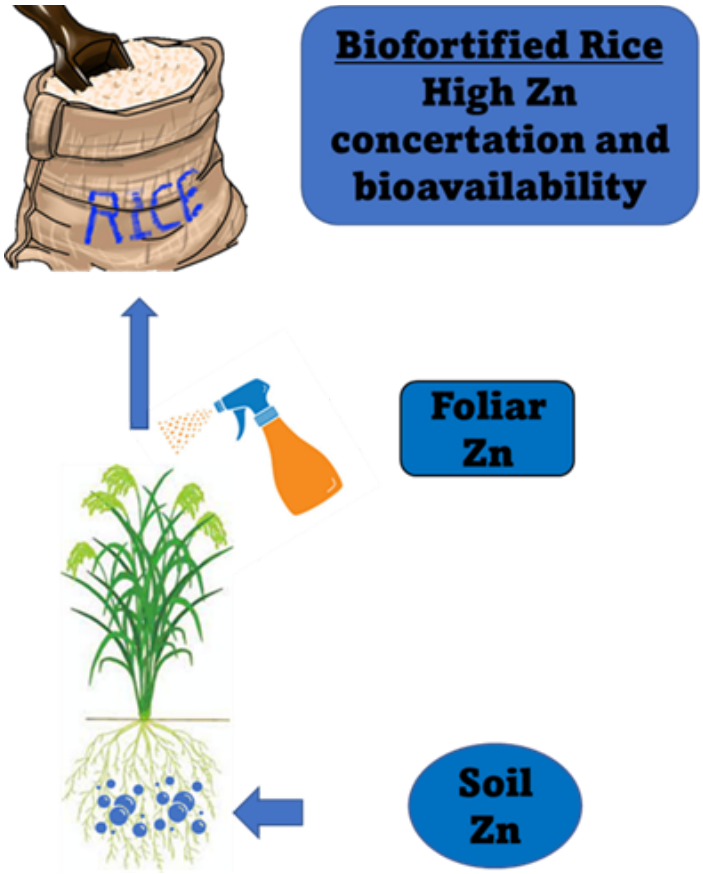


However, while significant work has been done in wheat, only limited studies focus on zinc biofortification in rice globally. Rice, a major staple crop, lacks sufficient zinc content to meet human nutritional needs, contributing significantly to zinc deficiency in populations relying heavily on rice consumption.

We aimed to address this gap by exploring various zinc application methods to enhance local rice genotypes. The objectives include evaluating how different zinc application techniques affect rice growth and yield while analyzing zinc concentration and bioavailability in rice grains. Despite a few studies conducted in Pakistan, such as one focusing on Basmati rice, there's a lack of comprehensive research on zinc biofortification in local rice varieties, making this study significant in addressing widespread zinc deficiency.

KEY PROBLEMS

Zinc Deficiency in Humans: The primary issue tackled was the widespread zinc deficiency in human populations, particularly in regions reliant on rice consumption. Zinc deficiency leads to various health problems, and this study aimed to find effective methods to increase zinc levels in rice to combat this deficiency.

