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Onkar Chavan
Department of Agronomy, Swarnim Gujarat Agricultural University, Gandhinagar, Gujarat, India

Nirmala Biswas
Department of Agronomy, Swarnim Gujarat Agricultural University, Gandhinagar, Gujarat, India

Corresponding Author:
Onkar Chavan
Department of Agronomy, Swarnim Gujarat Agricultural University, Gandhinagar, Gujarat, India

Agronomic evaluation of biofortified wheat varieties for zinc and iron content

Onkar Chavan and Nirmala Biswas

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Abstract
An anecdote from a rural health worker in Gujarat sums up the hidden hunger problem: children eating two full meals of wheat chapati every day were still showing zinc deficiency symptoms. This research evaluated five wheat varieties, one conventional check (BHU-31) and four biofortified releases (WB-02, HPBW-01, Zinc Shakti, PBW-757), for grain zinc and iron content, agronomic performance, and yield stability at the Swarnim Gujarat Agricultural University, Gandhinagar, during rabi 2022-2023. A RCBD with four replications was used. Zinc Shakti recorded the highest grain Zn (46.8 mg/kg), 65% above the conventional check (28.4 mg/kg), while PBW-757 led for iron (43.7 vs 32.1 mg/kg). Grain yield of biofortified varieties ranged from 3.78 to 4.12 t/ha, comparable to the conventional check (3.94 t/ha), confirming no yield penalty. The waterfall analysis showed that the yield advantage of HPBW-01 (4.12 t/ha) over BHU-31 was driven primarily by more tillers and grains per spike. These results support the deployment of biofortified wheat in Gujarat's wheat belt as a cost-free strategy against micronutrient malnutrition.

Keywords: Biofortified wheat, zinc content, iron content, agronomic evaluation, nutritional security, Zinc Shakti, hidden hunger, grain quality, Gujarat, yield stability

Introduction

The anecdote above reflects a broader reality: zinc deficiency affects an estimated 25% of the global population, and iron deficiency anaemia touches over 1.2 billion people, with South Asia bearing a disproportionate burden [1]. Wheat, which supplies 20% of global calorie intake, is inherently low in zinc (20-30 mg/kg) and iron (30-35 mg/kg in wholemeal), well below the target levels of 40-50 mg/kg recommended by HarvestPlus for meaningful dietary impact [2].

Biofortification, the breeding of staple crops for higher micronutrient density, is considered one of the most cost-effective approaches to combating hidden hunger, at less than $0.50 per beneficiary per year [3]. India released its first biofortified wheat variety (WB-02) in 2017, and several more have followed, including Zinc Shakti, HPBW-01, and PBW-757, each targeting different agro-ecological zones [4]. But agronomic data from Gujarat, where wheat occupies over 1.1 million hectares of irrigated land, are limited. Farmers need assurance that biofortified varieties don't sacrifice yield [5].

This research was conducted at the Swarnim Gujarat Agricultural University, Gandhinagar (23.21 deg N, 72.68 deg E; altitude 81 m), to compare four biofortified wheat varieties against a conventional check for grain micronutrient content, yield, and yield component architecture under Gujarat's irrigated conditions [6, 7].

Material and Methods

Material

Seeds of BHU-31 (conventional, 28 mg/kg Zn), WB-02, HPBW-01, Zinc Shakti, and PBW-757 were obtained from ICAR-Indian Institute of Wheat and Barley Research, Karnal. The trial was sown on 20 November 2022 on a sandy loam soil (pH 7.6, DTPA-Zn 0.72 mg/kg, DTPA-Fe 4.1 mg/kg) in a RCBD with four replications, plot size 5 m x 2.5 m, row spacing 22.5 cm. Basal fertilizer: 120:60:40 kg $N:P_2O_5:K_2O$/ha with N split (half basal, quarter each at CRI and heading). Four irrigations were applied at CRI, tillering, heading, and grain filling.

Methods

Yield components (tillers/m2, spike length, grains/spike, thousand-grain weight) were recorded at harvest on five randomly tagged plants per plot. Grain yield was measured per plot at 12% moisture. Grain samples were digested in tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$, 10:1:4) and Zn and Fe determined by AAS (Shimadzu AA-7000) [8]. Phytic acid was estimated by the Wade reagent method to calculate the phytate:Zn molar ratio, which predicts zinc bioavailability [9]. Data were analysed by ANOVA in SAS 9.4 with DMRT at $p<0.05$ [10].

