International Journal of Natural and Engineering Sciences
E-ISSN: 2146-0086 17(3): 79-86, 2023
Research Article

Physiological response of wheat genotypes toward zinc regimens

Muhammad Asad Ullah, Muhammad Abu Bakar Zia*

University of Layyah, College of Agriculture, Department of plant breeding and genetics, Layyah, Pakistan

*Corresponding author: abzia@ul.edu.pk

(Received: August 3, 2023 / Accepted: September 18, 2023)

Abstract

Wheat is an essential cereal crop and being used as staple food all over the world. Wheat production in field condition decreases because of various factors. Zinc plays essential role in protection from damage of stresses. Zinc interacts with plant hormones resulting in stimulation of antioxidant enzymes to invalidate stress effect. Two-year field experiment was executed during growing seasons 2021-22 and 2022-23 at farm area of University of Layyah to evaluate various wheat genotypes that can perform better through zinc application and considered as better genotypes to the farmer communities to overcome the vigorous increase of food demand. The experiments were carried out in Randomized Complete Block Design and each experiment was replicated thrice. Eighteen wheat genotypes were used in the experiment. Soil application of zinc was applied. Data of various agronomic parameters was collected. Traits like plant height and number of grains per spike were found significantly correlated with yield. Bhakkar star was superior most for grain yield under zinc 10kg per hectare concentration. Yield and yield related components of wheat at later growth stages are highly raised through zinc application.

Keywords: wheat, zinc, morphology, growth, grain yield

Introduction

Wheat is world's most significant cereal crop (ranks 2nd in cereals) and staple food in the world that have critical importance to increase yield and grain quality for unbridled increase of human population [1]. According to an estimate, wheat is grown at 223.2 million hectares all over the world with total production of 781 million tons [2]. Wheat is source of half calories being consumed in a day. Approximately 68% of wheat is consumed as food, 19% as feed and rest is utilized as biofuel and other purposes [3]. Wheat trade value was approximately thirty six billion dollars for whole amount of 184 million tons of wheat in 2016 [4]. According to an estimate, wheat production should be increased upto 60% by 2050 to meet food demand of nine billion people [5].

Zinc (Zn) plays essential role in protection from damage of heat stress photo-oxidation and act as a functional and structural cofactor for various enzymes [6-7]. Zinc have potential role in protein synthesis and various physiological functions as it act as component of catalytic sites of different essential enzymes [8-9]. Zinc act as activator of multiple essential enzymes and directly participate in synthesis of various growth regulators such as auxin [10]. Requisite zinc (Zn) application remarkably elevates activities peroxidase (POD), superoxide dismutase (SOD) and catalase (CAT) enzymes in response to shortage of water. Reactive oxygen species (ROS) generation decreases through zinc while Zn deficiency may lead to high ROS ultimately causing plant damage and may become more prominent in Zn-deficient soil [11]. Zinc inhibits damage through ROS via improving anti-oxidative defence mechanism in plant [12]. Zinc application improves leaf area chlorophyll content and stomatal conductance that led to high growth and improved yield.

Zinc application has significant positive results to reduce cadmium accumulation in plants [13]. Zinc acts as cofactor for many major antioxidant enzymes and performs a crucial function in preserving plasma membrane integrity [13-14]. Because of chemical resemblance to cadmium, Zn could compete with Cd for absorption by roots of plant and it interacts with cadmium in the plant's transport system [15]. In plants, variety of antioxidant enzymes contains zinc as key component. Cadmium, under optimum supply, can't replace Zn to inhibit oxidative stress. Different studies showed that zinc affects the cadmium accumulation in plants inconsistently. These effects vary with concentrations of Cd and Zn in the soil and plants species [15]. Zinc improves yield and components related to yield of wheat [16].

The most common cause, especially in underdeveloped countries is that people depend upon the food made up of cereals which are deficit in micronutrients [17]. Micronutrients like zinc, iron, iodine and selenium are needed for a variety of important tasks such as development, cognition, immunological response, antioxidant activity, thyroid function and chronic disease prevention [18].