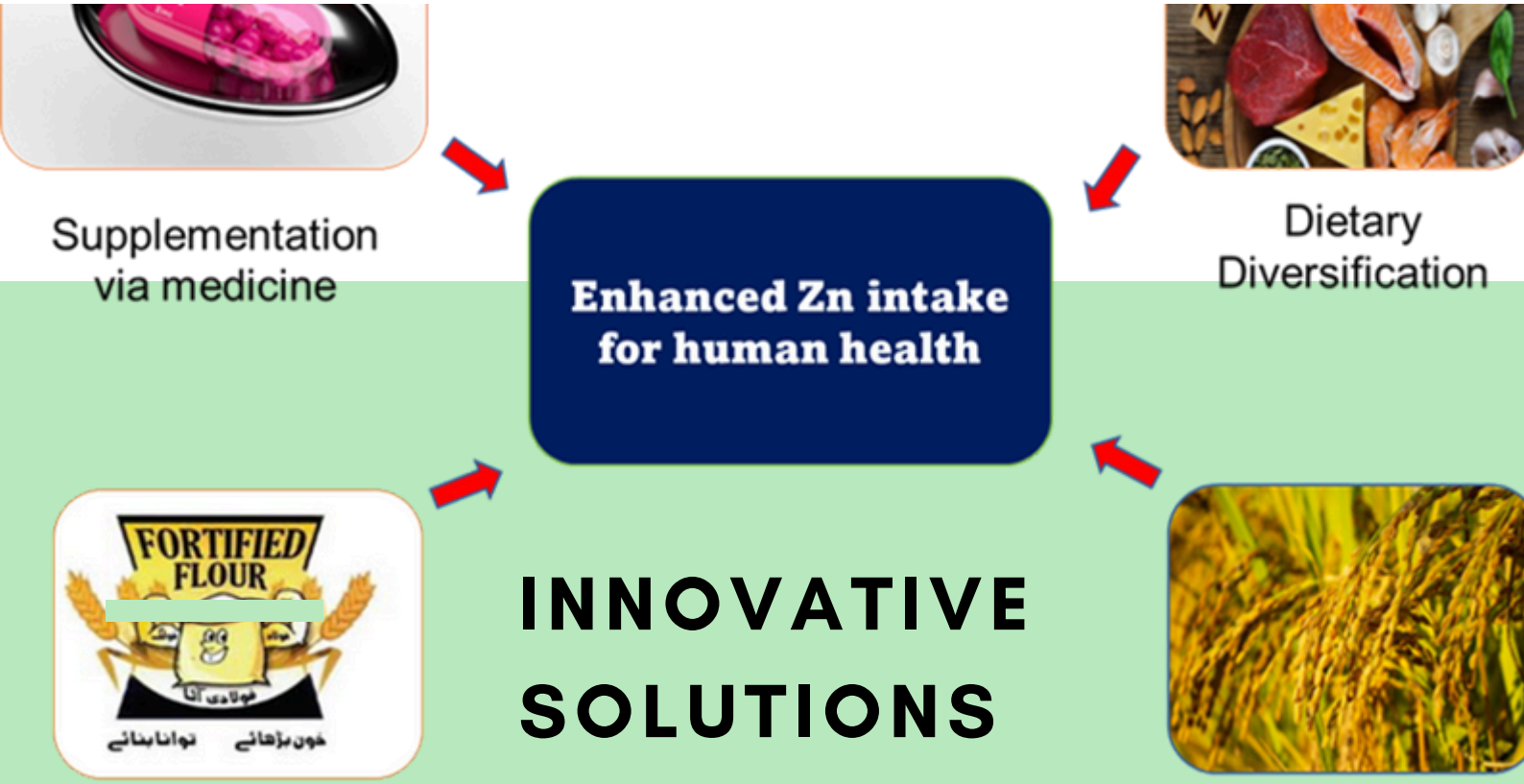
Low Zinc Content in Rice: Rice, a staple food for many populations, often lacks sufficient zinc content to meet human nutritional needs. This study sought to enhance the zinc content in rice grains, specifically in both polished and brown rice, to make it a more viable source of zinc for these populations.

Zinc Bioavailability: Simply increasing the zinc content in rice isn't sufficient if the zinc isn't readily available for human absorption. The research focused on enhancing zinc bioavailability in rice grains, crucial for addressing zinc deficiency in affected populations.

Phytic Acid Content: Phytic acid present in rice can inhibit zinc absorption in the human body. This study aimed to reduce phytic acid concentrations in rice grains, thus improving the bioavailability of zinc.

Optimal Zinc Application Methods: Evaluating different zinc application methods (soil versus foliar application) to determine which technique yields the best results in terms of enhancing zinc concentration, bioavailability, and overall yield in rice.

