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Agronomic biofortification strategy through zinc and iron application in wheat (*Triticum aestivum* L.) varieties

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Abstract
Field experiments were conducted during *Rabi* seasons of 2015-16 and 2016-17 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, situated at 125.9 meter altitude, 26.4148^0 North latitude, 80.2321^0 East longitude, to study "Agronomic biofortification strategy through Zinc and Iron application in wheat (*Triticum aestivum* L.) varieties". The experiment consisted three varieties (PBW 550, DBW 17 and K 402), two FYM levels (FYM @10 t ha^{-1} and without FYM) and three nutrient management treatments (NPK- 150:60:40 kg ha^{-1} only, NPK+ $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ 1% sprayed at tillering stage, NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSo_4$ 1% sprayed at flag leaf stage). The treatments were accommodated in Split-Split Plot Design with three replications. The soil of experimental field was sandy loam in texture having low organic carbon (0.36 %), medium in available Nitrogen (174 kg ha^{-1}) low in available Phosphorus (14.0 kg ha^{-1}), medium in available Potassium (154.0 kg ha^{-1}), low in available Zinc (0.68 mg ha^{-1}) and normal in available Iron (8.42 mg ha^{-1}) with normal P^H (7.92). Pooled results of two years experimentation indicated that highest value of grain yield (5017.6 kg ha^{-1}), harvest index (38.15 %), grain zinc concentration (41.70 ppm), grain Iron concentration (48.82 ppm) and net income (Rs.70978 ha^{-1}) was recorded under the variety K 402. Application of FYM @10 t ha^{-1} + NPK (150: 60: 40 kg ha^{-1}) recorded maximum grain yield (4678.51 kg ha^{-1}), harvest index (36.97 %), grain zinc concentration (41.21 ppm), grain iron concentration (47.15 ppm), net income (Rs.63918 ha^{-1}) compared to without FYM treatment. Application of NPK @ (150:60:40 kg ha^{-1} + $ZnSO_4$ @25 kg ha^{-1} as basal + $FeSO_4$ 1% sprayed at tillering stage recorded highest grain yield (4805.69 kg ha^{-1}), harvest index (37.13 %), grain zinc concentration (42.03 ppm), grain iron concentration (47.88 ppm) and net income (Rs.67774 ha^{-1}) compared to other nutrient management treatments. The interaction effect of varieties, FYM levels, and nutrient management treatments were found non-significant.

Keywords: wheat (*Triticum aestivum* L.), biofortification, zinc, iron and FYM

Introduction
Wheat is the most important grain of trade for human consumption. The crop is most successfully grown between latitudes of 30 ^{0} N to 60 ^{0} N and 27 ^{0} S to 40 ^{0} S in the world with 11^0 N to 30 ^{0} N and from sea level up to an elevation of 3658 m in the Himalayas. In India wheat is the second most important food crop after rice, both interms of area and production. Wheat production of India is 98.38 million tonne from 30.59 million hectares with productivity of 3.22 tonne per hectare during 2016-17. It accounts for about 36 percent of country's total food grain production as per the fourth advance estimate. (Anonymous, 2017) [2].

Modernization of agriculture does not only affect the diversity of crops but also the diversity of nutrition. Crop production geared towards high yielding cereal crops mainly wheat, rice and maize could significantly reduce the production of nutritionally richer grains. This reliance on few crops is the major reason for wide spread of zinc and iron deficiencies. Globally in Asia, Africa and Latin American countries deficiency of micronutrients such as iron, zinc, folic acid and beta-carotene is the most prevalent. (Anteneh *et al.* 2016) [3]. In developing countries women and children are prone to risks associated with deficiency of micronutrients. The deficiency in zinc could result in impaired immune function, children's stunted growth and adverse pregnancy outcome in women. Likewise the absence of iron also leads to numerous physiological diseases such as anemia and neurodegenerative diseases. (Bilski *et al.* 2012) [4].
The implementation of agronomic biofortification of cereal crops with iron, and zinc appear to

be a rapid and simple solution to the deficiency of these elements in the soils and plants. Zinc play an important role in carbohydrate metabolism, detoxification of super oxide radical and imparts resistance to disease in plants. Since Zn is associated with enzymes its deficiency leads to several disorders in plants. Zn deficiency has received great attention in India, because nearly half of the Indian soils are poor in available Zn content. (Shivay *et al.* 2014) [10]. Zinc is mainly localized and concentrated in the aleurone and embryo parts of wheat grain. Zinc concentration of the endosperm (white flour) is very small. Wheat grain is consumed after milling, which removes the Zn-rich parts and leaves just the Zn-poor endosperm behind. (Cakmak and Kutman 2017) [5].

