Print ISSN: 0976-2876 Online ISSN: 2250-0138

Available online at: http://www.ijsr.in

INDIAN JOURNAL OF SCIENTIFIC RESEARCH

DOI:10.32606/IJSR.V11.I2.00024

Received: 08-05-2020 Accepted: 23-11-2020 Publication: 31-01-2021

Indian J.Sci.Res. 11 (2): 135-140, 2021 Original Research Article

BIOFORTIFICATION OF WHEAT (*Triticum aestivum*) WITH ZINC THROUGH SOIL AND FOLIAR APPLICATION INALLUVIAL SOIL OF EASTERN UP

DEVASHISH SINGH[a1] AND SUMAN SHARMA[b]

[ab]Department of Botany, Harishchandra P.G. College, Varanasi, Uttar Pradesh, India

ABSTRACT

The present investigation was conducted with Wheat (*Triticum aestivum*) crop during *Rabi* season of 2019. The experiment was conducted in pots in net house with 12 treatments; first 6 treatments (T_1-0,T_2-10,T_3-20,T_4-30,T_5-40,T_6-50) kg Zn / ha+ soil application alone at 6 levels and last 6 treatments (T_7-0 ,T_8-10,T_9-20,T_{10}-30,T_{11}-40,T_{12}-50) kg Zn/ ha+ soil +0.5% Foliar Spray(FS). Nitrogen, phosphorous, potassium and zinc uptake in grain and straw were estimated. Standard methods of observation, analysis of soil and plant samples and appropriate statistical methods for the analysis of data were used. Zinc levels had significant effect on nitrogen, phosphorous, potassium and zinc uptake in grain and straw. The nitrogen, phosphorous, potassium and zinc uptake in grain and straw were recorded maximum with (30kg+ 0.5% FS).Therefore, application of zinc @ (30 kg + 0.5% FS) is to be recommended get higher N, P, K and Zn uptake in grain and straw.

KEYWORDS: Wheat, Nitrogen, Phosphorous, Potassium, Zinc

Wheat (*Triticum aestivum L.*), a major agronomic crop cultivated worldwide, is a self-pollinated long day plant belonging to family Poaceae that flourishes well under arid and semi-arid regions (Belderok, 2000). It has been a chief staple food, supplying approximately 35% of the total food as consumed by the global population (Mohammadi-joo *et al*., 2015). It is one of the important sources of daily diet in developing countries, but its Zn content is relatively low. The Zn content of wheat grains need to reach 45.00 $mgkg^{-1}$ to meet the Zn needs of the human body (Liu, 2017).Most (about 95%) of the globally cultivated wheat is hexaploid, which is extensively used for the preparation of varieties of baked products and bread (Debasis and Khurana, 2001). Therefore, the composition and nutritional concentrations of the wheat crop have a substantial impact on human health. It provides nearly 20% calorie and protein per capita worldwide (Long, 2019). Therefore, improving the daily Zn intake through wheat-derived processed foods is an important way to solve Zn deficiency.

Zinc is one of the eight trace elements (manganese, copper, boron, iron, zinc, chlorine, molybdenum and nickel) that are essential for normal, healthy growth and reproduction of plants. Zn is required as a structural component of a large number of proteins, such as transcription factors and metalloenzymes (Figueiredo *et al*., 2012). If an insufficient amount of Zn is available, the plants will suffer from physiological stresses due to the failure of metabolic processes in which Zn plays a critical role. Zinc in soils can be separated into fractions based on particle size distribution and/or chemical analysis procedures.

Zinc (Zn) deficiency is the most widespread micronutrient deficiency in agricultural lands around the world, causing yield decreases and diminishing the nutritional quality of agricultural plants. Zn is important for plant growth, as plants require a proper balance of all the essential nutrients for normal growth and optimum yield. Plant-based foods are significant sources of Zn for humans (Welch and Graham, 2004).