Genotypic Variability: The study investigated how different rice genotypes responded to zinc application methods in terms of growth, yield, zinc, and phytic acid concentrations, as well as zinc bioavailability parameters. This could help in identifying suitable rice varieties for effective zinc biofortification.



Effective Strategies to Combat Zn Malnutrition in Humans Creator

Foliar Zinc Application: The study demonstrated that foliar zinc application, especially when done two or three times at specific growth stages, significantly enhanced zinc concentrations in rice grains. This innovative method proved more effective in improving zinc bioavailability compared to conventional soil application.

Improved Zinc Bioavailability: The research not only focused on increasing zinc content in rice but also aimed at enhancing its bioavailability for human absorption. By reducing phytic acid concentrations and altering zinc bioavailability biomarkers, such as phytic acid to zinc molar ratios, the study contributed innovative insights into making zinc more readily available for the human body.

Genotype-Independent Results: The findings revealed that different rice genotypes responded similarly to zinc application methods. This suggests that the innovative strategies identified, such as foliar application, could be universally applicable across various rice varieties to address zinc deficiency.

Targeted Zinc Levels: The study successfully achieved targeted zinc levels for effective biofortification, particularly in polished rice, indicating a viable pathway for ensuring that rice meets recommended zinc nutritional requirements.

Encouraging Brown Rice Consumption: The research highlighted the potential of brown rice, with its inherently higher zinc content and bioavailability compared to polished rice, as an innovative solution to address zinc deficiency. Promoting the consumption of brown rice over polished rice could significantly contribute to combating zinc malnutrition.

Factors for Success

Triumph Over Trials: Despite facing numerous challenges, my supervisory committee members —Dr. Saleem Maseeh Bhatti, Dr. Inayatullah Rajpar, and Dr. Nizamuddin Depar—and I remained determined. We worked together to overcome obstacles and successfully conducted the first study on Rice Zinc Biofortification in Sindh, Pakistan. This groundbreaking research marked a significant achievement for both our team and the scientific community, aiming to address malnutrition and improve health outcomes in our region.

Support from Research Institutions: The study faced challenges due to a lack of analytical facilities, making innovative research seem unlikely without institutional support. The Rice Research Institute Dokri in Sindh, Pakistan, provided crucial milling facilities, enhancing the research's quality and feasibility. Additionally, the Nuclear Institute Tando Jam contributed experimental fields, genotypes, and analytical resources, playing a key role in the study's success.

The Igniting Question: The study began with a pivotal question from my supervisor, Dr. Saleem Maseeh Bhatti: "What is novel in this?" This challenge motivated me to push beyond limitations and conduct international-level research despite Pakistan's limited resources. Dr. Bhatti's question fueled my determination to innovate and exceed expectations, leading to significant contributions in the field. I credit much of my success to this statement, which continually reminded me of the importance of innovation and excellence in my research.

CRITICAL CAPACITIES

The success of the Agronomic Zinc (Zn) Biofortification research depended on the availability of Zn-efficient genotypes, which were provided by the Nuclear Institute of Agriculture Tandojam, led by breeder Mr. Hafeez ur Rehman Bughio, my father.

His expertise in breeding Zn-efficient varieties played a crucial role in advancing the research. Additionally, the collaboration with national and international experts greatly contributed to the study's success. Their shared knowledge, resources, and feedback were vital in driving progress and fostering innovation within the scientific community.

CHALLENGES ENCOUNTERED

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Undertaking a research study with novel objectives, especially the first of its kind in a specific region like Pakistan, indeed presented numerous challenges including: Limited Precedence, Resource Constraints, Expertise and Skill Development

Limited information: Undertaking a research study with novel objectives, especially the first of its kind in a specific region of Tandojam Sindh Pakistan, indeed presented numerous challenges.

Research Gap: The first challenge faced was the limited information available. The studies reported in literature were mainly focused on Wheat crop. This created a information gap as Rice differs from Wheat, and we have to rely on the experiences and results of International researchers who have already conducted Agronomic Zn Biofortification based research in Rice.

