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Studies on the effect of zinc, iron, and FYM on growth, yield and quality improvement in timely sown wheat (*Triticum aestivum* L.) varieties

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Abstract
An experiments on "Studies on the effect of Zinc, Iron, and FYM on growth, yield and quality improvement in timely sown wheat (*Triticum aestivum* L.) varieties". was 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), 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}), grain zinc concentration (41.70 ppm) and grain Iron concentration (48.82 ppm) 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}), grain zinc concentration (41.21 ppm) and grain iron concentration (47.15 ppm), 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}), grain zinc concentration (42.03 ppm) and grain iron concentration (47.88 ppm) and 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.), zinc, iron concentration & uptake, FYM and NPK

Introduction
Wheat is one of the first cereal known to have been domesticated, and its ability to self pollinate greatly facilitated the selection of many distinct domesticated varieties. Wheat is the most important grain of trade for human consumption. It is produced in a vast range of environments from central Russia to the great India and Chinese river valleys and across the Great Plains and pampas of Americas. In India wheat is the second most important food crop after rice, both in terms 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) [1].

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. 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) [2].

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) [12]. 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, 2017) [4].

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 factors under study comprised of treatment combinations viz. 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 ^{0}C, 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 3rd SMW (15-21 January) during 2015-16 and 27.8 mm in 4th 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

Growth characters

Pooled data regarding growth of crop summarized in Table 1 & 2, reveal that among different varieties, K 402 (Mahi) exhibited significant increase in growth character's compared to PBW 550 and DBW 17, respectively. The variation in growth entities are an inherent character of individual varieties visible in different location and reported by Sandhu and Dhaliwal (2017) [11]. The application of FYM @ 10 t ha^{-1} + NPK improved the growth characters significantly compared to without FYM treatment. Application of FYM along with NPK, significantly increased growth character's compared to without FYM treatment. The better efficiency of organic matter might be due to the fact that the organic manure especially FYM would have provided micronutrient at optimum level which play important role in chlorophyll formation which increase rate of photosynthesis and ultimately growth of the plant. These results are in accordance with the findings of Navrang and Tomar (2016) [9]. Among nutrient management treatments application of NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) at tillering stage recorded significant improvement in growth characters viz. shoot length (4.00 %), root length (12.71 %), root diameter (15.37 %), shoot fresh weight (7.16 %), shoot dry weight (7.62 %), root fresh weight (28.57 %), root dry weight (39.83 %), number of tillers (14.05 %) and plant leaf area (12.02 %) as compared to only NPK treatment (Control). Beneficial effect of Zn through soil incorporation and foliar application of $FeSO_4$ at tillering stage to effect an increase in growth characteristics in this study may probably be assigned to harmonious plant physiology as stated by Gul *et al.* (2011) [5]

Yield

The ultimate effect of experimental variable was reflected in the final yield of wheat crop (Table.3). 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), and straw yield (8.05 % and 14.23 % compared to PBW 550 and DBW 17, respectively). The better yield of K 402 (Mahi) may be the resultant of superior growth and yield attributing characters compared to other two varieties. Several findings on the performance of different varieties of wheat have been reported by Maurya *et al.* (2014) [7]. 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 as reported by Reena *et al.* (2017) [10]. 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 %) and straw yield (14.30 %) 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 sported by the report of Aatif *et al.* (2007).

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 3). Application FYM @10 t ha^{-1} along with NPK 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) [8]. 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 Zinc uptake (23.24 %) in wheat grain as compared to only NPK treatment. Cakmak *et al.* (2008) [3] reported that there is increasing evidence showing that foliar or combined soil foliar application of Zn fertilizers under field conditions are highly effective and very practical way to maximize uptake and accumulation of Zn in whole wheat grain, raising concentration up to 60 mg Zn kg^{-1}.

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} along with NPK 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 Zhao *et al.* (2011) [13].

Conclusion

Based on findings of result it may be concluded that among three varieties tested, K-402, exhibited better growth, displayed highest yielding ability 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 growth, 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 enhancement in growth characters, yield and quality of wheat compared to other nutrient management treatments. The interaction effect of varieties, FYM levels and nutrient management treatments found non-significant.

Table 1: Effect of varieties, FYM doses and nutrient management on growth characteristics of wheat at different stages