Iron plays a key role in the synthesis of chlorophyll, carbohydrate production, cell respiration, chemical reduction of nitrate and sulphate, and in N assimilation. The Fe is mainly involved in biochemical processes which are mostly enzymatic oxidation-reduction reactions in plants. With the progress of time and advancement in agricultural technology, there is a need to maximize awareness regarding healthy nutrition at both national and international level. There is a paucity of research data on agronomic biofortification of new wheat varieties using fertilizer strategies for improvement in yield and grain quality in Uttar Pradesh (India). Keeping in view the above facts this study was initiated to assess the impact of zinc and iron fertilization on growth characteristics, yield attributes, yield and quality of wheat.

Materials and Methods

Field experiments were conducted during *Rabi* seasons of 2015-16 and 2016-17 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, situated at 125.9 meter altitude, 26.4148^0 North latitude, 80.2321^0 East longitude. The experiment consisted three varieties (PBW 550, DBW 17 and K 402), FYM Doses (0 t ha^{-1} and 10 t ha^{-1}), nutrient management treatments (NPK @150:60:40 kg ha^{-1}, NPK+$ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at tillering, and NPK+ $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at flag leaf stage. The varieties were sown in main plot, two FYM doses in sub plot and three nutrient management treatments in sub-sub plot. The field experiment was laid out in Split-Split Plot Design. Treatments were randomly allocated in main; sub plot and sub-sub plot separately and were replicated three times. Nutrients viz. Nitrogen as DAP and Urea; P_2O_5 as Di-Ammonium Phosphate, K_2O as Muriate of Potash, Zn as Zinc Sulphate ($ZnSO_4$) and Fe as Ferous sulphate ($FeSO_4$) were applied as per treatment. FYM was applied in the field before sowing at the time of field preparation. 50 % N and full amount of P_2O_5, K_2O and Zn were applied at the time of sowing. Remaining N was applied in two equal splits as top dressing (viz. first and third irrigation). Foliar spray of Iron was done as per treatments at tillering and flag leaf stage in respective plots. The other crop management practices were performed as per standard recommended practices. The soil of the experimental field was sandy loam in texture having 54.30 % sand, 27.20 % silt and 18.50 % clay particle with P^H of 7.92. The soil was moderately fertile being low in Organic Carbon (0.36%), medium in available Nitrogen (174 kg ha^{-1}), available Phosphorus (14.0 kg ha^{-1}) and available Potassium (154.0 kg ha^{-1}), low in available Zinc (0.68 mg kg^{-1}) and normal in available Iron (8.42 mg kg^{-1}).

The meteorological observation recorded during both years of experimentation reveal that the maximum temperature averaged at 27.1^0 & 26.2^0C minimum at 13.2^0 & 12.5^0C, relative humidity at 83.7 & 50.8 % and cumulative rainfall at 49.9 & 32 mm. respectively, during 2015-16 and 2016-17. The maximum rainfall (11mm) was recorded in 3^{rd} SMW (15-21 January) during 2015-16 and 27.8 mm in 4^{th} SMW (22-28 January) during 2016-17, which was quite beneficial for crop growth during second year as compared to first year. The crop experienced average wind speed ranged of 3.6 and 4.7 km h^{-1} and the average evaporation rate of 2.0 and 2.4 mm day^{-1}, respectively, during 2015-16 and 2016-17.

Crop response to the treatment was measured in terms of various quantitative and quality indices. The year wise as well as pooled values have been recorded and were analyzed statistically. Valid comparisons between various treatments were drawn by using respective C. D. value.

Results

Yield attributes

Yield attributes are the function of vegetative & reproductive development. Pooled data of 2015-16 and 2016-17 summarized in Table. 1 exhibited that among different varieties K 402 (Mahi) recorded maximum number of ears per m^2, ear length, number of grains per ear, grain weight per ear and test weight compared to PBW 550 and DBW 17. This might be due to better genome characteristic of the variety. The application of FYM @ 10 t ha^{-1} along with NPK recorded significant increase in yield attributes viz. number of ears (9.36 %), ear length (4.80 %), number of grains per ears (6.64 %), grain weight per ears (3.95 %) and test weight (4.00 %) as compared to without FYM treatment. The application of NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1 %) at tillering stage recorded significantly higher number of ears (14.43 %), ear length (8.21 %), number of grains per ear (11.91 %), grain weight per ear (10.00 %) and test weight (4.62 %) compared to only N.P.K treatment (control), while NPK + $ZnSO_4$ @ 25 kg^{-1} as basal + $FeSO_4$ (1%) at flag leaf stage recorded the increment in number of ears per (5.79 %), ear length (4.26 %), number of grains per ear(5.91 %), grain weight per ear (5.65 %) and test weight (2.16 %) compared to control treatment but inferior to NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) at tillering stage treatment.

