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Growth and yield attributes of wheat crop in response to application of micronutrients: A review

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Abstract
Wheat is one of the most important cereal crop and staple foods in the world. Increase in productivity of wheat by balance nutrient management is one of the most crucial factors. The main objective this study is to assessing the role of micronutrients in improving different components of wheat yield. There are different methods of application such as seed priming, soil application and fortification but foliar application is more beneficial. This is due to response of foliar application has positive and quadrate in nature *i.e.* the optimum dose of foliar application of zinc for grain yield of wheat was observed as 0.04%. Among treatments of micronutrient alone or combined forms give better results over control. Results have show that micronutrient application substantially improved leaf area index (LAI), leaf area duration, CGR (Crop growth rate), RGR (Relative growth rate), NAR (Net assimilation rate), plant height, spike length, spikelets/spike, grains/spike, test weight, tillers m^{-2}, grain yield, chlorophyll content and biological yield as well as harvest index of wheat. The yield and quality of wheat products improved and boosted by micronutrient applications. Therefore, human and animal health will be protected with the feed of enriched and balanced nutrition of produce as well as it will help in facing the severe global food security.

Keywords: Crop growth rate, Leaf area index, Micronutrient, Net assimilation rate, Relative growth rate

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops which provide staple food to many countries in the world. Deficiency of micronutrients such as iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B), molybdenum (Mo) increased in crops worldwide in recent years. Many factors which causes deficiency problems are intensification in cropping system, chemical fertilizers (NPK), over liming of acid soils, and the increased demand of high-yielding varieties to feed the global population (Fageria *et al.,* 2007). A balanced fertilization of macronutrients with micronutrients for plant nutrition is very important for high yield crops and good quality products. Micronutrients play a vital role in chlorophyll synthesis and formation, nucleic acid, protein synthesis, enzymatic activities, photosynthesis as well as respiration (Reddy, 2004).

The balance use of macronutrients and micronutrients is vital role in crop nutrition for improved yield and quality (Saeed *et. al,* 2012). High fertilizer responsive cultivars having potential to more crop yield, when applied micronutrients with NPK fertilizers (Nataraja *et al.,* 2006). Leiw (1988) has observed that there is an increase in crop production due to application of micronutrients. There are different methods to apply the micronutrients such as seed priming, soil application and fortification but foliar application is more beneficial. Bameri *et al*. (2012) stated that by spraying micronutrients root growth in wheat can be improved which increase in uptake of macro and micronutrients. Ziaeian and Malakouti (2001) observed that fertilization of Fe, Mn, Zn and Cu significantly increased grain and straw yield, test weight, and the number of grains per spikelet. Also found that application of Fe will increased the concentration and total uptake of Fe in grain, flag leaves, and grain protein contents.

Among the micronutrients, especially Zn and Fe reduce the susceptibility of plants to drought stress (Sultana *et al.,* 2001; Khan *et al.,* 2003; Cakmak, 2008). Asad and Rafique (2002) showed that increased in wheat dry matter, grain yield, and straw yield significantly by application micronutrients over an unfertilized control. Khan *et al.,* (2010) observed that when micronutrients (Fe, Mn, Zn, Cu and B) applied at different growth stages of wheat by foliar application significantly increased the plants height, grains per spike, test

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weight, biological yield, harvest index, straw and grain yield etc. Ali (2012) showed that foliar application of Fe at different growth stages increased the plant height, spike length, 1000-grain weight, grain weight per spike, grain yield, grain protein content and protein yield of wheat over a control treatment. Chaudry *et al.* (2007) found that micronutrients (Zn, Fe, B) positively increased the wheat yield over control while Mandal *et al.* (2007) found that positive interaction between fertilizer treatments and physiological stages of wheat growth. Rehm and Albert (2006) found that the Fe -chlorosis in wheat can be corrected by foliar spray of ferrous sulphate.