Zinc sulphate as a fertilizer has an essential role in stomatal adjustment of plant system in decreasing stress caused by scarcity of water [19]. Application of zinc fertilizer increases accessible zinc (DTPA-Zn) content in the soil that might effects root development. Root surface area (RSA) and root length density (RLD) should be enhanced to improve immobile zinc capture. RLD (root length density) and RSA (Root surface area) should be enhanced to improve the uptake of immovable zinc [20]. Current study involves the application of different levels of zinc to check physiological and phonological traits in wheat genotypes and which level of zinc is more suitable to enhance grain yield and yield related components.

Materials and Methods

A two-year field experiment was conducted in sandy loam soil during growing seasons of 2021-22 and 2022-23 at farm area of University of Layyah (longitude 70˚ 56' 20.5" E, latitude 30˚ 57' 40.6" N, and altitude 151 m) to detect the effect of zinc regimens. Eighteen wheat genotypes were utilized in the experiment (Table 1). The experiments were carried out in Randomized Complete Block Design (RCBD) and each experiment was replicated thrice. Row to row distance between every two genotypes was 15cm and seeds were sown at depth of 1.5 inches. Standard fertilization was applied to the experiments. Three treatments of zinc were applied viz. control, zinc was applied at 5kg per hectare (Zn1) and zinc was applied at 10kg per hectare (Zn2). After wheat plants maturity data of various morphological parameters were collected including plant height, number of spikelets, grains per spike, biological yield and grain yield.

Data of various parameters was analysed through MS EXCEL 2016 and Statistix 8.1. Morphological traits data was evaluated using Fisher's analysis of variance (ANOVA). Regression, correlation and pathway analysis were evaluated using MS EXCEL 2016. Pathway analysis and correlation were evaluated to check how various parameters are correlating to each other.

Table 1. *List of wheat genotypes used in the experiment*

Sr. No	Genotypes	Source
1	Chakwal-50	Arid Zone Research Institute
2	Ujala-2016	Arid Zone Research Institute
3	Akbar-2019	Arid Zone Research Institute
4	Sehar-2006	Arid Zone Research Institute
5	Johar-16	Arid Zone Research Institute
6	Glaxy-2013	Arid Zone Research Institute
7	Ghazi-2019	Arid Zone Research Institute
8	Faislabad-2008	Arid Zone Research Institute
9	Gold -16	Arid Zone Research Institute
10	Anaj-17	Arid Zone Research Institute
11	Fakher-e-Bhakkar	Arid Zone Research Institute
12	Miraj-2008	Arid Zone Research Institute
13	Syn-50	Arid Zone Research Institute
14	As-2002	Arid Zone Research Institute
15	Bhakkar Star	Arid Zone Research Institute
16	Subhani-2021	Arid Zone Research Institute
17	Dilkash-2021	Arid Zone Research Institute
18	Punjab-1996	Arid Zone Research Institute

Results and Discussion

The results taken from various morphological parameters are:

Plant height

Analysis of variance (ANOVA) depicted that individual effect of genotype is significant. Interactive effect of genotype and treatment (genotype × treatment) is non-significant (P>0.05) because genotypes haven't shown response to zinc fertilization. Plant height has shown great variation through application of zinc treatment (Table 2). Maximum plant height was observed in AS-2002 under Zn2 treatment (Figure 1).

