E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(6): 455-458
Received: 01-03-2024
Accepted: 04-04-2024

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Enhancing seed yield and seed quality of wheat (*Triticum aestivum* L.) through foliar fertigation of micronutrients under restricted irrigation conditions

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i6Sg.910

Abstract
To increase the nutritional value of food crops and their endurance to water shortage circumstances, agronomic foliar fertigation of micronutrients with zinc (Zn) and (Fe) may be used. Wheat (*Triticum aestivum* L.) is an important cereal crop that provides sample nutritious calories for humans and animals. Foliar application of fertilizers can guarantee nutrient availability to wheat, leading to higher yield and seed quality. However, limited research has been undertaken to understand the response of foliar application of Zn and Fe on wheat in Kanpur. The experiment was laid out in Factorial Randomized block design replicated thrice with eighteen treatments which combination with zinc and iron forms of fertilizers. A field trial was conducted to investigate the effect of Zn (0, 1.0, and 2.0%), Iron (0, 0.5, 1.0%) and combined zinc and Iron foliar fertilizer application on two improved Wheat (*Triticum aestivum* L.) varieties locally referred to as K-1317 and K-1616 agro-ecological zones of Kanpur during the 2022-23. Foliar fertilization will be applied at the tillering, booting and earing stages while control plots were sprayed with tap water. There was significant effect of micronutrient application of Plant Height, Chlorophyll Intensity, and number of grains per spike, 1000-grain weight, straw yield and biological yield. The results were showed that combined foliar application of $ZnSO_4$ and $FeSO_4$ with the combine doses Zn1.0% × Fe0.5% expressed the highest growth and yield attributing characters. In conclusion, foliar application of micronutrient may be helpful to improve the yield and reduces micronutrient deficiency (Hidden Hunger).

Keywords: Foliar application, micronutrient, wheat, grain yield, chlorophyll

Introduction
One of the earliest cereals known to have been domesticated is wheat (*Triticum aestivum* L.). In terms of production and area, wheat is India's second-most significant food crop, right behind rice [1]. According to [5, 12], wheat is a crop that is relatively susceptible to iron and zinc deficiencies. The global production volume of wheat amounted to over 781 million metric tonnes, in an area of 222.7 million hectare [21]. The nation's demand for wheat is rising daily. Increased acreage devoted to wheat or higher yields per area will be required to meet the high demand for wheat in the upcoming years. India is the second largest wheat producer in the world. It contributes about 12% of wheat production in world.

Wheat output in India reached 112.74 mt and ranked next to the China in global wheat production during 2022–23, with an average productivity of 35.07q/ha from an area of 30.47 million ha, accounting for 36% of the nation's total production of food grains [2]. With an area of 9.42 million ha, Uttar Pradesh produced 33.95 mt of wheat overall, with an average productivity of 36.04 q/ha. According to a review of state-by-state output, Uttar Pradesh is in first place with 33.95 mt, followed by Madhya Pradesh (22.42 mt), Punjab (14.82 mt), Haryana (10.45 mt), Rajasthan (9.48 mt) and Bihar (6.22 mt). About 92 per cent of the overall production was produced by these top six states together [3]. According to [19], harvest index and biomass productivity are the two key factors that influence wheat productivity. The amount of Zn, Cu, and Fe (Micronutrients) absorbed by the roots during grain development and the amount transferred to the grain from vegetative tissue via the phloem will determine how much of each micronutrient is present in the grain.

In order to maintain crop productivity, proper nutrient management is essential. Micronutrients are essential for plant growth and development, and they account for a sizable portion due to their importance in increasing crop yields [6]**.**To maintain an adequate level of available zinc and iron in soil solution as well as in plants and adequate zinc and iron transport to plants, agronomic biofortification appears to be essential. The Iron and Zinc deficiencies affect more thanthree billion people globally and the frequency is rising at an alarming rate [23, 24].

The main cause of human micronutrient deficiencies is poor nutritional quality of agricultural goods, especially in developing nations where products from cereal crops, including wheat and rice, represent staple diets [22]. In additionto the low concentration and low bioavailability of micronutrients in cereal grain, milling further lowers the concentrations of Fe, Zn, and other minerals [23, 7]. Recently, researchers have focused on "bio-fortification" as a fresh approach to addressing micronutrient deficiencies. In bio- fortification, the basic grain is improved by the use of fertilizer at appropriate crop growth stages while the crop is growing. The biofortification of the grains through agronomic methods is more cost-effective, sustainable, and simple to apply than genetic bio-fortification [22, 10, 7]. The foliar application of micronutrient is an important method of fertilizer application because it facilitates easy and quick nutrient utilization [14]. Depending on the application technique, Zn and Fe fertilizers can increase grain Zn and Fe concentration by up to three or four times. The most effective method for doing this was foliar application method, which increased the concentration of Zn and Fe in grain and yield attributing parameters of wheat by roughly three and a half times [4].