Many scientists, researchers, and field related experts have been working to find the way and techniques of improving nutrient contents in under-nutritive wheat varieties. Though a number of strategies have been made, they aren't cost-effective and sustainable for combating malnutrition (White and Broadely, 2009; Gomez-Galera *et al*., 2010; Hurrell *et al*., 2010). Effective approaches to solving the problem are supplementation, dietary diversification, fortification, agronomic biofortification.

Biofortification is the idea of breeding crops to enhance their nutritional value in an economic and sustainable manner (DeValenca *et al.*, 2017). Cereal crops like wheat, due to some barriers in potential uptake of soil nutrients, are usually mineral deficient for which fortification is the must (Fageria and Baligar, 2008). Also, the continuous applications of weak fertilizers that are poor in mineral concentrations have negatively impacted the nutrient availability of wheat. (Fageria *et al*., 2002). Considering this fact, biofortification acts as a feasible way of delivering micronutrients to populations

[1]Corresponding author

who have inadequate access to diverse diets (Bouis and Saltzman, 2017; Garg *et al.*, 2018). In wheat, itcan be done through different approaches; Agronomic approach through direct foliar or soil application of fertilizers and Genomic approach which include genomic section, Marker Assisted Selection (MAS), and Quantitative TraitLoci (QTL) mapping. Owing to a large number of wild wheat relatives still unexploited, the genetic improvement of wheat can highly be achieved in the future focusing on breeding programs (Ahmadi *et al.*, 2018; Dempewolf *et al.*, 2017).

Biofortification for enhancing Zn content

Every human being requires essential minerals and micronutrients to enhance metabolism, which humans obtain from their diet. Wheat, like many other staple kinds of cereals, holds suboptimal levels of the essential micronutrients, particularly zinc. Hidden hunger is emerging as a major challenge for the majority of the developing countries as it has become a common public health problem for poor people. Inadequacy of micronutrients results in stunted growth in children, decline in immunity, and work efficiency in adults, in particular women, and impairments in physical development.

Zinc has been considered as the most crucial among micronutrients. Its deficiencies causes serious human health hazards such as malnutrition, distorted growth, decreased immunity, increased susceptibility to infections and diseases and many others (Tulchincky, 2010).The potentiality of wheat in reducing micronutrient related malnutrition can be improved through direct (nutrition-specific) interventions, which include nutrient supplementation, dietary diversification, post-harvest food fortification, etc. and indirect (nutrition-sensitive) interventions, which includes biofortification (Ruel and Alderman,2013). Although the wheat crop is usually fortified during processing, an effective and more sustainable solution is biofortification, which needs developing new varieties of wheat with inherently higher iron and zinc concentrations in their grains (Bouis *et al.*, 2011). Genetic biofortification (plant breeding) and agronomic biofortification (application of fertilizer) are two common means of biofortification which were supposed to be cost-effective to the dietary problems (Mara and Petra, 2012; White and Broadely, 2009; Cakmak, 2008).

METHODS AND MATERIALS

The pot experiment was conducted in pots in net house during 2019 with wheat in alluvial soil. The experiment had 12 treatments with first 6 treatments(T_1-0, T_2-10, T_3-20, T_4-30, T_5-40, T_6-50 kg / ha+ soil application) of soil application alone at 6 levels and last 6 treatments (T_7-0 , T_8-10, T_9-20, T_{10}-30, T_{11}-40, T_{12}-50 kg / ha+ soil +0.5% FS) as soil+ foliar sprays ($ZnSO_4$) @ 0.5% were made separately for all the above treatments.

All the treatments were applied to wheat in *Rabi*. Soil moisture was maintained the field capacity by regular weighing the pots. Irrigation was given throughout the experiment period to keep the soil moist. At maturity, clean plants were harvested by cutting at above the soil surface by using a stainless-steel scissors and grain samples were separated from wheat plant. The dried grain and straw samples were then finely ground in a grinder for laboratory analysis. Total N was determined by semi micro-kjeldhal method (Jackson, 1973) and zinc content was determined by using AAS in diacid digest of plant samples (Jackson, 1973).

