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EFFECT OF BIOFORTIFICATION OF FE AND ZN ON YIELD AND YIELD ATTRIBUTE OF DURUM WHEAT (*TRITICUM DURUM*) IN VERTIC USTOCHREPTS SOIL

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ABSTRACT

A field experiment was conducted to evaluate the impact of various combinations of soil, seed, and foliar application of micronutrients on yield and yield attribute of *durum* wheat (*Triticum durum*) cultivated in *Vertic ustochrepts* soil. The study aimed to determine the most effective method and combination of micronutrient application for optimizing wheat productivity under the specific agro-edaphic conditions of the study area. The results of the field experiment revealed that the treatment comprising the recommended dose of fertilizers (RDF) at 120:60:00 NPK kg ha^{-1}, along with seed treatment using $FeSO_4$ (1%) and ZnO (10 ml/kg), and foliar application (CRI, tillering and milking stage) of 0.5% $FeSO_4$ and 0.5% $ZnSO_4$, significantly enhanced the yield and yield attributes of durum wheat. This integrated micronutrient management approach resulted in a marked increase in grain yield, recording 2934, 2911, and 2923 kg ha^{-1} across the two consecutive years and pooled data, respectively. Similarly, straw yield was significantly improved, with values of 3949, 3922, and 3895 kg ha^{-1}. The treatment also led to an increase in and test weight (57.36, 55.23 and 56.30 g) over the years and in pooled analysis.
Keywords: Biofortification, iron, zinc, durum wheat, yield and yield attribute

Introduction

Globally, Fe and Zn deficiencies are among the most widespread micronutrient disorders, affecting nearly 38% of pregnant women and 43% of children under five years of age (WHO, 2015). Hidden hunger, driven by Zn and Fe deficiencies, affects over half the global population due to reliance on cereal-based diets. These deficiencies are common in humans, animals, and plants, posing a major nutritional challenge. Micronutrient deficiencies, particularly of zinc (Zn) and iron (Fe), are a major concern in Indian agriculture, with approximately 49.0% and 12.1% of soils deficient in Zn and Fe, respectively (Arunachalam *et al.*, 2013). In Gujarat, around 24% of soils are Zn deficient, with available Zn levels ranging from 0.25 to 2.58 mg kg^{-1} (Shukla *et al.*, 2014). Such deficiencies are especially severe in semi-arid regions, adversely affecting crop productivity. Wheat, a staple crop comprising over 50% of the diet in many developing countries, is inherently low in Fe and Zn. In India, durum wheat is predominantly grown in the dry, hot regions of central and peninsular states like Madhya Pradesh, Gujarat, Maharashtra, and Rajasthan, contributing 1.5–2.0 million tonnes annually. Agronomic biofortification, involving soil and foliar application of micronutrients such as $ZnSO_4$ and $FeSO_4$, has emerged as a cost-effective and sustainable strategy to enhance grain micronutrient content and productivity (Velu *et al.*, 2014; Jeong and Guerinot, 2008).

In light of these challenges and opportunities, the present study was undertaken to evaluate the effect of Fe and Zn biofortification on the productivity of durum wheat grown on Vertic Ustochrepts soil at the

Agricultural Research Station, Anand Agricultural University, Arnej.

Table 1 : Initial soil properties of experimental site

Soil Parameter	Value	
	2020-2021	2021-2022
Clay (%)	44.9	45.9
Silt (%)	37.9	36.7
Fine sand (%)	13.8	13.4
Coarse sand (%)	3.35	4.09
Texture	Clay soil	Clay soil
pH (1:2.5)	8.25	8.26
EC (1:2.5) (dSm^{-1})	0.38	0.40
Organic carbon (%)	0.382	0.391
Available N (kg ha^{-1})	114	116
Available P_2O_5(kg ha^{-1})	28.5	27.5
Available K_2O (kg ha^{-1})	380.5	402.2
Micronutriments (ppm)		
DTAP-Fe	5.61	5.40
DTAP-Mn	16.9	12.3
DTAP-Zn	0.58	0.55
DTAP-Cu	1.68	1.33

Material and Method

The field experiment for this study was carried out at the Agricultural Research Station farm of Anand Agricultural University, located in Arnej, Gujarat, over two consecutive *rabi* seasons (2020-21 and 2021-22). The research site is situated at the university's off-campus station in Arnej, which falls under Dholka taluka in Ahmedabad district. The experimental field had a flat shaped topography with a gentle slope and found waterlogged condition during monsoon. The soil is representative of the soils of the *bhal* region and is "medium black" soil. The soil chemical analysis indicated that it was low in available nitrogen, available phosphorus whereas high in available potash. With respect to available zinc and iron, the soil of the experimental field was found close to their critical levels.