Table 2. *Analysis of variance table for plant height*

Source	DF	SS	MS	F	P
Replication	2	6.77	3.384		
Genotype	17	859.84	50.579	23.28	0.0000*
Treatment	2	467.45	233.726	107.56	0.0000*
Genotype*Treatment	34	89.02	2.618	1.20	0.2344
Error	106	230.34	2.173		
Total	161	1653.42			
Grand Mean	90.861				
CV	1.62				

*=significance level is ≤0.05. S.O.V: Source of Variance, DF: Degree of Freedom, SS: Sum of Square, MS: Mean Square

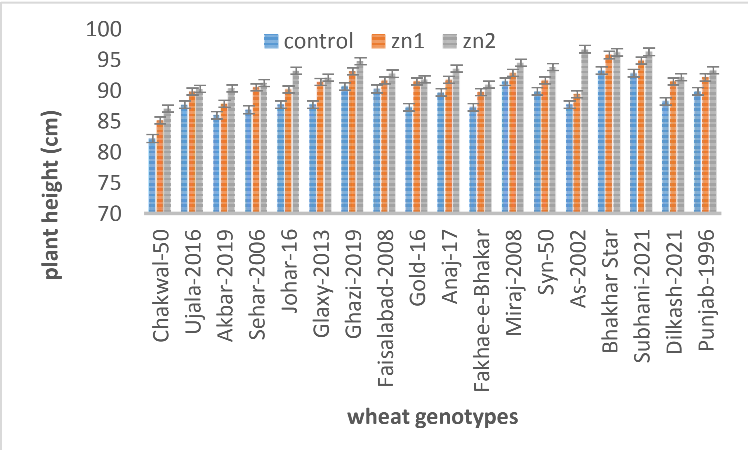

Figure 1. *Effect of different zinc concentrations on plant height (cm) of wheat genotypes*

Number of spikelets per spike

Analysis of variance (ANOVA) for number spikelets per spike depicted that effect of treatment on number of spikelets is significant (P<0.05). Spikelets per spike increase significantly due to application of treatment (Table 3). Results revealed that genotypes showed great variation in number of spikelet per spike. Interactive effect of genotype and treatment (genotype×treatment) is non-significant (P>0.05) as genotypes are not much influenced through application of zinc various concentrations. Seher-2006 doesn't respond to zinc application for number of spikelets per spike (Figure 2). Maximum number of spikelets per spike was observed in Chakwal-50 under Zn2 treatment.

Table 3. *Analysis of Variance Table for No of spikelet per spike*

Source	DF	SS	MS	F	P
Replication	2	7.272	3.636		
Genotype	17	52.420	3.084	2.13	0.0104*
Treatment	2	308.605	154.302	106.63	0.0000*
Genotype*Treatment	34	63.173	1.858	1.28	0.1687
Error	106	153.395	1.447		
Total	161	584.864			
Grand Mean	18.210				
CV	6.61				

*=significance level is ≤0.05. S.O.V: Source of Variance, DF: Degree of Freedom, SS: Sum of Square, MS: Mean Square