RESULTS AND DISCUSSION

The application of $ZnSO_4$ with various combinations of 12 treatments having first 6 treatments only with soil application and last 6 treatments with soil+ 0.5% foliar application. It has been applied in the wheat crop to find the effect of this treatment on uptake of N,P,K and Zn in grain and straw. The completely randomized design has been made to find out the effect of N,P,K and Zn uptake in grain and straw. It has been described in the present study. The separate analysis has been carried out for these nutrients. Effect of various treatments has been shown in the Table1and 2.

Nutrient Uptake in Grain

Nitrogen Uptake in Grain (g/pot)

Nitrogen uptake by grain (Table 1) was significantly improved by different zinc levels during experimentation. All zinc levels treatments were at par to each other and significant over control. Maximum and minimum nitrogen uptake by grain was obtained with treatment (30 kg Zn ha^{-1} + 0.5% FS) as 0.590g/pot, and (0 kg soil Zn ha^{-1}) as 0.364g/pot.

Phosphorous Uptake in Grain (g/pot)

The data regarding effect of zinc levels on phosphorus uptake in grain was given in Table 1.The evaluation of data indicated that application of zinc levels had significant effect on phosphorus uptake in grain. Maximum and minimum phosphorus uptake in grain with treatment (30 kg Zn ha^{-1}+ 0.5% FS) as 0.034g/pot and (0 kg soil Zn ha^{-1}) as 0.023g/pot.

Potassium Uptake in Grain (g/pot)

Potassium uptake in grain shown in (Table 1) markedly improved by the application of zinc practices. Highest and lowest potassium uptake by grain was recorded with treatment (30 kg Zn ha^{-1}+ 0.5% FS) as 0.221g/pot and (0 kg soil Zn ha^{-1}) as 0.165g/pot.

Zinc Uptake in Grain (g/pot)

Zinc levels had marked influence on zinc uptake in grain shown in (Table 1). Maximum and minimum zinc uptake by grain was recorded with treatment (30 kg + 0.5% FS) as 1.500g/pot and (0 kg soil Zn ha^{-1}) as 0.720g/pot. However, application of T_{10} (30 kg Zn ha^{-1} + 0.5% $ZnSO_4$ spray) improved zinc uptake by grain over control T_1.

Uptake of Zn was increased in soil + foliar application in comparison to soil application alone. The highest uptake of Zn was registered with soil application + 0.5% foliar spray which were higher over control (no Zn). Higher Zn concentration in soil + foliar applied Zn might be due to foliar applied Zn was more easily absorbed by the leaves of the plant and translocated to reproductive parts, hence accumulation was more as compared to soil application alone. Similar results were also reported by Mathpal *et al.,* (2015), Shivay *et al.,* (2015), Ghasal *et al.,* (2015). More concentration of Zn and uptake of micronutrients in chelated-Zn applied plots were also reported by Singh (2013), (Ghasal *et al.,* 2017).

The movement of nutrients into grains is affected by the source-sink relationship at the grain-filling stage. Kutman *et al*., (2012) found that Zn remobilization rather than root uptake is critical for Zn accumulation in wheat grains when Zn availability in soil is restricted at the grain-filling stage. Foliar Zn application is much more effective than soil Zn application in Zn enrichment of wheat grains (Wang *et al*., 2012; Zhang *et al*., 2012b). The concentrations of Zn in wheat grains were positively correlated with foliar Zn rates (Zhang *et al.*, 2012b). All these results suggested that Zn translocation to grains or grain sink strength is not a limiting factor and the grain Zn concentration is most probably limited by source supply (Zhang *et al*., 2012b).