Rawashdeh and Sala (2013) observed that combined foliar application of mixture nutrients Fe and B also increased plant height, number of tillers and root depth than control treatment. Gomaa *et al.,* (2015) showed that the highest grain and yield components and quality of wheat grain obtained by foliar application of both Zn and Fe. Ali *et al.,* in 2009 and Moghadam *et al.,* in 2012 found that foliar application of B and Zn increased the yield and yield components of wheat. Foliar application of B was positive effect on grain yield, number of grains per spike and 1000-grain weight Raza *et al.* (2014).

The main objective of this study was to identify the micronutrients deficiencies, factors responsible for fertilizer efficiency improvement under the agro-ecology of the wheat area as well as required adequate amount of micronutrients to achieve maximum yields and suggested diagnostic criteria for identification of crop responsive to micronutrients.

Growth and yield attributes of wheat

Leaf area index (LAI) at 49 and 98 days after sowing: The LAI is the ratio of total leaf area to ground cover. In general it increases to maximum after the crop emergence (Reddy, 2004). Application of boron in wheat will increases the tissue formation with good plant growth which increases the concentration of B in wheat leaves and results in higher leaf area index. Whereas, when combined application of B with zinc, copper, iron and manganese, it helps in chlorophyll formation and increased the photosynthetic activities (Ziaeian and Malakouti, 2001; Card *et al.,* 2005; Manal *et al.,* 2010). The application of iron (12 kg ha^{-1}) and copper (6 kg ha^{-1}) produced the minimum leaf area index of 2.31 and 2.38, respectively.

Leaf area duration (LAD) at 49 and 98 days after sowing: Leaf area duration is directly related with leaf area index. Nadim *et al.* (2011) observed that non significant effect on LAD at 49 DAS and significant effect on LAD 98 DAS in wheat. The application of boron @ 2 kg ha^{-1} gives maximum LAD (48.90) and it was statistically similar to combined Zn+Cu+Fe+Mn+B with LAD 47.25.

Crop growth rate (g m^{-2} day^{-1}): Crop growth rate (CGR), defined as the dry matter production per unit time. It is affected by several factors such as temperature, solar radiation and age of cultivar. Nadim *et al.* (2011) observed that application of micronutrients improved the plant growth of wheat through increased plant photosynthesis and other physiological activities. When applied boron @ 2 kg ha^{-1} improved the crop growth rate (33.40 g m^{-2} day^{-1}). The combined application of micronutrients (Zn+Cu+Fe+Mn+B) and sole application of zinc and copper gives CGR of 28.08, 27.44 g m^{-2} day^{-1}, respectively. This is due to boron helps in better utilization of available nutrients which increased leaf area, high photosynthesis and dry matter accumulation. Asad and Rafique (2002) reported that use of medium doses of boron or zinc and/or iron enhances higher CGR of wheat whereas low amount of copper, manganese and combination of all micronutrients application gives higher CGR.

Relative growth rate (mg m^{-1} day^{-1}): Relative growth rate (RGR) refers to the increase in dry weight with time related to the initial weight. So CGR is an absolute measure of growth, similar values could be expected for different initial weights (Reddy, 2004). Nadim *et al.* (2011) revealed that application of boron (3 kg ha^{-1}) in wheat gives significantly maximum RGR (89.60), which was statistically at par (88.73, 88.45 and 87.38 mg m^{-1} day^{-1}) with the sole application of Cu (6 kg ha^{-1}), Zn (10 kg ha^{-1}) and Fe (12 kg ha^{-1}), respectively. The reason behind the high concentrations of B and Zn in the leaves increased plant food accumulation which resulted in more RGR (Card *et al.,* 2005; Nataraja *et al.,* 2006). Kumar *et al.* (2009) also revealed that high dose of copper increased the Cu concentrations in wheat leaves and dry matter production. As compared to its sole application, combined application of boron gives good relative growth rate.

