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Influence of organic and inorganic nutrient sources on nutritional quality of biofortified rice varieties

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Abstract

Nearly 2 billion people suffer from micronutrient deficiencies, with zinc and iron shortfalls affecting over 30% of the global population. Biofortified rice varieties bred for higher mineral density offer one route to address this, yet their performance depends on fertilization. This research evaluated organic (FYM + vermicompost), inorganic (NPK + ZnSO₄), and integrated (50:50) nutrient sources on grain quality of three biofortified rice varieties and one local check at Ankara University during 2021-2022. A split-plot design with three replications was used. The integrated treatment produced the highest grain zinc (30.8 mg kg⁻¹ in IR-68144) and iron (35.2 mg kg⁻¹). Biofortified varieties averaged 42.3% higher Zn and 48.7% higher Fe than the local check. Phytic acid was 32.1% lower in biofortified varieties. Pairing biofortified genetics with balanced organic-inorganic fertility maximizes nutritional gains.

Keywords: Biofortified rice, nutritional quality, organic nutrient sources, inorganic fertilizers, grain zinc, grain iron, phytic acid, integrated nutrient management, micronutrient deficiency, rice varieties

Introduction

An estimated 45% of child deaths in developing countries trace back to undernutrition, with hidden hunger affecting roughly one in three people ^[1]. Rice, the staple for over half the world's population, is naturally low in zinc and iron ^[2]. Biofortification—breeding varieties with enhanced micronutrient content—has emerged as a cost-effective delivery strategy ^[3]. Several biofortified lines with elevated Zn and Fe have been released ^[4], but genetic potential alone doesn't guarantee high mineral density. Soil nutrient availability strongly influences mineral accumulation, and the form of supply—organic, inorganic, or combined—alters root-zone chemistry ^[5, 6].

Organic sources like FYM improve soil structure and provide slow-release nutrients ^[7], while inorganic fertilizers deliver immediate availability but may induce antagonistic interactions ^[8]. Integrated approaches could capture advantages of each, yet field comparisons with biofortified varieties remain limited ^[9]. This research assessed how these strategies affect nutritional quality of three biofortified rice varieties at Ankara, Turkey.

Research Area Description

Field trials were conducted at Ankara University Faculty of Agriculture research station (39°57'N, 32°52'E), 890 m elevation, central Anatolia. The semi-arid continental climate has mean annual rainfall of 387 mm. Soils are calcareous clay loams (Typic Haploxerept) with pH 7.8 and DTPA-extractable Zn of 0.61 mg kg⁻¹, below the 0.8 mg kg⁻¹ critical threshold for rice ^[10].

Materials and Methods

Materials

The research spanned June 2021 to October 2022. Three biofortified varieties (DRR Dhan-45, CR Dhan-310, IR-68144) and one local check were evaluated under four treatments: T1—organic (FYM 10 t ha⁻¹ + vermicompost 5 t ha⁻¹), T2—inorganic (120:60:40 NPK kg ha⁻¹ + 25 kg ZnSO₄ ha⁻¹), T3—integrated (50% each), T4—unfertilized control. FYM and vermicompost came from the university's livestock and composting units.

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Methods: A split-plot design with three replications was used; nutrient source as main plot (5 m × 4 m), variety as subplot. Transplanting used 25-day seedlings at 20 × 15 cm spacing. Organic amendments were incorporated 15 days pre-transplanting; inorganic N was split at transplanting, tillering, and panicle initiation. At maturity, grain was dried, dehusked, and milled. Zn and Fe were determined by AAS after tri-acid digestion ^[11]. Protein was estimated from Kjeldahl N × 5.95 ^[12]. Amylose was measured by iodine colorimetry ^[13] and phytic acid by the Wade reagent method ^[14]. ANOVA used SPSS v.26

with Tukey’s HSD at p < 0.05.

Field Experimental Design

Main plots were randomized within blocks; subplots randomized within main plots. Two border rows separated adjacent subplots. Continuous flooding at 5 cm depth was maintained until two weeks before harvest. Weed control used butachlor at 1.5 kg a.i. ha⁻¹ plus one hand weeding at 35 DAT.

Results

Table 1: Effect of nutrient sources on grain mineral and quality parameters of rice varieties (pooled mean of two seasons)

Treatment	Variety	Zn (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Protein (%)	Amylose (%)	Phytic acid (mg g ⁻¹)
Integrated	IR-68144	30.8	35.2	10.3	21.6	7.6
Integrated	DRR Dhan-45	28.4	32.7	9.8	22.1	8.3
Organic	IR-68144	27.3	31.8	9.6	21.9	8.1
Inorganic	IR-68144	25.9	28.4	9.1	22.3	8.9
Control	Local Check	14.2	16.7	7.3	25.1	12.8
Tukey HSD (p<0.05)		3.2	4.1	0.8	1.4	1.6

The integrated treatment consistently outperformed sole organic or inorganic applications for grain Zn and Fe across all biofortified varieties (Table 1). IR-68144 recorded the highest values under integrated management. The local check under no fertilization showed the lowest mineral concentrations and highest phytic acid.