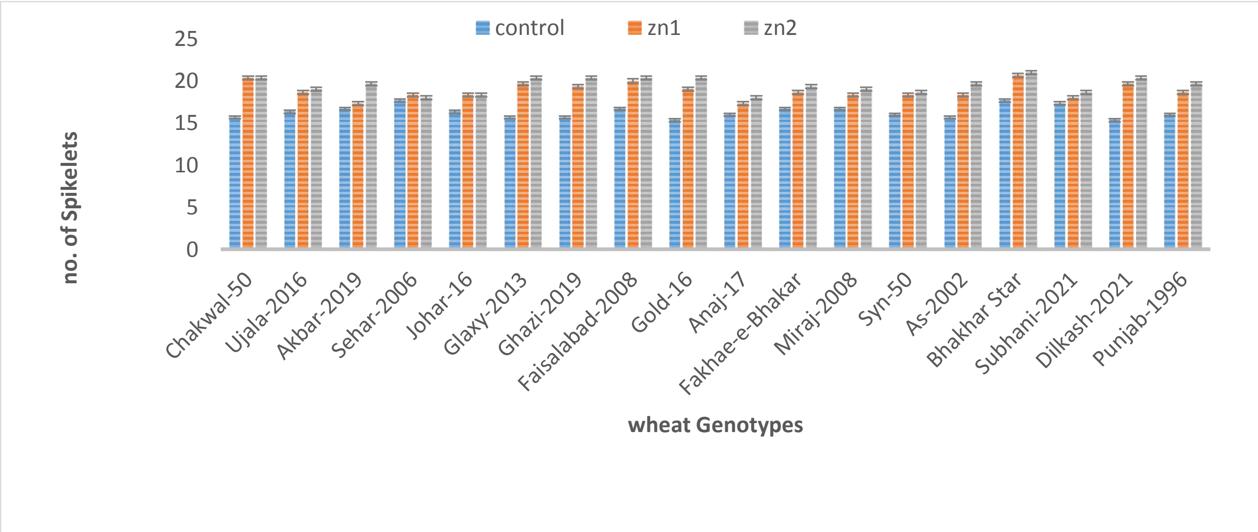

Figure 2. *Effect of different zinc concentrations on number of spikelets per spike of wheat genotypes*

Biological yield

ANOVA depicted that biological yield has shown greater variation through application of zinc treatment (Table 4). Biological yield is the fresh weight of plant. It is already reported by Das and Karak [21] that zinc fertilizer application increases the biological yield of wheat genotypes. It was revealed in results that treatments significantly affected the biological yield. It changed in different genotypes due to application of treatments. Ghazi-2019 and Punjab-1996 doesn't respond to zinc application for biological yield (Figure 3). Fakhar-e-Bhakkar have shown highest biological yield under Zn2 treatment.

Table 4. *Analysis of variance table for biological yield*

Source	DF	SS	MS	F	P
Replication	2	80.44	40.222		
Genotype	17	760.28	44.722	3.37	0.0001*
Treatment	2	252.26	126.130	9.50	0.0002*
Genotype*Treatment	34	269.74	7.934	0.60	0.9561
Error	106	1406.89	13.273		
Total	161	2769.61			
Grand Mean	40.426				
CV	9.01				

*=significance level is ≤0.05. S.O.V: Source of Variance, DF: Degree of Freedom, SS: Sum of Square, MS: Mean Square

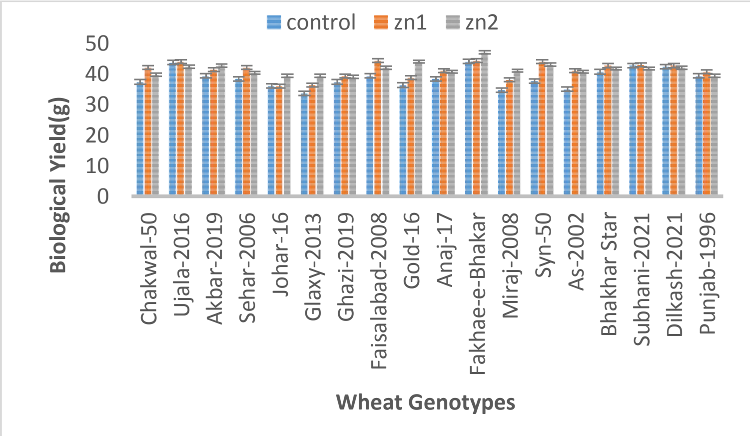

Figure 3. *Effect of different zinc concentrations on biological yield (grams) of wheat genotypes*

Grains per spike

Analysis of variance (ANOVA) resulted that number of grains per spike of plant respond significantly to genotypes and interactive effect of genotype and treatment (genotype×treatment) is significant ($P<0.05$). Individual effect of treatment on number of grains per spike is significant which means that there are significant differences in number of grains per spike due to zinc treatment (Table 5). It's already reported by Ghasal et al [22] that grains per spike increased duo to zinc treatment. Chakwal-50 showed much more increase in number of grains per spike under Zn2 treatment (Figure 4).