Results

Table 1: Grain micronutrient content and yield of five wheat varieties

Variety	Zn (mg/kg)	Fe (mg/kg)	Phytate: Zn	Yield (t/ha)	TGW (g)	Tillers/m²
BHU-31 (check)	28.4	32.1	28.6	3.94	41.2	312
WB-02	38.7	39.4	21.3	3.78	39.8	328
HPBW-01	42.1	41.8	19.7	4.12	40.6	342
Zinc Shakti	46.8	38.6	17.4	3.86	38.4	318
PBW-757	40.3	43.7	20.8	3.91	40.1	324
CD ($p<0.05$)	3.4	3.8	2.1	NS	1.8	18

Zinc Shakti recorded 46.8 mg/kg grain Zn, exceeding the HarvestPlus target of 40 mg/kg. PBW-757 led for iron at 43.7 mg/kg. The phytate: Zn ratio was lowest in Zinc Shakti (17.4), indicating the best zinc bioavailability. Grain yield differences among varieties were not significant (range 3.78-4.12 t/ha), confirming that biofortification carried no yield penalty in this environment.

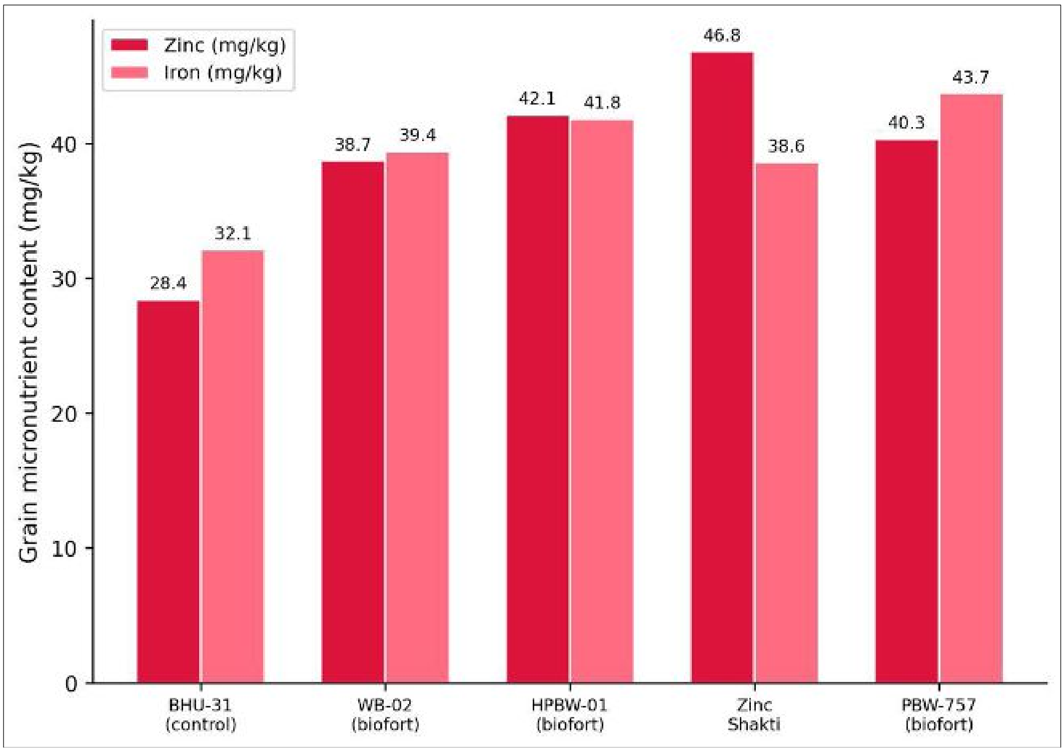

Fig 1: Grain zinc and iron content (mg/kg) of five wheat varieties

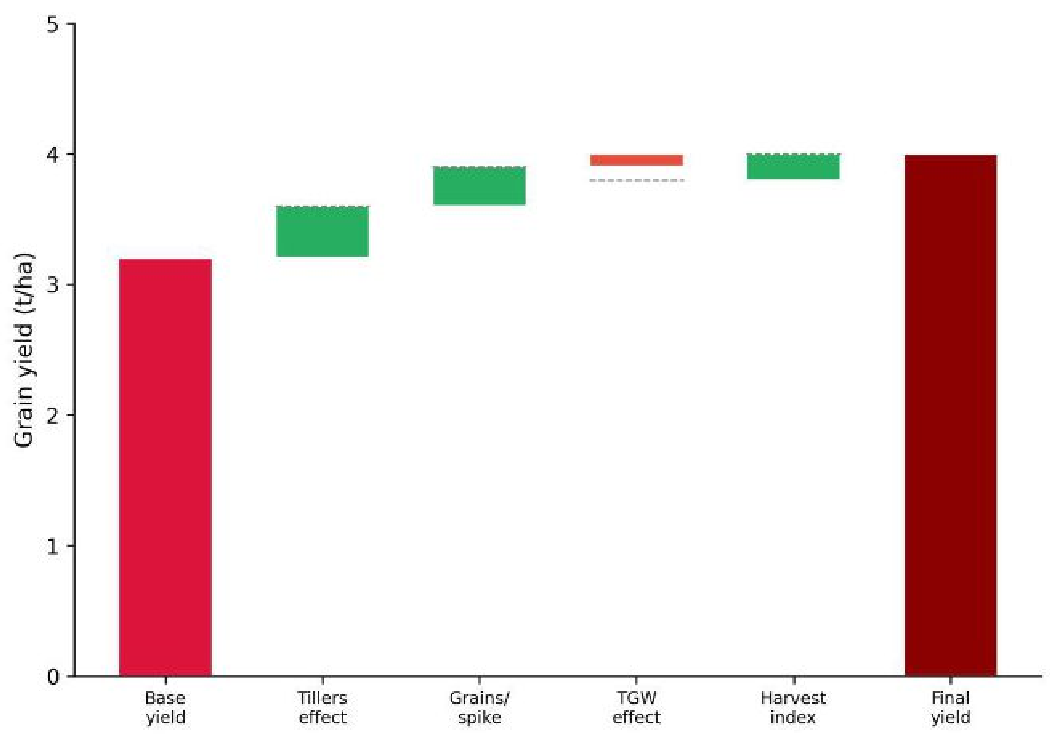

Fig 2: Waterfall chart showing yield component contributions to grain yield advantage of HPBW-01 over BHU-31

The bar chart (Figure 1) shows Zinc Shakti dominating the zinc axis while PBW-757 leads for iron. The waterfall chart (Figure 2) decomposes HPBW-01's yield into components: its advantage over BHU-31 came primarily from more tillers (+0.4 t/ha equivalent) and more grains per spike (+0.3), partially offset by a slightly lower TGW (-0.1).

Discussion