Resource Constraints: With self-funding and limited analytical facilities available, the task of conducting Zn biofortification based research was a huge one. Since the research involved the milling of rice, the milling facilities were not available within the vicinity. I personally travelled around 400 km to carryout the milling work at Dokri. Furthermore, I had to bear the cost of some expensive chemicals on my own and had to look for support from other research institutions for acquiring analytical facilities.

Expertise and Skill Development: The limited expertise and skill development presented significant challenges for conducting agronomic biofortification research, particularly in settings where such research is novel, as was the case with the first-ever biofortification-based research conducted at Sindh Agriculture University Tandojam, Pakistan.

Outcomes and Measurable Impacts

In rice grain tissues, the concentration of Zn increased while the concentration of phytic acid reduced with Zn applications. The reduction in phytic acid and increase in Zn concentration with Zn applications increased the estimated Zn bioavailability factors (reduction in phytate to zinc molar ratios and increase in total daily absorbed Zn) in rice tissues. Among Zn application methods, foliar applications (twice or thrice) were far better than soil application for the majority of parameters. However, foliar application was found best for improved growth and yield and Zn concentration in rice grains.

Foliar application thrice ensured the successful biofortification of both rice genotypes by increasing the Zn concentration in polished rice above the target value (28 mg Zn kg-1) which is set by HarvestPlus breeding program. In terms of Zn bioavailability, foliar application thrice decreased the PA: Zn molar ratio in polished and brown rice. However, only the molar ratio in brown rice nearly met the optimum ratio for Zn bioavailability in humans (< 18). Foliar application thrice also improved TAZ values in both brown and polished rice. The increase in TAZ values accounted for 33% in polished rice and 53% in brown rice.

LESSONS LEARNED

The lessons learned from the research on zinc biofortification in rice can serve as valuable guidelines for planning experiments related to biofortification in other crops. Applying these lessons learned from the research on zinc biofortification in rice to experiments involving other crops could enhance the effectiveness and impact of biofortification efforts, potentially leading to promising results and valuable contributions to agricultural and nutritional sciences.

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Acknowledgements

Farmers: The study's findings aim to benefit farmers by providing them with innovative approaches (such as foliar zinc application) to enhance rice yield, improve crop quality, and potentially increase income through better crop productivity.

Consumers: The research aims to address the nutritional needs of consumers, particularly those reliant on rice as a staple food. By enhancing zinc content and bioavailability in rice grains, the study targets improving the nutritional intake of individuals, potentially reducing zinc deficiency-related health issues.

Food Security Programs: Organizations and programs focused on food security and nutrition, both at national and international levels, are stakeholders targeted by this research. The findings provide insights into effective strategies for biofortifying rice, a crucial staple crop, which could be integrated into food security initiatives aiming to combat micronutrient deficiencies.

Policy Makers and Agricultural Institutions: The study's outcomes may be of interest to policymakers and agricultural institutions involved in formulating agricultural policies and recommending farming practices. These stakeholders could use the research findings to guide policies supporting biofortification programs and sustainable agricultural practices to enhance crop nutrition.

Nutrition and Health Agencies: Stakeholders involved in public health, nutrition, and welfare programs are targeted as beneficiaries of the research. The findings could guide interventions aimed at addressing zinc deficiency in populations through dietary improvements and nutritional education initiatives.

THE TROPICAL AGRICULTURE PLATFORM

The Tropical Agriculture Platform (TAP) is a G-20 initiative launched in 2012 to promote agricultural innovation in the tropics. TAP has formed a coalition of more than 50 partners, led by the Food and Agriculture Organization of the United Nations (FAO) and generously supported by the European Union (EU). The main goal of TAP is to strengthen agricultural innovation systems (AIS) in developing countries through coordinated multi-stakeholder interventions.

CONTACTS

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Global Call for Agrifood System Innovations and Stories of Capacity Development for Innovation

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