Foliar Zn application was much more effective than soil Zn application in the enrichment of wheat grains. The foliar 0.4% $ZnSO_4 \cdot 7H_2O$ application resulted in the best effect on grain Zn with 58% increase in grain Zn concentration, 76% increase in wheat flour Zn, and up to 50% decrease in the molar ratio of phytic acid to Zn in flour (Zhang *et al*., 2011). Foliar Zn application alone or in combination with soil Zn application resulted in significant improvement in grain Zn concentrations as it increased from 27.4 mg kg^{-1} to 48.0 ppm by foliar Zn application (Zhang *et al*., 2012).

The foliar application of 0.1% zinc gave maximum zinc uptake by wheat grain. Due to alkaline nature of soil there is inhibition in absorption of Zn^{+2} as well as other alkaline earth cations by plants. It is doable to supply adequate Zn to the wheat crop by foliar application (Bhatt *et al.*, 2020).

Nutrient Uptake by Straw

Nitrogen Uptake by Straw (g/pot)

Effect of zinc levels on nitrogen uptake by straw (g/pot) was given in Table 2. Zinc levels treatments caused marked variation in nitrogen uptake by straw. Maximum and minimum uptake by straw with treatment (30 kgZn ha^{-1}+ 0.5% FS) as 0.342g/pot and (0 kg soil Zn ha^{-1}) as 0.165g/pot. However, treatment showed superiority over control T_1.

Phosphorous Uptake by Straw (g/pot)

Zinc levels treatments significantly affected the phosphorus uptake by straw (Table 2). Maximum and minimum phosphorus uptake as achieved with treatment (30 kgZn ha^{-1}+ 0.5% FS) as 0.034g/pot and (0 kg soil Zn ha^{-1}) as 0.023g/pot.

Potassium Uptake by Straw (g/pot)

The evaluation of data in Table 2 revealed that zinc levels treatment had significant effect on potassium uptake by straw. Treatment (30 kg Zn ha^{-1}+0.5% FS) showed maximum potassium uptake 0.694g/pot in straw and minimum potassium uptake by straw with control (0 kg soil Zn ha^{-1}) as 0.410g/pot.

Zinc Uptake by Straw (g/pot)

The data (Table 2) revealed that zinc levels treatment had significant effect on zinc uptake by straw during both years. Maximum zinc uptake by straw was recorded with treatment (30 kg + 0.5% FS) as 1.732% which was highly significant over rest of the treatments and minimum zinc uptake by straw were recorded with control (0 kg soil Zn ha^{-1})as 0.697g/pot. However, application of (30 kg Zn ha^{-1}+ 0.5% FS) significantly increased the zinc uptake by straw over control.

Significantly higher value of N,P,K and Zn content and their uptake by grain as well as straw was recorded with application of treatment T_{10}(30Zn ha^{-1} kg + 0.5%FS) compared to control. Application of zinc through soil and foliar application in deficient soil might have increased the availability of zinc in rhizosphere.

In the case of Zn, remobilization of Zn from old leaves is enhanced by leaf senescence (Longnecker and Robson, 1993). The increase in uptake of these components is the combined effect of substantial increase in concentration of these parameters and yields of wheat under influence of various zinc levels scheduling. According to Patel (2010) foliar or combined soil + foliar application of zinc levels under field condition are effective and very practical way to maximize uptake and accumulation of Zn in whole wheat grain. It is expected that large increases in loading of zinc into grain can be achieved when foliar zinc levels are applied to plants at a late growth stage. These results are in agreement with the previous studies of Cakmak *et al*., (2010a), Gopal and Nautiyal (2012) Zou *et al*., (2012), Srivastava *et al*., (2014), Zhao *et al*., (2014), Gomez-Coronado *et al*., (2016), Ram *et al.*,(2015) and Saha *et al.*,(2017).

