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Rahmat Gul
Ph.D., Scholar, Division of Agronomy, SKUAST, Jammu and Kashmir, India

Meenakshi Gupta
Professor, Agronomy Division, SKUAST, Jammu and Kashmir, India

Rajeev Bharat
Sr. Scientist (Agronomy), AICRP-Rapeseed & Mustard, SKUAST, Jammu and Kashmir, India

B.C. Sharma
Professor & Head & Dean, FOA, SKUAST, Jammu and Kashmir, India

Sarabdeep Kour
Associate Professor, Soil Science & Agri, Chemistry, SKUAST, Jammu and Kashmir, India

Brajeshwar Singh
Associate Professor& Head Division of Microbiology, F.B.Sc., SKUAST, Jammu and Kashmir, India

Corresponding Author:
Rahmat Gul
Ph.D., Scholar, Division of Agronomy, SKUAST, Jammu and Kashmir, India

Effect of soil and foliar application of zinc and iron on economics and yield of wheat (*Triticum aestivum* L.) in Jammu

Rahmat Gul, Meenakshi Gupta, Rajeev Bharat, BC Sharma, Sarabdeep Kour and Brajeshwar Singh

Abstract
The experiment was carried to determine the efficacy of soil and foliar application of zinc and iron on wheat yield and productivity during *rabi* (winter) season 2020-21 at the Research Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha. The experiment comprised of three wheat varieties and 6 levels of Zn and Fe as Factor-B arranged in factorial randomized block design with 3 replication. The results revealed that Wheat variety WH 1105 gave the maximum grain, straw, straw yield and harvest index than varieties WB 02 and HD 3086 I comparison whereas application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages (T_6) resulted in maximum grain yield, straw yield and harvest index besides the gross returns, net returns and near to aximum B:C ratio than other treatments in comparison.

Keywords: Wheat, zinc, Iron, bio-fortification, economics, harvest index, grain yield

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 (Anonymous 2021). In 2020–21, [3] India produced 98.38 million tons of wheat on 30.59 million hectares, yielding 3.22 tons /ha. 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 (Cakmak *et al*., 2007) [5]. 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 bio-fortification appears to be essential. The Iron and Zinc deficiencies affect more than three billion people globally and the frequency is rising at an alarming rate (WHO, 2002; Welch and Graham, 2004) [19, 18]. 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 (Welch and Graham, 1999) [17]. In addition to the low concentration and low bioavailability of micronutrients in cereal grain, milling further lowers the concentrations of Fe, Zn, and other minerals (Welch, 2004; Cakmak, 2010) [17, 5]. 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 bio-fortification of the grains through agronomic methods is more cost-effective, sustainable, and simple to apply than genetic bio-fortification. (Welch and Graham, 1999; Frossard *et al*., 2000; Cakmak, 2008) [17, 6, 11]. The soil and foliar nutrition is an important method of fertilizer application because it facilitates easy and quick nutrient utilization (Kandoliya *et al*., 2018) [12]. 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 the soil + foliar application method, which increased the concentration of Zn and Fe in grain by roughly three and a half times. (Bana *et al*., 2021).

Material and Method
The experiment was carried to determine the efficacy of soil and foliar application of zinc and iron on wheat yield and productivity during *rabi* (winter) season 2020-21 at the Research

Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha. The experiment comprised of three wheat varieties *viz*, V_1-WB 02 (fortified), V_2-HD-3086 (non-fortified), V_3-WH-1105 (non-fortified) in Factor-A and 6 levels of Zn and Fe as Factor-B *viz*, Rec. NPK (T_1), Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1}(T_2), Rec. NPK+ soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $ZnSO_4$ @ 0.5% at both during pre-anthesis and grain filling stages (T_3), Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% both during pre-anthesis and grain filling stages (T_4), Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $ZnSO_4$ @ 0.5% at pre-anthesis and chelated $FeSO_4$ @1% at grain filling stages (T_5) and Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages (T_6) arranged in factorial randomized block design with 3 replication. The soil of the experimental field was sandy clay loam in texture, slightly alkaline (7.43) in reaction, low in organic carbon (4.9), low in available nitrogen (218.85) and Zinc (0.56 mg kg^{-1}) but medium in available potassium (132.4) and available phosphorous (14.11). The soil contained sufficient levels of Fe (20.13 mg Kg^{-1}). The crop was sown in second week of November, 2021. 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 $ZnSO_4$ applied as per the treatments. The grain and straw yield was calculated using the net plot area and converted to kg /ha. The costs associated with each cultivation operation, including the cost of inputs such as seeds, foliar spray, fertilizers, irrigation and etc. applied to each treatment, were calculated based on the prevailing market rates. The gross returns in rupees /ha was calculated using the grain and straw yields from each treatment as well as local market prices. Each treatment's net return was calculated by subtracting the total cost of cultivation from the gross returns. The benefit: cost ratio (B: C) was calculated by dividing the net return by the cultivation cost. 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 presented in Table 1 indicates that the highest grain yield (4678.43 kg /ha), straw yield (7130.87 kg /ha) and harvest index (40.84%) was noticed in WH-1105, which was at par with WB 02. However, lowest grain yield (3710.20kg /ha), straw yield (5260.58kg /ha) and harvest index (42.40%) was recorded in wheat variety HD-3086. This may be attributed to greater genetic potential and efficient utilization of Zn and Fe thereby leading to production of maximum leaf area and dry matter which tranlated into higher yield attributes and yield of wheat varieties WH 1105 and WB 02. Similar findings were reported by Yilmaz *et al*., 1997 [21] who reported increased grain and straw yield, zinc content in wheat crop with soil and foliar application of Zn. Similar findings were also reported by Chaudhary *et al*. (2007) [8].

Among various levels of Zn & Fe treatment, application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages (T6) recorded significantly highest grain yield (4520.90 kg /ha), straw yield (7325.04 kg /ha) and harvest index (40.35%) which remained statistically at par with application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $ZnSO_4$ @ 0.5% at pre-anthesis and chelated $FeSO_4$ @ 1% at grain filling stages (T_5). However, the minimum grain yield (4051.96kg /ha), straw yield (5643.05kg /ha) and harvest index (41.68%) was found in control plots i.e. recommended NPK fertilization in the wheat crop. The interaction effect remained to be not-significant. The result indicates that the maximum number of grain yield and straw yield were recorded with soil application of chelated $ZnSo_4$ as well as foliar spray of chelated $ZnSo_4$ and $FeSo_4$. This can be due to the role of Iron in the formation of starch and protein synthesis, as well as the preservation and formation of chlorophyll, regulate the photosynthetic and respiration activities in plants. Many of the enzymatic transformations have potential thanks to iron. A number of these enzymes are involved in the synthesis of chlorophyll, the formation of grains, and the production of dry matter, all of which contribute to final yield characteristics like the quantity of active tillers per plant. These results support those previously reported by (Wisal *et al*., 1990; Ananda and Patil, 2005; Kumar *et al*., 2009; and Abbas *et al*., 2016) [20, 1, 2, 13]. Also, the role of zinc in the biosynthesis of indole acetic acid (IAA) and particularly its role in the initiation of primordia for reproductive parts and the partitioning of photosynthesis is well documented and zinc can help in production of auxin also which help in cell division and cell elongation process along with these also motivate the crop to uptake more nutrients from the soil. This finding is agreement with (Dhaliwal *et al*., 2010; Gupta *et al*., 2022; El Habbasha *et al*., 2015; and Majd *et al*., 2015) [9, 4, 10, 14].

The perusal of the data presented in Table 2 divulged that higher gross return, net returns and B: C ratio observed in V_3-WH-1105 gross return (115856.93 ₹/ha), net return (84352.60 ₹/ha) and B: C ratio (2.70). Whereas, lowest gross return (88504.68₹ /ha), net return (57000.35 ₹/ha) and B: C ratio (1.83) was recorded with V_2- HD-3086 variety. Amongst various levels of Zn & Fe , application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages (T6) recorded significantly higher gross return (114716.73 ₹/ha) and net return (81395.73₹ /ha) followed by application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $ZnSO_4$ @ 0.5% at pre-anthesis and chelated $FeSO_4$ @ 1% at grain filling stages (T_5) with (111248.06 ₹/ha) gross return and (77927.06 ₹/ha) net return respectively. However, lowest gross return (96888.39 ₹/ha) and net return (69467.39 ₹/ha) was noted in control plot i.e. application of recommended NPK fertilizers. However, maximum B: C ratio was recorded with application of Rec. NPK+ soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $ZnSO_4$ @ 0.5% at both during pre-anthesis and grain filling stages (T_3) (2.57) due to the lower cost of production and comparable gross income in T_3 than T6 treatment in comparison whereas, minimum B: C ratio (1.62) was recorded with application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% both during pre-anthesis and grain filling stages (T_4).