Treatment Combinations	Tillers / m^2		Plant Leaf Area (cm^2)			Shoot length (cm)			Root length (cm)			Root Diameter (cm)		
	45 DAS	90 DAS	45 DAS	90 DAS	at maturity	45 DAS	90 DAS	at maturity	45 DAS	90 DAS	at maturity	45 DAS	90 DAS	at maturity
Varieties														
PBW 550	724.87	953.57	57.76	53.52	49.22	42.25	85.54	104.24	10.99	17.79	20.82	9.63	11.94	14.40
DBW 17	694.81	869.60	54.68	50.53	46.27	39.44	77.48	96.24	09.60	15.64	19.03	8.25	10.37	13.55
K 402 (Mahi)	893.74	1109.25	60.04	56.25	55.60	43.51	96.36	111.47	12.51	18.12	22.62	9.62	13.00	15.58
SE(d) ±	21.57	20.99	0.32	0.36	0.58	0.38	0.89	0.82	0.19	0.17	0.43	0.19	0.09	0.17
CD at 5%	49.73	48.41	0.74	0.84	1.34	0.89	2.06	1.90	0.45	0.40	0.95	0.44	0.21	0.40
FYM doses														
FYM - 0 t ha^{-1}	738.76	947.18	56.41	52.30	49.04	41.03	85.64	103.02	10.26	16.82	20.21	8.89	11.48	14.19
FYM - 10 t ha^{-1}	803.53	1007.77	58.57	54.57	51.68	42.43	87.28	104.94	11.81	17.55	21.44	9.43	12.06	14.83
SE(d) ±	6.25	7.40	0.32	0.25	0.30	0.14	0.36	0.31	0.27	0.10	0.18	0.05	0.09	0.12
CD at 5%	13.62	16.13	0.74	0.56	0.46	0.31	0.78	0.38	0.60	0.22	0.39	0.10	0.20	0.27
Nutrient management														
NPK (150:60:40 kg ha^{-1})	720.22	907.53	55.95	52.11	47.56	40.64	85.32	101.84	09.97	16.57	19.58	8.79	11.02	13.43
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at TS	816.71	1035.12	59.00	54.92	53.28	42.93	87.72	105.92	12.13	17.82	22.07	9.55	12.60	15.50
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at FLS	776.49	989.77	57.52	53.27	50.24	41.63	86.34	104.19	11.00	17.16	20.82	9.16	11.68	14.60
SE(d) ±	8.79	9.23	0.25	0.20	0.42	0.19	0.30	0.42	0.21	0.12	0.20	0.04	0.13	0.19
CD at 5%	17.69	18.57	0.50	0.41	0.85	0.38	0.60	0.85	0.43	0.25	0.40	0.08	0.26	0.38

Table 2: Effect of varieties, FYM doses and nutrient management on growth character's of wheat at different stages

Treatment Combinations	Shoot Fresh wt. (g)			Shoot Dry wt. (g)			Root Fresh wt. (g)			Root Dry wt. (g)		
	45 DAS	90 DAS	At maturity	45 DAS	90 DAS	At maturity	45 DAS	90 DAS	At maturity	45 DAS	90 DAS	At maturity
Varieties												
PBW 550	16.83	56.74	46.67	1.66	23.48	38.49	1.80	4.78	8.01	0.97	2.12	4.45
DBW 17	15.16	49.26	42.94	1.45	21.96	36.65	1.56	4.34	6.59	0.85	1.77	3.57
K 402 (Mahi)	18.07	66.17	52.75	1.97	25.58	43.46	2.41	5.54	10.48	1.39	2.60	5.53
SE(d) ±	0.26	0.69	0.40	0.02	0.47	0.40	0.06	0.05	0.19	0.05	0.09	0.17
CD at 5%	0.61	1.61	0.92	0.05	1.08	0.92	0.14	0.13	0.44	0.12	0.21	0.40
FYM doses												
FYM - 0 t ha^{-1}	16.17	56.24	46.69	1.61	23.10	38.53	1.83	4.64	7.91	0.99	2.06	4.26
FYM - 10 t ha^{-1}	17.20	58.54	48.22	1.77	24.25	40.53	2.02	5.14	8.80	1.14	2.26	4.78
SE(d) ±	0.25	0.54	0.25	0.02	0.09	0.39	0.02	0.03	0.15	0.01	0.06	0.07
CD at 5%	0.55	1.17	0.54	0.05	0.20	0.85	0.05	0.08	0.33	0.03	0.14	0.15
Nutrient management												
NPK (150:60:40 kg ha^{-1})	15.88	55.90	45.83	1.54	22.84	38.03	1.70	4.48	7.28	0.92	1.88	3.74
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at TS	17.50	58.88	49.11	1.86	24.62	40.93	2.16	5.29	9.36	1.21	2.47	5.23
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at FLS	16.68	57.38	47.41	1.68	23.57	39.64	1.91	4.90	8.43	1.07	2.14	4.58
SE(d) ±	0.16	0.44	0.26	0.05	0.11	0.33	0.02	0.05	0.16	0.05	0.06	0.11
CD at 5%	0.33	0.89	0.53	0.10	0.23	0.67	0.05	0.10	0.33	0.10	0.12	0.22

Table 3: Effect of varieties, FYM doses and nutrient management on yield and quality of wheat

Treatment Combinations	Biological Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	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	12104.49	4546.76	7554.96	40.78	185.92	45.96	209.62
DBW 17	11188.61	4038.46	7146.40	38.92	156.77	44.61	180.62
K 402 (Mahi)	13184.77	5017.61	8163.75	41.70	209.06	48.82	245.10
SE(d) ±	211.22	48.74	166.38	0.33	2.49	0.45	3.03
CD at 5%	487.06	112.39	383.67	0.77	5.74	1.04	6.99
FYM doses							
FYM - 0 t ha^{-1}	11673.61	4390.04	7280.98	39.73	174.93	45.78	201.88
FYM - 10 t ha^{-1}	12644.70	4678.51	7962.43	41.21	192.91	47.15	221.68
SE(d) ±	85.58	32.92	68.57	0.15	1.64	0.22	1.99
CD at 5%	186.48	71.75	149.41	0.32	3.58	0.48	4.35
Nutrient management							
NPK (150:60:40 kg ha^{-1})	11356.10	4233.70	7118.52	38.69	163.32	45.20	192.34
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at TS	12942.09	4805.69	8136.55	42.03	201.29	47.88	230.78
NPK + $ZnSO_4$ @ 25 kg ha^{-1} as basal + $FeSO_4$ (1%) sprayed at FLS	12179.26	4563.44	7610.04	40.68	187.14	46.32	212.21
SE(d) ±	97.25	45.00	82.53	0.20	2.05	0.25	2.45
CD at 5%	195.57	90.49	165.97	0.41	4.13	0.51	4.91

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