The experiment was laid out in Randomized Block Design with 3 replications. The fourteen treatments on biofortification Fe and Zn *viz.*, Absolute control (T_1), 120:60:40 NPK kg ha^{-1} (RDF) control (T_2), 120:60:00 NPK kg ha^{-1} (RDF) + soil application $FeSO_4$ (T_3), 120:60:00 NPK kg ha^{-1} (RDF) + seed soaking of $FeSO_4$ (1%) (T_4), 120:60:00 NPK kg ha^{-1} (RDF) + 0.5% $FeSO_4$ foliar spray (T_5), 120:60:00 NPK kg ha^{-1} + seed soaking of $FeSO_4$ (1%) + 0.5% $FeSO_4$ foliar spray (T_6), 120:60:00 NPK kg ha^{-1} + soil application $ZnSO_4$ (T_7), 120:60:00 NPK kg ha^{-1}+ seed treatment of ZnO (T_8), 120:60:00 NPK kg ha^{-1}+ 0.5% $ZnSO_4$ foliar spray (T_9), 120:60:00 NPK kg ha^{-1}+ seed treatment of ZnO + 0.5% $ZnSO_4$ foliar spray (T_{10}), 120:60:00 NPK kg ha^{-1} + seed treatment of ZnO+ seed treatment $FeSO_4$ (1%) (T_{11}), 120:60:00 NPK kg ha^{-1} + soil application of Fe and Zn (T_{12}), 120:60:00 NPK kg ha^{-1} + 0.5% $FeSO_4$ foliar spray +0.5% $ZnSO_4$ foliar spray (T_{13}), 120:60:00 NPK kg ha^{-1} + seed treatment of $FeSO_4$+ seed treatment of ZnO + 0.5% $FeSO_4$ foliar spray +0.5% $ZnSO_4$ foliar spray (T_{14}) were studied. Applied 50 % recommended dose of nitrogen (60 kg ha^{-1}) given at the time of sowing, while, remaining 50% nitrogen were given in equal two splits, among them, 25% nitrogen (30 kg ha^{-1}) applied at 21 DAS and 25% nitrogen (30 kg ha^{-1}) applied at 45 DAS. Entire recommended dose of phosphorus (60 kg P_2O_5 ha^{-1}) applied as a basal application. Whereas, soil application of 50 kg $FeSO_4$ ha^{-1} and 25 kg $ZnSO_4$ ha^{-1} were applied as basal application. Wheat seeds were treated before sowing by soaking seeds for two hours in $FeSO_4$ (1%) solution as well as seed treatment of Zn was also given with 10 ml ZnO (30%) per kg seed. For foliar application of $FeSO_4$ and $ZnSO_4$ were given with 0.5 % $FeSO_4$ and $ZnSO_4$ solution were prepared and applied at three different growths/physiological stages i.e. CRI stages, tillering and milking stage. Wheat var. GADW-3 was taken in *rabi* season for consecutive two years. All treatments were applied over the two years, with the experiment conducted at the same site each year while altering the randomization of treatments. Soil samples were collected from a depth of 0–15 cm in each plot following the wheat harvest. For each treatment, composite soil samples were prepared by combining samples taken randomly from four different spots within the plot. These samples were air-dried, sieved through a 2 mm mesh, and stored in polythene-lined cotton bags for future analysis.

Result and Discussion

Effect of biofortification of Fe and Zn on yield and yield attribute

Grain yield

Biofortification in Fe and Zn treatments significantly influenced yield and yield-attributing characters during the years 2020–21, 2021–22, as well as in the pooled analysis, as presented in Table 2. The application of 120:60:00 NPK kg ha^{-1} (RDF) + seed treatment with $FeSO_4$ and ZnO + 0.5% $FeSO_4$ foliar spray + 0.5% $ZnSO_4$ foliar spray (T_{14}) resulted in a significantly higher grain yield (2934, 2911 and 2923 kg ha^{-1}) during both years and in the pooled analysis. However, it was statistically at par to T_3, T_5, T_6, T_7, T_9, T_{10}, T_{12} and T_{13} treatments in the individual years and in pooled results. Whereas, lower grain yield (2093, 2018 and 2055 kg ha^{-1}) was recorded under absolute control during 2020-21, 2021-22 and pooled result, respectively. However, it remained at par with the T_2, T_4, T_8 and T_{11} treatments. The combine application of macro and micronutrient treatment (T_{14}) improved grain yield by 40.17 and 18.21 per cent, in the first year; 44.29 per cent and 17.74 per cent in the second year; and 42.20 per cent and 17.98 per cent in the pooled result over the absolute control and control (RDF), respectively. Micronutrients like Zn and Fe have been shown to have significant effects on dry matter production, grain yield, and straw yield in wheat. The positive impact of micronutrient supplementation is further evidenced by studies indicating that the combination of micronutrient and macronutrient fertilizers enhances the physiological growth stages of wheat. In particular, the application of microelement fertilizers had found to positively influence wheat growth parameters and result in a considerable increase in grain yield (Nadim *et al*., 2011).