Materials and Methods

The experiment was carried to determine the efficacy of foliar application of zinc and iron on wheat yield and productivity during Rabi (winter) season 2022-23 at the Students' Instructional Farm, Division of Agronomy, Rama University, Kanpur, U.P. The experiment comprised of two wheat varieties *viz*, V1-K-1317 and V2-K-1616 in Factor-A and two micronutrients each three levels of Zn and Fe as Factor-B Zn (0, 1.0 and 2.0%) and Fe (0, 0.5, and 1.0%). The crop was sown in second week of November 2022-23. Full doses of P and K, along with one-third of N, were applied as a basal dose at the time of sowing using inorganic sources of nutrients, such as DAP, MOP and Urea respectively. The remaining two-thirds of N were applied in two equal splits depending on the treatments at the CRI and pre-booting stages, with chelated ZnSO4 applied as per the treatments. The grain and straw yield was calculated using the net plot area and converted to kg /ha. Individual data from the various characters studied in the experiment were statistically analyzed. The standard error of mean, critical difference (C.D.) at 5% level of probability and coefficient of variance were calculated using standard procedures.

Results and Discussion

The data regarding the raw seed yield Kg plot^{-1} presented in a table (i) clearly showed that the variety significant each other, highest raw seed yield Kg plot^{-1} (19.018) was found in K- 1317 variety of wheat which was significantly superior than wheat variety K-1616 recorded lowest raw seed yield Kg plot^{-1} (18.509) during research year. The data regarding the graded seed yield q ha^{-1} presented in a table (ii) clearly showed that the variety significant each other, highest graded seed yield q ha^{-1} (41.130) was found in K-1317 variety of wheat which was significantly superior than wheat variety K-1616 recorded graded seed yield q ha^{-1} (40.046) during research year.

The effect of zinc and iron significant effect on raw seed yield Kg plot^{-1}. However, numerically it was found maximum raw seed yield Kg plot^{-1} (22.656) in the combination of $Zn_{1.0\%} \times Fe_{0.5\%}$ and minimum raw seed yield Kg plot^{-1} was found in $Zn_{0\%} \times Fe_{0\%}$ (16.756) in wheat variety K-1317 from the graph (i). In wheat variety K-1616, combination of $Zn_{1.0\%} \times Fe_{0.5\%}$ (22.036) was found maximum and the minimum raw seed yield Kg plot^{-1} found in $Zn_{0\%}$ $\times Fe_{0\%}$ (16.788) from the graph (i). The effect of zinc and iron significant effect on graded seed yield q ha^{-1}. However, numerically it was found maximum graded seed yield q ha^{-1} (49.000) in the combination of $Zn_{1.0\%} \times Fe_{0.5\%}$ and minimum graded seedyield q ha^{-1} was found in $Zn_{0\%} \times Fe_{0\%}$ (36.250) in wheat variety K-1317 from the graph (ii). In wheat variety K-1616, combination of $Zn_{1.0\%} \times Fe_{0.5\%}$ (47.667) was found maximum and the minimum graded seed yield q ha^{-1} found in $Zn_{0\%} \times Fe_{0\%}$ (36.333) from the graph (ii).

Table 1: Effect of foliar spray Zinc and Iron on Raw seed yield Kg plot^{-1} in wheat varieties (K-1317 and K-1616

Treatment	Raw seed yield Kgplot^{-1}
Variety	
K-1317	19.018
K-1616	18.509
SE (m)	0.155
CD(p=0.05)	0.446
Zinc Doses	
(Zn0%)	17.227
(Zn1.0%)	20.764
(Zn2.0%)	18.299
SE (d)	0.19
CD(p=0.05)	0.546
Iron doses	
(Fe0%)	18.612
(Fe0.5%)	19.019
(Fe1.0%)	18.659
SE (d)	0.19
CD(p=0.05)	NS