Table 5. *Analysis of variance table for grains*

Source	DF	SS	MS	F	P
Replication	2	177.8	88.89		
Genotype	17	3357.3	197.49	5.81	0.0000*
Treatment	2	3211.7	1605.85	47.27	0.0000*
Genotype*Treatment	34	3940.7	115.90	3.41	0.0000*
Error	106	3600.9	33.97		
Total	161	14288.4			
Grand Mean	52.185				
CV	11.17				

*=significance level is ≤0.05. S.O.V: Source of Variance, DF: Degree of Freedom, SS: Sum of Square, MS: Mean Square

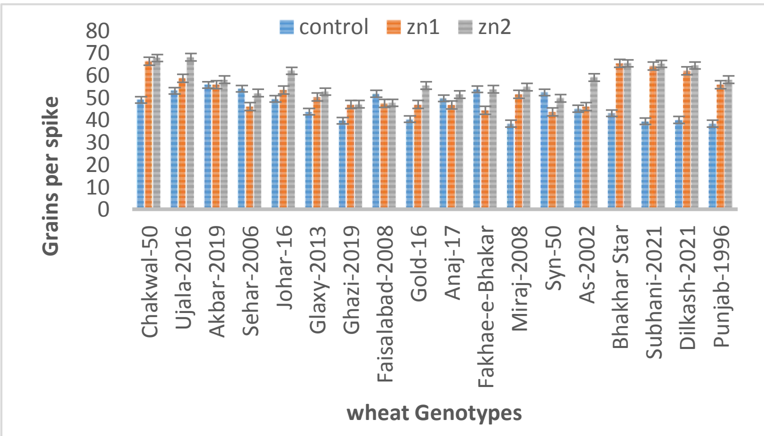

Figure 4. *Effect of different zinc concentrations on grains per spike of wheat genotypes*

Grain yield

Grain yield is the weight of grains obtained per plant and considered as final yield. Analysis of variance (ANOVA) shown that individual and interactive effect of genotype and treatment is significant (Table 6). P-value of all sources i.e., genotype, treatment and genotype×treatment is lower than 0.05 ($P \leq 0.05$). Grain yield have shown great variation because of zinc application. Significant increase in grain yield was observed in genotypes through zinc fertilization. Bhakkar star shown maximum increase in grain yield under Zn2 treatment (Figure 5).

Table 6. *Analysis of variance table for grain*

Source	DF	SS	MS	F	P
Replication	2	406.04	203.019		
Genotype	17	266.50	15.676	1.89	00.0268*
Treatment	2	968.48	484.241	58.29	0.0000*
Genotype*Treatment	34	444.63	13.077	1.57	0.0420*
Error	106	880.63	8.308		
Total	161	2966.28			
Grand Mean	16.204				
CV	17.79				

*=significance level is ≤0.05. S.O.V: Source of Variance, DF: Degree of Freedom, SS: Sum of Square, MS: Mean Square

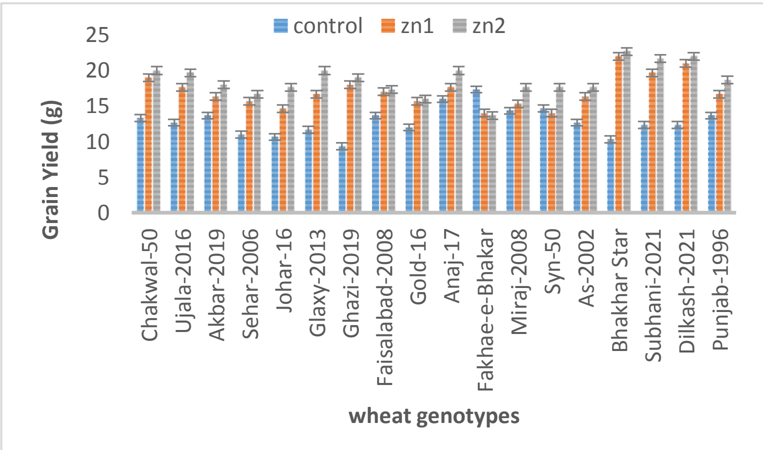

Figure 5. *Effect of different zinc concentrations on grains yield (grams) of wheat genotypes*

Correlation

Correlation analysis shows that the traits including plant height, no. of spikelets, number of grains spike^{-1} and biological yield are positively correlated with yield (grain yield). These traits showed higher direct effects on yield which means that the yield will increase with increase in plant height, grains spike $^{-1}$ and biological yield. Direct effects of these traits on grain yield (Table 7).