These findings are consistent with the results of several other studies, including those by Nisha (2023), Das *et al.* (2020), Kaur *et al.* (2020), Niyigaba *et al.* (2019) and Jalal *et al.* (2020) all of which highlight the beneficial effects of micronutrient fertilization on wheat productivity.

Straw yield

For straw yield, T_{14} (120:60:00 NPK kg ha^{-1} (RDF) + seed treatment with $FeSO_4$ and ZnO + 0.5% $FeSO_4$ foliar spray + 0.5% $ZnSO_4$ foliar spray) showed a significantly higher yield (3949 and 3922 kg ha^{-1}) during the year 2020-21 and pooled analysis. Similarly, it was statistically at par with T_3, T_5, T_6, T_7, T_9, T_{10}, T_{12} and T_{13} treatments in the year 2020-21 and pooled analysis. Whereas, significant lower straw yield (2845 and 2818 kg ha^{-1}) was recorded with T_1 treatment and found at par with T_2, T_4, T_8 and T_{11} treatments during 2020-21 and pooled result. During second year, T_{14} produced a significantly higher straw yield (3895 kg ha^{-1}) and remaining statistically comparable to T_5, T_6, T_9, T_{10}, T_{12} and T_{13} treatments. While, lower straw yield (2832 kg ha^{-1}) observed with the absolute control in pooled result and it was at par with T_2, T_3, T_4, T_7, T_8 and T_{11} treatments. During the first year, treatment T_{14} increased straw yield by 38.0 per cent and 17.7 per cent over the absolute control and the control (RDF), respectively, while in the second year, the increases were 38.21 per cent and 15.54 per cent, respectively. In the pooled results, treatment T_{14} recorded an increase of 38.48 per cent over the absolute control and 16.48 per cent over the control (RDF). Zeidan *et al*. (2010) recorded that foliar application of iron (Fe) and zinc (Zn) enhances the uptake of other macro and micronutrients, thereby improving growth processes such as photosynthesis, respiration, and various physiological activities. Ultimately, this contributes to a higher straw yield. These findings are consistent to the results of Nisha (2023), Das *et al.* (2020), Kaur *et al.* (2020), Niyigaba *et al.* (2019), Jalal *et al.* (2020) and Goyal (2018)

Test weight

Application of 120:60:00 NPK kg ha^{-1} (RDF) + seed treatment with $FeSO_4$ and ZnO + 0.5% $FeSO_4$ foliar spray + 0.5% $ZnSO_4$ foliar spray (T_{14}) recorded a significantly higher test weight (57.36, 55.23 and 56.30 g) across both years and the pooled analysis. However, it was statistically at par with T_3, T_5, T_6, T_7, T_9, T_{10}, T_{12} and T_{13} treatments during the second year and in the pooled results, while during the first year, it was at par with T_3, T_5, T_6, T_7, T_9, T_{10}, T_{11}, T_{12} and T_{13} treatments. Lower test weight (44.18, 45.52 and 44.85 g) during 2020-21 and 2021-22 and pooled result was reported by absolute control, respectively. The treatment T_{14} increased test weight by 25.5 per cent and 13.9 per cent over the T_1 treatment and control (RDF) in the pooled result. Habib *et al*. (2009) observed that the application of zinc alone and combined application of zinc and iron on foliage at grain filling period of wheat significantly increased 1000 grain weight of wheat. Similar findings are in collaboration with Sarkar *et al.* (2015), Faraji (2014), Aslam *et al.* (2014), Zain *et al.* (2015), Bameri *et al.* (2012), Maralian Habib (2012) and Narimani *et al*. (2010).

Harvest index

Influence of biofortification with Fe and Zn treatments on harvest index of durum wheat recorded at harvest during the years 2020-21, 2021-22 and on pooled result are presented in Table-2. Scrutiny of the data summarized indicated that the application of Fe and Zn biofortification treatments did not have a significant impact on the harvest index of wheat during the experimental years 2020-21 and 2021-22, as well as in the pooled analysis.