Net assimilation rate (mg m^{-2} day^{-1}): The capacity of plant to increase dry weight in terms of area of its assimilatory surface termed as the net assimilation rate (NAR). Generally it is photosynthetic efficiency in the overall sense and related with LAR and RGR (Reddy, 2004). Among various treatments, the application of copper @ 6 kg ha^{-1} in wheat produced maximum net assimilation rate (3.19) which was statistically at par with the application of zinc (2.92 mg m^{-2} day^{-1}). This is due to high concentrations of Cu in the wheat leaves and more RGR resulted increased in photosynthetic rate and chlorophyll formation. Shukla and Warsi (2000) also found that the highest NAR with the application of Zn alongside with NPK.

Number of tillers (m^{-2}): Tillering capacity of crop generally depends on the genotype and environment. Zain *et al.* (2015) reported that combined application of ($FeSO_4$+ $ZnSO_4$+$MnSO_4$) produced maximum number of tillers (292.33) followed by ($FeSO_4$+$ZnSO_4$) and (3 Kg $ZnSO_4$) while ($FeSO_4$

+ $MnSO_4$) treatment gives minimum tillers. Islam *et al*. (1999) suggested that zinc application improved wheat spike length and productive tillers/ plant. Among various treatments, Cu (8 kg ha^{-1}) gives maximum number of tillers (249.0), followed by sole application of Mn, Cu, Zn and Mn @ 8, 6, 10 and 16 kg ha^{-1} produced similar number of tillers (229.8, 226.5, 220.8 and 218.5 m^{-2}), respectively. Kumar *et al.* (2009) also found that increased number of tillers with the application of Cu in wheat while Manal *et al.* (2010) obtained higher number of tillers with the application of Mn.

Number of grains ($spike^{-1}$): Number of grains $spike^{-1}$ mainly affected by unbalanced nutrition. Application of micronutrients combined with basal dose of NPK significantly improved the number of grains $spike^{-1}$ in wheat. Modaihsh (1997) repoted that Zn application can increased the grain yield as well as biological yield of wheat. biomass.The application boron (2 kg ha^{-1}) gives maximum number of grains (46.50) which were statistically at par with Zn+Cu+Fe+Mn+B (45.25). Because of boron is helps in translocation of food materials, grain setting as well as higher number of grains in wheat. Uddin *et al.* (2008) also obtained higher number of grains by the application of boron (2 kg ha^{-1}) while Tahir *et al.* (2009) showed that substantially increase in number of wheat grains with the foliar application of boron. The application of Zn, Fe and Mn @ 5, 16 and 12 kg ha^{-1} gives statistically similar results (44.25). whereas the combined application of medium doses of micronutrients and sole application of B and Cu @ 3 and 10 kg ha^{-1} obtained same number of grains $spike^{-1}$ (43.50, 43.25 and 43.00).

Spike length (cm): Zain *et al.* (2015) showed that spike length significantly increased by foliar application of micronutrients. Maximum spike length (10.97 cm) was observed in wheat by (FeSO4 + ZnSO4) which treatment was statistically similar to (ZnSO4 + MnSO4), and (1.6 kg FeSO4), whereas minimum spike length (8.733 cm) was observed in (3 kg ZnSO4) treatment which was similar to (1 kg MnSO4) treatment. According to Abbas *et al*. (2009) spike length of wheat can be increase up to 11.8 % by application of Zn @10 kg ha^{-1}. Also Blevins and Lukaszewki (1998) revealed that spike length of wheat may increased by balanced availability of nutrients in the rhizosphere, their uptake and absorption by the plant.

1000 grain weight (g): The combined application of (Zn+Cu+Fe+Mn+B) gives significant maximum wheat grain weight (44.64g) which was statistically at par (44.02g) with grain weight obtained by Cu and Fe @10 and 12 kg ha^{-1} respectively. This may be due to higher accumulation of assimilates in the grains, which resulted in heavier grains of wheat. Soleimani (2006) also observed increased in seeds weight by combined application of Zn, Fe, Mn and Cu.