Yield and harvest index

The ultimate effect of experimental variable was reflected in the final yield of wheat crop (Table.1). Among different verities K 402 (Mahi) exhibited significant improvement in biological yield (8.92 % and 17.84 % compared to PBW 550 and DBW 17, respectively), grain yield (10.35 % and 24.24 % compared to PBW 550 and DBW 17, respectively), straw yield (8.05 % and 14.23 % compared to PBW 550 and DBW 17, respectively) and harvest index (0.52 % and 2.92 %, respectively over PBW 550 and DBW 17. The better yield and harvest index of K 402 (Mahi) may be the resultant of superior growth and yield attributing characters compared to other two varieties. The findings on the performance of different varieties of wheat have been reported by Maurya *et al.* (2014) [8]. The application of FYM @ 10 t ha^{-1} along with NPK recorded significantly higher biological yield (8.31 %), grain yield (6.57 %), straw yield (9.35 %) and harvest index (0.49 %) as compared to without FYM treatment. The addition of FYM must have improved the physical conduction of soil and there by improved the efficiency in utilization of native nutrients. Among difference nutrient management treatment NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) at tillering stage recorded significantly greater biological yield

(13.96 %), grain yield (13.51 %), straw yield (14.30 %) and harvest index (0.08 %). compared to only NPK treatment (control). Zinc is known to decrease the carbohydrate content of leaves and stem during spike formation, which apparently facilitates the flow of carbohydrates to reproductive organs and contributed to improved grain yield (Hemantaranjan and Garg, 1988) [6].

The favorable effect of $FeSO_4$ as foliar application might be due to physiological role of iron as a constituents of electron transport enzymes, like cytochrome and ferridoxin which are actively involved in photosynthesis and mitochondrial respiration which resulted in higher dry matter accumulation and bolder grains. This was possible due to enhanced synthesis of carbohydrates and protein and their transport to storage parts. The above findings are supported by the report of Aatif *et al.* (2007) [1].

Economics

On the basis of gross income, net income and B: C ratio the most profitable variety identified was K 402 (Mahi) which gave 8.75 % and 20.35 % more gross income, 15.45 % and 37.42 % more net income, 32 paise and 37 paise more B: C Ratio compared to PBW 550 and DBW 17, respectively (Table.2). The application of FYM @ 10 t ha^{-1} recorded 7.01 % more gross income, 8.66 % more net income and 8.00 paise more B: C Ratio compared to without FYM treatment. The findings are in conformity with the results of Singh *et al.* (2016) [11]. Among nutrient management treatment NPK + $ZnSO_4$ @ 25 kg^{-1} as basal + $FeSO_4$ (1%) at tillering stage recorded significantly more gross income (13.85 %), net income (23.52 %) and more B: C Ratio (28 paise) compared to only NPK treatment (control). The above findings are correlated with the findings of Khan *et al.* (2009) [7].

Quality improvement

Grain zinc concentration and uptake

Among different varieties K 402 (Mahi) recorded maximum Zinc concentration in wheat grain (2.25 % and 7.14 % more as compared to PBW 550 and DBW 17, respectively), zinc uptake by 12.44 % and 33.35 % more compared to PBW 550 and DBW 17, respectively (Table.2). Application FYM @10 t ha^{-1} recorded 3.72 % more Zinc concentration and 10.27 % more Zinc uptake in wheat grain compared to without FYM treatment. Similar findings were reported by Narwal *et al.* (2010) [9]. Among different nutrient management treatments NPK + $ZnSO_4$ @ 25 kg^{-1} as basal + $FeSO_4$ (1%) at tillering stage recorded the maximum Zinc concentration (8.63 %) and uptake (23.24 %) in wheat grain as compared to only NPK treatment. Similar findings have been reported by Cakmak and Kutman (2017) [5].

Grain iron concentration and uptake

In comparison to the varieties, K 402 (Mahi) has recorded 6.22 % and 9.43 % more iron concentration compared to PBW 550 and DBW 17, respectively. The variety K 402 (Mahi) also exhibited 16.92 % and 35.69 % more iron uptake compared to PBW 550 and DBW 17, respectively. Application of FYM @ 10 t ha^{-1} recorded 2.99 % more iron concentration and 9.88 % more iron uptake compared to without FYM treatment. Application of NPK + $ZnSO_4$ @ 25 kg^{-1} as basal + $FeSO_4$ (1%) at tillering stage recorded 4.92 % more iron concentration and 19.98 % more iron uptake compared to only NPK treatment. Similar findings were reported by Zhao *et al.* (2011) [12].