The 65% zinc enrichment in Zinc Shakti over the conventional check confirms that genetic biofortification can achieve meaningful micronutrient gains without agronomic management changes. At the daily wheat consumption of 350 g per capita in Gujarat, switching from BHU-31 to Zinc Shakti would add roughly 6.4 mg Zn to the diet, covering about 50% of the adult RDA shortfall [2, 3]. The low phytate: Zn ratio (17.4) further enhances this benefit, since phytate chelates zinc and reduces its absorption in the gut [9].

The absence of a yield penalty is consistent with multi-location data from ICAR's biofortification network, which has shown that modern biofortified lines carry yield genes comparable to the best conventional releases [4]. This is a marked improvement over early biofortified materials, which often traded 5-10% yield for higher micronutrient content [11]. One limitation: our trial was single-location and single-season. The G x E interaction for grain Zn is known to be large, and soil Zn status strongly influences absolute concentrations [12, 13].

Conclusion

All four biofortified wheat varieties exceeded the conventional check for grain zinc and iron without sacrificing yield. Zinc Shakti is recommended for Gujarat's irrigated wheat belt based on its 65% zinc advantage and lowest phytate: Zn ratio. PBW-757 is the preferred choice where iron deficiency is the greater concern. Biofortified wheat offers a zero-cost, seed-based approach to improving micronutrient intake that requires no behaviour change from farmers or consumers. Multi-year, multi-location testing should follow to confirm stability of the micronutrient advantage across Gujarat's diverse soils.

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