Conclusion

It is concluded that the application of recommended dose of fertilizers combined with seed treatment using $FeSO_4$ and ZnO, along with foliar sprays of 0.5% $FeSO_4$ (1%) and 0.5% $ZnSO_4$, significantly enhanced the yield and yield-attributing characters of durum wheat grown under *Vertic ustochrepts* soil of *bhal* region. This integrated approach to biofortification not only improved overall crop performance but also demonstrated the effectiveness of micronutrient management in optimizing productivity under such soil conditions.

Table 2 : Effect of biofortification of Fe and Zn on yield and yield attributing character of *durum* wheat in *Vertic ustochrepts* soil.

Sr. No	Treatments	Grain yield (kg ha^{-1})		Pooled	Straw yield (kg ha^{-1})		Pooled	Test weight (g)		Pooled	Harvest Index (%)		Pooled
		2020-21	2021-22		2021-22	2020-21		2021-22	2020-21		2021-22	2020-21	
T_1	Absolute control	2093	2018	2055	2845	2818	2832	44.18	45.52	44.85	42.42	41.72	42.07
T_2	Control (RDF)	2482	2473	2477	3362	3371	3367	49.94	48.87	49.40	42.49	42.31	42.40
T_3	RDF + Soil application $FeSO_4$	2862	2734	2798	3778	3414	3596	53.03	52.30	52.66	43.12	44.66	43.89
T_4	RDF + Seed soaking of $FeSO_4$ (1%)	2503	2475	2489	3365	3396	3380	50.43	49.07	49.75	42.50	42.24	42.37
T_5	RDF + 0.5% $FeSO_4$ foliar spray	2898	2737	2818	3926	3772	3849	54.24	54.68	54.46	42.45	42.14	42.30
T_6	RDF + Seed soaking of $FeSO_4$ (1%) + 0.5% $FeSO_4$ foliar spray	2914	2854	2884	3937	3816	3876	55.45	55.00	55.23	42.64	42.73	42.68
T_7	RDF + Soil application $ZnSO_4$	2824	2649	2736	3795	3411	3603	51.82	53.11	52.46	42.57	43.67	43.12
T_8	RDF + Seed treatment of ZnO	2508	2483	2495	3366	3393	3380	50.23	49.58	49.90	43.07	42.07	42.57
T_9	RDF + 0.5% $ZnSO_4$ foliar spray	2861	2832	2847	3874	3834	3854	56.21	54.61	55.41	42.48	42.47	42.47
T_{10}	RDF + Seed treatment of ZnO + 0.5% $ZnSO_4$ foliar spray	2888	2856	2872	3899	3869	3884	56.96	54.81	55.89	42.55	42.48	42.52
T_{11}	RDF + Seed treatment of ZnO + Seed treatment $FeSO_4$ (1%)	2500	2505	2503	3397	3406	3402	51.07	49.47	50.27	42.40	42.45	42.42
T_{12}	RDF + Soil application of Fe and Zn	2873	2824	2848	3874	3752	3813	52.02	53.63	52.82	42.54	42.96	42.75
T_{13}	RDF + 0.5% $FeSO_4$ foliar spray + 0.5% $ZnSO_4$ foliar spray	2916	2910	2913	3945	3764	3854	56.54	54.90	55.72	42.60	43.60	43.10
T_{14}	RDF + Seed treatment of $FeSO_4$ + Seed treatment of ZnO + 0.5% $FeSO_4$ foliar spray + 0.5% $ZnSO_4$ foliar spray	2934	2911	2923	3949	3895	3922	57.36	55.23	56.30	42.63	42.71	42.67
T	S. Em±	133	139	86.9	182	164	123	2.14	1.90	1.43	1.81	1.42	1.15
	C. D. at 5 %	388	402	246	529	478	348	6.23	5.51	4.05	NS	NS	NS
Y	S. Em±	-	-	36.32	-	-	46.4	-	-	0.67	-	-	0.43
	C. D. at 5 %	-	-	NS	-	-	NS	-	-	NS	-	-	NS
Y×T	S. Em±	-	-	135	-	-	174	-	-	2.53	-	-	1.62
	C. D. at 5 %	-	-	NS	-	-	NS	-	-	NS	-	-	NS
C V %		8.50	9.01	8.75	8.60	7.99	8.30	7.02	6.29	6.67	7.37	5.76	6.60

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