Table 1: Effect of varieties, FYM doses and nutrient management on yield attributes and yield of wheat

Treatment Combinations	Ears / m^2	Ear length (cm)	Grains per ear	Grain weight (g) per ear	Test weight (g)	Biological Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)
Varieties									
PBW 550	629.94	10.23	49.43	8.06	37.52	12104.49	4546.76	7554.96	37.63
DBW 17	586.27	9.32	45.60	6.77	37.12	11188.61	4038.46	7146.40	35.86
K 402 (Mahi)	783.26	10.52	54.84	9.15	40.02	13184.77	5017.61	8163.75	38.15
SE(d) ±	7.03	0.18	0.84	0.10	0.19	211.22	48.74	166.38	0.46
CD at 5%	16.21	0.41	1.94	0.24	0.45	487.06	112.39	383.67	1.06
FYM doses									
FYM - 0 t ha^{-1}	635.87	9.79	48.39	7.84	37.47	11673.61	4390.04	7280.98	37.46
FYM - 10 t ha^{-1}	697.11	10.26	51.52	8.15	38.97	12644.70	4678.51	7962.43	36.97
SE(d) ±	6.03	0.06	0.35	0.03	0.22	85.58	32.92	68.57	0.27
CD at 5%	13.15	0.14	0.76	0.08	0.47	186.48	71.75	149.41	N. S
Nutrient management									
NPK (150:60:40 kg ha^{-1})	624.38	9.62	47.15	7.60	37.37	11356.10	4233.70	7118.52	37.05
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at TS	714.51	10.41	52.77	8.36	39.10	12942.09	4805.69	8136.55	37.13
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at FLS	660.59	10.03	49.94	8.03	38.18	12179.26	4563.44	7610.04	37.46
SE(d) ±	6.86	0.09	0.35	0.04	0.18	97.25	45.00	82.53	0.41
CD at 5%	13.80	0.18	0.50	0.09	0.37	195.57	90.49	165.97	N. S

Table 2: Effect of varieties, FYM doses and nutrient management on economics and quality improvement of wheat

Treatment Combinations	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B: C ratio	Zinc Concentration (ppm) in grain	Zinc uptake (g ha^{-1}) in grain	Iron Concentration (ppm) in grain	Iron uptake (g ha^{-1}) in grain
Varieties							
PBW 550	103466.56	61479.17	2.39	40.78	185.92	45.96	209.62
DBW 17	93498.56	51650.08	2.34	38.92	156.77	44.61	180.62
K 402 (Mahi)	112527.92	70978.48	2.71	41.70	209.06	48.82	245.10

SE(d) ±	1498.89	1560.38	0.05	0.33	2.49	0.45	3.03
CD at 5%	3456.43	3598.24	0.11	0.77	5.74	1.04	6.99
FYM doses							
FYM - 0 t ha^{-1}	99756.64	58819.86	2.44	39.73	174.93	45.78	201.88
FYM - 10 t ha^{-1}	106754.40	63918.63	2.52	41.21	192.91	47.15	221.68
SE(d) ±	773.26	719.98	0.02	0.15	1.64	0.22	1.99
CD at 5%	1684.94	1568.83	0.04	0.32	3.58	0.48	4.35
Nutrient management							
NPK (150:60:40 kg ha^{-1})	96498.78	54868.92	2.34	38.69	163.32	45.20	192.34
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at TS	109865.82	67774.71	2.62	42.03	201.29	47.88	230.78
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at FLS	103401.96	61464.12	2.48	40.68	187.14	46.32	212.21
SE(d) ±	946.05	921.79	0.02	0.20	2.05	0.25	2.45
CD at 5%	1902.50	1853.71	0.04	0.41	4.13	0.51	4.91

Conclusion

Based on finding of results it may be concluded that among three varieties tested, K-402, exhibited better yield attributes, displayed highest yielding ability, economics, as well as quality building characteristics. The application of FYM @ 10 t ha^{-1} along with NPK doses proved superiority over without FYM interms of maximum yield attributes, yield, as well as quality of wheat. The use of NPK (150:60:40 kg ha^{-1}) + $ZnSO_4$ @25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at tillering Stage recorded maximum enhancement in yield attributes, yield, economics and quality of wheat compared to other nutrient management treatments.

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