Table 1: Effect of zinc levels on total N,P,K (g/pot) and Zn (mg/pot) uptake by wheat grain

Treatment	Nitrogen Uptake (g/pot)	Phosphorous uptake (g/pot)	Potassium uptake (g/pot)	Zinc uptake (mg/pot)
	2019	2019	2019	2019
T_1	0.364	0.023	0.137	0.720
T_2	0.404	0.026	0.165	0.811
T_3	0.478	0.030	0.195	1.138
T_4	0.506	0.031	0.205	1.224
T_5	0.491	0.029	0.178	1.084
T_6	0.477	0.028	0.167	1.024
T_7	0.392	0.024	0.154	0.867
T_8	0.430	0.026	0.158	0.944
T_9	0.536	0.031	0.230	1.379
T_{10}	0.590	0.034	0.238	1.500
T_{11}	0.547	0.032	0.221	1.398
T_{12}	0.541	0.031	0.214	1.339
SEm±	0.022	0.002	0.010	0.057
CD(at 5%)	0.045	0.003	0.020	0.117

Table 2: Effect of zinc levels on N,P,K (g/pot) and Zn (mg/pot)uptake by wheat straw

Treatment	Nitrogen uptake (g/pot)	Phosphorous uptake (g/pot)	Potassium uptake (g/pot)	Zinc uptake (mg/pot)
	2019	2019	2019	2019
T_1	0.165	0.023	0.410	0.697
T_2	0.203	0.026	0.448	0.814
T_3	0.253	0.030	0.585	1.240
T_4	0.277	0.031	0.614	1.357
T_5	0.261	0.029	0.566	1.184
T_6	0.287	0.028	0.501	1.105
T_7	0.186	0.024	0.461	0.902
T_8	0.226	0.026	0.490	0.999
T_9	0.300	0.031	0.640	1.563
T_{10}	0.342	0.034	0.694	1.732
T_{11}	0.316	0.032	0.650	1.601
T_{12}	0.293	0.031	0.634	1.523
SEm±	0.013	0.002	0.031	0.079
CD(at 5%)	0.028	0.003	0.064	0.163

CONCLUSION

Biofortification approaches that also ensure high wheat grain yield will have high adoptability among farmers. Zinc fertilization with due consideration of yield and grain Zn concentration are important contemplation to be followed in Zn deficient soils. Application of Zn as $ZnSO_4$ to soil or foliar application is an effective way to increase grain Zn concentration with remarkable yield increase. Applying Zn with macronutrient fertilizers or at higher rates will give optimum yield and higher grain Zn concentration. Similarly, applying Zn for ≈ 100% relative grain yield will greatly increase grain Zn concentration.

REFERENCES

Ahmadi J., Pour- Aboughadareh A., Ourang S.F., Mehrabi A. and Sidduqe K.H.M., 2018. Wild Relatives of Wheat: Ageliops Triticum accessions disclose differential anti-oxidative and physiological responses toward water stresses. Asta Physiological Plant, **40**: 1-14.

Belderok B., 2000. Bread making quality of wheat: A century of Breeding in Europe. Kulwer Academic Publisher Belderok, Netherlands, Pp;34.

Bouis H.E. and Saltzman A., 2017. Improving nutrition through Biofortication: A Review of evidences from Harvest Plus., 2003 through 2016. Global Food Security, **12**: 49-58. DOI: https://doi.org/10.1016/j.gfs.2017. 01.009.

Bouis H.E., Hotz C., McClafferty B., Meenakshi J.V and Pfeiffer W.H., 2011. Biofortication: A new tool to reduce micronutrient malnutrition. Food Nutrition Bull, **32**: 31-40. DOI: 10.1177/15648265110321S105.

Cakmak I., 2008. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant Soil, **302**: 1-17. DOI: https://doi.org/10.1007/s11104-007-9466-3.

Debasis P. and Khurana P., 2001. Wheat Biotechnology: A mini-review. Electronic J. Biotech., **4**(2): 74-102. DOI:10.4067/S0717-34582001000200007.

De Valenca A.W., Bake A., Brouwel D. and Giller K.E., 2017. Agronomic Biofortication of crops to fight hidden hunger insub-saharan Africa. Global Food Security, **12**: 8-14. DOI: https://doi.org/10.1016/j.gfs.2016.12.001.