Table 7. *Correlation table showing the direct effects of traits on yield of wheat.*

	Plant Height	No. of Spikelets	Biological Yield	Grains per Spike	Grain Yield
Plant Height	1				
No. of Spikelets	0.41502	1			
Biological Yield	0.190632	0.309526	1		
Grains per Spike	0.172008	0.491844	0.205192	1	
Grain Yield	0.343782	0.429023	0.173077	0.325895	1

Path analysis

Path analysis shows that how different traits/parameters are correlated with the yield. In path analysis, correlation and regression analysis were performed to check direct and in direct effects of different traits on yield (grain yield). Results showed that there are high direct effects of plant height and number of spikelets per spike on final yield i.e. grain yield (Table 8). The trait, number of spikelets per spike, is indirectly affecting the yield through grains per spike. Other indirect effects are number of grains per spike through number of spikelets and biological yield through number of spikelets and number of grain per spike on the yield.

Table 8. *Path coefficient analysis*

	Plant Height	No. of Spikelets	Biological Yield	Grains per Spike	Total Yield
Plant Height	0.31982	0.198427	0.198427	0.033403	0.750077
No. of Spikelets	0.132732	0.478113	0.095513	0.095513	0.801871
Biological Yield	0.060968	0.147989	-0.0499	0.039847	0.198901
Grains per Spike	0.055012	0.235157	-0.01024	0.194193	0.474123

Conclusion

The findings of experiment shown that soil application of zinc increases the yield of wheat. Yield was increased with increase in zinc concentration. Traits including number of spikelets and biological yield do not show significant result by soil application of zinc. Overall, growth and yield of wheat increased due to zinc application through soil. Traits like plant height, number of grain per spike and biological yield were found positively correlated with yield and have positive direct effect on yield. Zinc at 10kg per hectare can be considered as more suitable to enhance wheat productivity. Bhakkar star genotype was superior most for grain yield under zinc 10kg per hectare concentration. Overall varietal selection along with zinc application can be proved as suitable to increase wheat productivity and quality.

References

[1] Murray, D., & McIntosh, A. (2019). Breeding new cultivars for sustainable wheat production. 作物学报: 英文版. 7(6): 715–717.

[2] Zhang, W., Zhang, T., & Yang, X. (2023). 1 km-resolution gridded dataset of phosphorus rate for rice wheat and maize in China over 2004–2016. Scientific Data. 10(1): 363.

[3] Ahmed, H. G. M. D., Sajjad, M., Li, M., Azmat, M. A., Rizwan, M., Maqsood, R. H., & Khan, S. H. (2019) .Selection criteria for drought-tolerant bread wheat genotypes at seedling stage. Sustainability. 11(9): 2584.

[4] Dhakal, A. (2021). Effect of drought stress and management in wheat—A review. Food Agribus. Manag. 2(2): 62–66.

[5] Borisjuk, N., Kishchenko, O., Eliby, S., Schramm, C., Anderson, P., Jatayev, S., ... & Shavrukov, Y. (2019). Genetic modification for wheat improvement: from transgenesis to genome editing. BioMed Research International. 2019.

[6] Madhu, Sharma, A., Kaur, A., Tyagi, S., & Upadhyay, S. K. (2023). Glutathione Peroxidases in

Plants: Innumerable Role in Abiotic Stress Tolerance and Plant Development. Journal of Plant Growth Regulation. 42(2): 598–613.

[7] Mannan, M. A., Tithi, M. A., Islam, M. R., Al Mamun, M. A., Mia, S., Rahman, M. Z., ... & Hossain, M. S. (2022). Soil and foliar applications of zinc sulfate and iron sulfate alleviate the destructive impacts of drought stress in wheat. Cereal Research Communications. 50(4): 1279–1289.