Table 1: Effect of Zn and Fe application on grain, straw yield and harvest index of wheat

Treatments	Grain yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)
Varieties			
V1- WB 02 (Fortified)	4567.63	6996.61	40.61
V2- HD-3086 (Non fortified)	3710.20	5260.58	42.40
V3- WH-1105 (Non fortified)	4678.43	7130.87	40.84
SEm (±)	48.69	73.43	0.23
C D (5%)	139.93	211.04	NS
Zn and Fe levels			
T1 : Rec. NPK	4051.96	5643.05	41.68
T2 : Rec. NPK + SA of Ch. ZnSO4 @ 20 kg ha^{-1}	4254.31	5964.87	42.50
T3 : Rec. NPK+ SA of Ch. ZnSO4 @ 20 kg ha-1 & FA of Ch. ZnSO4 @ 0.5% at PA & GF stages	4288.98	6200.30	42.18
T4 : Rec. NPK+ SA of Ch. ZnSO4 @ 20 kg ha-1 & FA of Ch. FeSO4 @ 1.0% at PA & GF stages	4306.89	6404.76	41.25
T5 :Rec. NPK+ SA of Ch. ZnSO4 @ 20 kg ha-1 & FA of Ch.4 @ 0.5% at PA & Ch. FeSO4 @1.0% at GF stages	4489.49	7138.09	39.72
T6 :Rec. NPK+ SA of Ch. ZnSO4 @ 20 kg ha-1 & FA of Ch. FeSO4 @1.0% at PA & Ch. ZnSO4 @ 0.5% at GF stages	4520.90	7325.04	40.35
SEm (±)	68.86	103.85	0.33
C D (5%)	196.89	298.45	NS

*SA-Soil application, Chel.-Chelated, FA- Foliar application, PA- Pre-anthesis, GF-Grain filling

Table 2: Effect of Zn and Fe application on economics of wheat

Varieties	Cost of Cultivation (₹ . ha^{-1})	Gross returns (₹ . /ha)	Net returns (₹ . /ha)	B:C ratio
V_1- WB 02 (Fortified)	31504	112376.91	80872.57	2.50
V_2- HD-3086 (Non fortified)	31504	88504.68	57000.35	1.83
V_3- WH-1105 (Non fortified)	31504	115856.93	84352.60	2.70
Zn and Fe levels				
T_1: Rec. NPK	27421	96888.39	69467.39	2.53
T_2: Rec. NPK + SA of Ch. $ZnSO_4$ @ 20 kg ha^{-1}	28321	101132.93	72811.93	2.57
T_3: Rec. NPK + SA of Ch. $ZnSO_4$ @ 20 kg ha^{-1}& FA of Ch. ZnSO4 @ 0.5% both PA & GF stages	28881	103084.47	74203.47	2.57
T_4: Rec. NPK + SA of Ch. $ZnSO_4$ @ 20 kg ha^{-1}& FA of Ch. $FeSO_4$ @ 1.0% both PA & GF stages	37761	106406.45	68645.45	1.62
T_5: Rec. NPK + SA of Ch. $ZnSO_4$ @ 20 kg ha^{-1}& FA of Ch. $ZnSO_4$ @ 0.5% at PA & Ch. $FeSO_4$ @1.0% at GF stages	33321	111248.06	77927.06	2.34
T_6: Rec. NPK + SA of Ch. $ZnSO_4$ @ 20 kg ha^{-1}& FA of Ch. $FeSO_4$ @1.0% at PA & Ch. $ZnSO_4$ @ 0.5% at GF stages	33321	114716.73	81395.73	2.44

*SA-Soil application, Chel.-Chelated, FA- Foliar application, PA- Pre-anthesis, GF-Grain filling

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 gross returns, net returns and near to maximum B:C ratio, the Wheat variety WH 1105 with application of Rec. NPK + soil application of chelated $ZnSO_4$ @ 20 kg ha^{-1} and foliar application of chelated $FeSO_4$ @ 1% at pre-anthesis and chelated $ZnSO_4$ @ 0.5% at grain filling stages (T_6) may be recommended for bio-fortification in Jammu region.

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