Dempewolf H., Baute G., Anderson J., Killian B., Smith C. and Guarion L., 2017. Past and future uses of wild Relative in Crop Breeding. Crop. science, **57**: 1070-1082. DOI: https://doi.org/10.2135/cropsci2016.10.0885.

Fageria N.K. and Baligar V.C., 2008. Ameliorating soil acidity of tropical oxisols by liming for crop production. Adv. Agron, **99**: 345-399. DOI: 0.1016/S0065-2113(08)00407-0.

Fageria N.K., Baligar V.C. and Clark R.B., 2002. Micronutrients in crop production. Adv. Agron, **77**: 85-268. DOI: https://doi.org/10.1016/S0065-2113(02)77015-6.

Figueiredo D.D., Barros P.M., Cordeiro A.M., Serra T.S., Lourenço, T., Chander S., Oliveira M.M. and Saibo N.J., 2012. Seven zinc-finger transcription factors are novel regulators of the stress responsive gene OsDREB1B. Journal of Experimental Botany, **63**: 3643-3656.

Garg M., Sharma N., Sharma S., Kapoor P., Kumar A., Chandari V. and Arora P., 2018. Biofortified Crops generated by Breeding agronomy & Transgenic Approaches are improving lives of millions of people around the world. Front Nutr., **5**: 12. DOI: 10.3389/fnut.2018.00012.

Gomez-Galera S., Rojas E., Sudhakar D., Zhu C.F., Pelacho A.M. and Capell T., 2010. Critical evaluation of strategies for mineral fortification of staple food crops., Transgenic Resources, **19**: 165-180. doi: 10.1007/s, 11248-009-9311-y.

Hurrell R., Ranum P., De P. S., Biehinger R., Holthen L. and Johnson Q., 2010. Revised recommendations for iron fortification of wheat flour and an evaluation of the expected impact of current national wheat flour fortification. Programs Food Nutrition Bull, **31**: S7-S21. DOI: 10.1177/15648265100311S102.

Liu D.Y., 2017. Zinc Nutrition of High-Yielding Wheat and Maize and Its Management on Calcareous Soil. Beijing: China Agricultural University.

Long D.Y., 2019. Molecular Cytogentic Identification of BC1F8 Generation of Common Wheat–Aegilops Geniculata Roth SY159 Progeny. Xianyang: Northwest A&F University.

Mara C. and Petra B., 2012. Strategies for Iron Biofortication of Crop Plants. Food quality source in Technology, **2**: 953-978. DOI: 10.5772/34583.

Mohammadi-joo S., Mirasi A., Saediaboeshaghi R. and Amiri M., 2015. Evaluation of bread wheat (*Triticum aestivum* L.)genotypes based on resistance indices under field conditions. Intl. I. Biosci., **6**(2): 331-337. DOI: 10.12692/ijb/6.2.331-337.

Ruel M.T. and Alderman H., 2013. Nutrition-sensitive interventions and Programmes: How can they help to accelerate progress in improving material and child nutrition? Maternal and child nutrition study group, Lancet, **382**: 536-551.

Tulchincky T.H., 2010. Micronutrient Deficiency Conditions: Global Health Issues. Public Health Rev., **32**: 243–255. DOI:https://doi.org/10.1007/BF03391600.

Wang J.W., Mao H. and Zhao H.B., 2012. Different increases in maize and wheat grain zinc concentrations caused by soil and foliar applications of zinc in loess plateau, China. Field Crops. Res., **135**: 89–96. doi: 10.1016/j.fcr.2012.07.010.

Welch R.M. and Graham R.D., 2004. Breeding for Micronutrients in staple food crops from a human nutrition perspective. J. Exp. Bot., **55**: 353-364. DOI: 10.1093/jxb/erh064.

White P.J. and Broadely M.R., 2009. Biofortication of crops with seven mineral elements often lacking in human diets-iron, zinc, copper, calcium, magnesium, selenium & iodine. New Phytologist., **182**: 49-84. DOI: https://doi.org/10.1111/j.1469-8137.2008.02738.x.