[8] Kumari, V. V., Banerjee, P., Verma, V. C., Sukumaran, S., Chandran, M. A. S., Gopinath, K. A., ... & Awasthi, N. K. (2022). Plant nutrition: An effective way to alleviate abiotic stress in agricultural crops. International Journal of Molecular Sciences. 23(15): 8519.

[9] Bastakoti, S. (2023). Role of zinc in management of plant diseases: A review. Cogent Food & Agriculture. 9(1): 2194483.

[10] Griffiths, C. A., Gaff, D. F., & Neale, A. D. (2014). Drying without senescence in resurrection plants. Frontiers in Plant Science. 5: 36.

[11] Eisvand, H. R., Kamaei, H., & Nazarian, F. (2018). Chlorophyll fluorescence, yield and yield components of bread wheat affected by phosphate bio-fertilizer, zinc and boron under late-season heat stress. Photosynthetica. 56: 1287–1296.

[12] Zhang, X., Zhang, W., Lang, D., Cui, J., & Li, Y. (2018). Silicon improves salt tolerance of Glycyrrhiza uralensis Fisch. by ameliorating osmotic and oxidative stresses and improving phytohormonal balance. Environmental Science and Pollution Research. 25: 25916–25932.

[13] Saifullah, Sarwar, N., Bibi, S., Ahmad, M., & Ok, Y. S. (2014). Effectiveness of zinc application to minimize cadmium toxicity and accumulation in wheat (*Triticum aestivum L.*). Environmental earth sciences. 71: 1663–1672.

[14] Fallah, A., Mohammad-Hasani, A., & Colagar, A. H. (2018). Zinc is an essential element for male fertility: a review of Zn roles in men's health, germination, sperm quality, and fertilization. Journal of reproduction & infertility. 19(2): 69.

[15] Sarwar, N., Saifullah, Malhi, S. S., Zia, M. H., Naeem, A., Bibi, S., & Farid, G. (2010). Role of mineral nutrition in minimizing cadmium accumulation by plants. Journal of the Science of Food and Agriculture. 90(6): 925–937.

[16] Khan, M., Fuller, M., & Baloch, F. (2008). Effect of soil applied zinc sulphate on wheat (*Triticum aestivum L.*) grown on a calcareous soil in Pakistan. Cereal Research Communications. 36(4): 571–582.

[17] Hussain, A., Zahir, Z. A., Asghar, H. N., Ahmad, M., Jamil, M., Naveed, M., & Zaman Akhtar, M. F. U. (2018). Zinc solubilizing bacteria for zinc biofortification in cereals: a step toward sustainable nutritional security. Role of Rhizospheric Microbes in Soil: Volume 2: Nutrient Management and Crop Improvement. 203–227.

[18] Hossain, A., Skalicky, M., Brestic, M., Maitra, S., Sarkar, S., Ahmad, Z., ... & Laing, A. M. (2021). Selenium biofortification: roles, mechanisms, responses and prospects. Molecules. 26(4): 881.

[19] Mannan, M. A., Tithi, M. A., Islam, M. R., Al Mamun, M. A., Mia, S., Rahman, M. Z., ... & Hossain, M. S. (2022). Soil and foliar applications of zinc sulfate and iron sulfate alleviate the destructive impacts of drought stress in wheat. Cereal Research Communications. 50(4): 1279–1289.

[20] Suganya, A., Saravanan, A., & Manivannan, N. (2020). Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (*Zea mays L.*) grains: An overview. Commun. Soil Sci. Plant Anal. 51(15): 2001–2021.

[21] Singh, A., & Shivay, Y. S. (2016). Effect of summer green manuring crops and zinc fertilizer sources on productivity, Zn-uptake and economics of basmati rice. Journal of Plant Nutrition. 39(2) 204–218.

[22] Ghasal, P. C., Shivay, Y. S., Pooniya, V., Choudhary, M., & Verma, R. K. (2017). Response of wheat genotypes to zinc fertilization for improving productivity and quality. Archives of Agronomy and Soil Science. 63(11): 1597–1612.