Grain yield (t ha^{-1}): The conversion of light energy into chemical energy by green plants through the process of photosynthesis results rate at which a crop accumulates organic matter termed as crop productivity (Reddy, 2004). The grain yield depends on number of spikes, kernels $spike^{-1}$ and kernels weight. Attributes such as (test weight) 1000-grain weight, grain and straw yield can be increased due to micronutrient application suggested by Ziaeian and Malakouti (2001) and Maralian (2009). Sultana *et al.* (2016) observed that highest grain yield of wheat (5.14 t ha^{-1}) obtained due to application of zinc up to 0.04%. Kaya and Higgs (2002) and Cakmak (2008) also onserved that zinc increased the production of biomass. This is due to Zn will be detoxifies the Reactive Oxygen Species (ROS) and results it preventing photoxidative damage catalyzed by ROS in chloroplasts (Cakmak, 2000; Ducic and Polle, 2005). Zn play role in drought stress tolerance by protection against oxidative damage of membranes (Cakmak, 2000; Ducic and Polle, 2005). Khan *et al*. (2007) also reported that by application of Zn (5 kg ha^{-1} grains yield increases up to 31.6% over control. Among various treatments, B (2 kg ha^{-1}) produced maximum grain yield (3.67 t ha^{-1}) whereas Cu and Mn both @8 kg ha^{-1} was statistically at par with boron producing grain yield of 3.62 and 3.60 t ha^{-1}, respectively. Boron gives the highest wheat grain yield due to maximum number of grains $spike^{-1}$ while Cu and Mn increased the number of tillers. Kumar *et al.* (2009) recorded 68% yield increase over control with the application of Cu. (Ali, 2012; Tahir *et al.,* 2009; Khan *et al.,* 2010; Nadim *et al*., 2012; Raza *et al.,* 2014), observed that the grain yield of wheat can be increased by application of Fe and B alone or combined with other micronutrients. Ma *et al.* (2017) conducted experiment to observe the physiological responses of wheat to Zn fertilizer application under drought stress, pot, and field experiment under different soil moistures and treated with soil and foliar Zn applications. Zn application in soil significantly increased grain yield of wheat and Zn concentration by 10.5 and 15.8%, 22.6 and 9.7%, and 28.2 and 32.8% under adequate water supply, moderate drought, and severe drought, respectively. Zinc directly alleviates wheat plant drought stress by Zn -mediated increase in photosynthesis pigment and active oxygen scavenging substances, and reduction in lipid peroxidation.

Plant height (cm): Zain *et al.* (2015) showed that foliar application of ($FeSO_4$+$MnSO_4$) gives increased maximum plant height (97.00 cm) that was statistically similar to (FeSO4 + ZnSO4), (ZnSO4 + MnSO4) and (FeSO4+ZnSO4+MnSO4). Single dose of (3 kg ZnSO4) gives minimum plant height (85.567 cm). Khan *et al*. (2009) showed that plant height increase up to 5.8% if treated with ZnSO4 (10 kg ha^{-1}) as compared to untreated wheat. Rawashdeh *et al.* (2015) observed that the plant height of wheat increased significantly (p=0.05) due to foliar application of micronutrient (Fe, B, Fe+B) at individual stages (at 21 days or 41 days) and at both stages (at 21+41 days). The highest plant height observed 14.00% by application of 333g Fe ha^{-1}+167g B ha^{-1} (at 21+41 days) followed by 12.33% and 11.20% by 333g Fe ha^{-1} (at 21+41days), and 333g Fe ha^{-1}+167g B ha^{-1} (at 21 days), respectively over control. This is due to Fe play an important role in chlorophyll synthesis, energy transfer and enters in root cells and B having role in physiological processes *i.e.* cell elongation, cell maturation, meristematic tissue development, sugar transportation, IAA, formation, germination and protein synthesis etc. Similar results obtained that plant height of wheat increased due to foliar application of micronutrient (Ali, 2012; Bameri *et al.,* 2012; Rehman *et al.,* 2012; Rawashdeh and Sala, 2013a). Kandoliya *et al.* (2018) recorded highest grain and straw yield of wheat under the application of RDF (Recommended dose of fertilizer) + soil application of ZnSO4 (10 kg ha^{-1}) + FeSO4 (20 kg ha^{-1}). Under same treatment the yield attributes such as plant height at 40 DAS, 70 DAS and at harvest; numbers of tillers at 45 DAS and at harvest and numbers of effective tillers at harvest of wheat crop were recorded significantly highest.