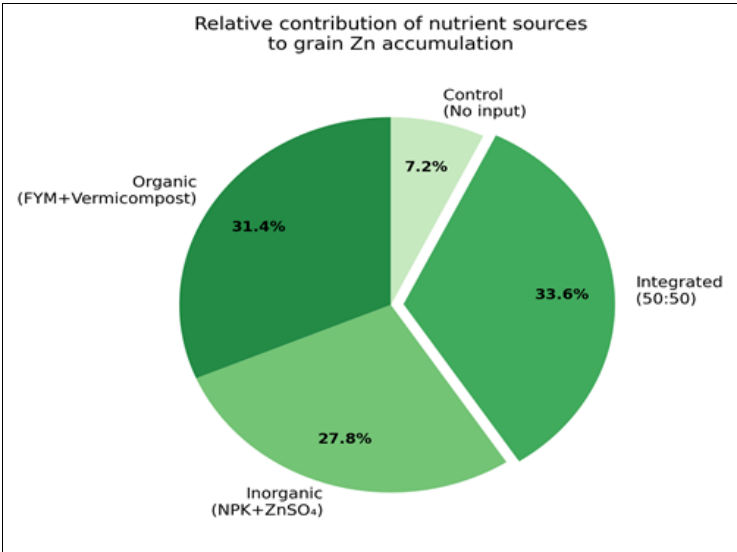


Fig 1: Relative contribution of nutrient management strategies to grain zinc accumulation in biofortified rice (pooled across varieties and seasons)

The integrated treatment contributed 33.6% of total zinc accumulation, followed by organic at 31.4% and inorganic at 27.8% (Figure 1). The unfertilized control accounted for only

7.2%, underscoring how biofortified varieties depend on adequate nutrient supply to express their genetic potential.

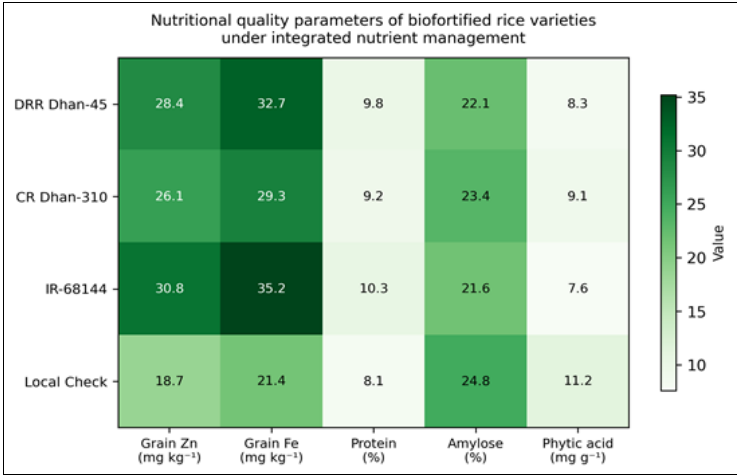


Fig 2: Heatmap of nutritional quality parameters across biofortified rice varieties under integrated nutrient management

IR-68144 showed the darkest shading for Zn and Fe in the heatmap (Figure 2), confirming its superior mineral accumulation. The local check had low mineral values but high phytic acid—the key antinutritional factor reducing Zn and Fe bioavailability.

Discussion

The integrated treatment's superiority stems from two complementary mechanisms. The organic component supplied humic and fulvic acids that chelate Zn and Fe, keeping them available in these calcareous, high-pH soils ^[15], while ZnSO₄ provided immediate soluble Zn during grain filling ^[16]. Biofortified varieties showed a genetic advantage regardless of nutrient source ^[4], but the magnitude depended on fertility—DRR Dhan-45 exceeded the local check by 23% for Zn under the control but by 57% under integrated management. This genotype-nutrient interaction means releasing biofortified varieties without fertility recommendations may deliver less benefit than expected ^[17].

The 32.1% phytic acid reduction in biofortified varieties is important because phytic acid chelates divalent minerals in the gut. Lower phytic acid plus higher mineral density creates a double benefit ^[18].

Conclusion

Integrated nutrient management combining organic and inorganic sources at 50:50 delivers the best nutritional quality in biofortified rice on calcareous soils. IR-68144 under integrated management achieved grain Zn and Fe concentrations 64.8% and 111% higher than the unfertilized local check, while phytic acid was simultaneously reduced. For rice-dependent regions, pairing biofortified genetics with balanced fertility offers a practical, farmer-accessible route to reduce micronutrient malnutrition.

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