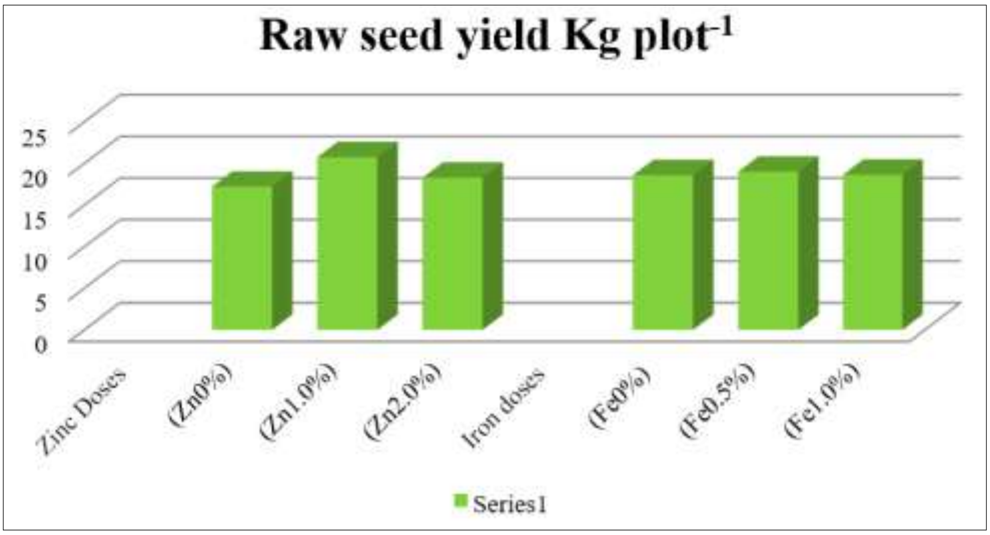

Fig 1: Effect of foliar spray Zinc and Iron on Raw seed yield Kg plot^{-1} in wheat varieties (K-1317 and K-1616

Table 2: Effect of Zinc and Iron on Graded seed yield q ha^{-1} in wheat varieties (K-1317 and K-1616)

Treatment	Graded seed yield q ha^{-1}
Variety	
K-1317	41.13
K-1616	40.046
SE (m)	0.337
CD(p=0.05)	0.97
Zinc Doses	
(Zn0%)	37.264
(Zn1.0%)	44.917
(Zn2.0%)	39.583
SE (d)	0.413
CD(p=0.05)	1.188
Iron doses	
(Fe0%)	40.264
(Fe0.5%)	41.139
(Fe1.0%)	40.361
SE (d)	0.413
CD(p=0.05)	S

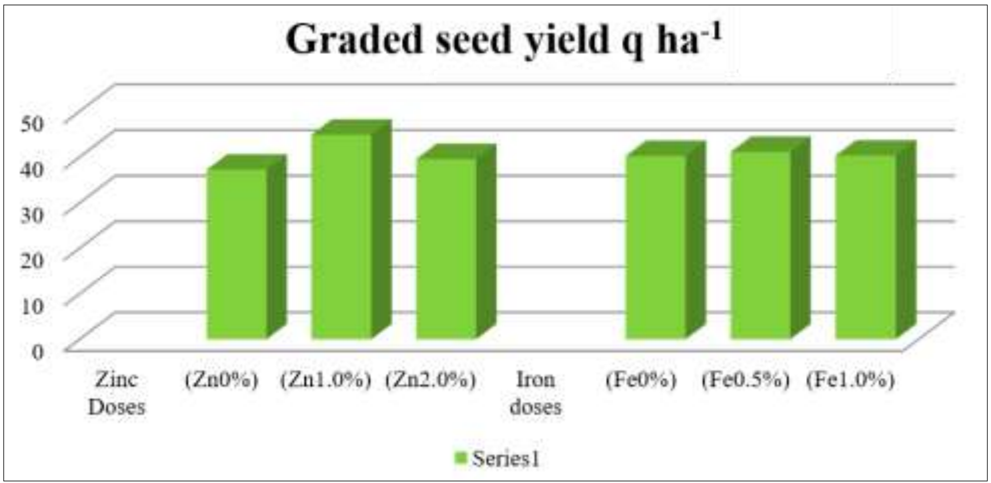

Fig 2: Effect of Zinc and Iron on Graded seed yield q ha^{-1} in wheat varieties (K-1317 and K-1616)

Conclusion

In view of the aim of the study i.e. to increase the concentration of Zn and Fe in grain to improve grain quality for fighting hidden hunger and nutrient malnutrition, especially in poor and developing countries where diets are dominated with wheat as staple food crops and realization of maximum seed yield the combination of foliar spray Zn and Fe (1% and 0.5, 1%) at tillering booting and earing growth stages off wheat may be recommended for bio- fortification indrought region.

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