Flag leaf area: Rawashdeh *et al.* (2015) showed that flag leaf area of wheat significantly increased (p=0.05) by application of (foliar) of micronutrient (Fe, B and Fe+B) at individual stages (at 21 days or 41 days) and at both stages (at 21+41 days). The maximum flag leaf area reported that 39.13% by application of 333g Fe ha^{-1}+167g B ha^{-1} (at 21+41 days) followed by 27.57%, 22.43% and 19.13% by 333g Fe ha^{-1} (at 21+41days), 167g B ha^{-1} (at 21+41days), and 333g Fe ha^{-1}+167g B ha^{-1} (at 41 days), respectively over control. Because of Fe is an important component of cytochrome which involved in electron transport chain (ETS), chlorophyll sysnthesis, maintain structure of chloroplasts, nitrogen fixation and enzymatic activities (Eskandari, 2011) which lead to higher crop production and leaf area increase (Zayed *et al.,* 2011).

Chlorophyll content: Rawashdeh *et al.* (2015) reported that foliar application of micronutrient (Fe, B and Fe+B) at individual stages of wheat (at 21 days or 41 days) and at both stages (at 21+41 days) increase in chlorophyll content of plant leaves. The highest chlorophyll content of plant leaves obtained that 18.96% by application of 333g Fe ha^{-1}+167g B ha^{-1} (at 21+41 days) followed by 16.22%, 12.40% and 12.07% by 333g Fe ha^{-1} (at 21+41days), 333 g Fe ha^{-1} (at 41days), and 333g Fe ha^{-1}+167g B ha^{-1} (at 41 days), respectively over control. Similar results reported by (Kazemi, 2013; Rawashdeh and Sala, 2014b) observed that application of Fe and B alone or in combined with other micronutrients increased chlorophyll content of plants leaves. Jat *et al.* (2018) also reported that, the application of zinc (3 kg ha^{-1}) increased the biosynthesis of important growth hormones *i.e.* indole acetic acid (IAA) which is responsible for wheat plant growth, resulted in increased plant height or plant growth. It was also observed the higher amount of chlorophyll content in a treatment of Zn and Fe (Sale *et al.,* 2018; Kandoliya *et al.,* 2018). Thus increase in photosynthetic process, resulting increase in the growth of wheat plants.

Micronutrients concentration in flag leaves and grains (µg g^{-1}): Rawashdeh *et al.* (2015) reported that the highest concentration of micronutrients (Fe, B, Zn and Cu) in flag leaves and grains of wheat were obtained by application of 333g Fe ha^{-1}+167g B ha^{-1} (at 21+41days). This results was supported by (Zeidan *et al.,* 2010; Gomaa *et al.,* 2015) that foliar application of micronutrients substantially increased concentration of micronutrients in flag leaves and grains.

Biological yield (kg/ha): Zain *et al.* (2015) found maximum biological yield of wheat by application of (ZnSO4 + MnSO4) followed by (FeSO4 + ZnSO4) treatment. Also found that significant positive correlation between micronutrient and dry matter production. Yadav *et al.* (2017) conducted the field experiment during the rabi season found that Zn application @10 kg ha^{-1} significantly improved all growth parameters and yield attributes of wheat crop over the control. Zinc plays an important role in regulating the auxin concentration in plant and nitrogen metabolism in wheat crop and improved in these growth attributes. Similar results were reported by Hrivna *et al.,* (2015) and Noonari *et al.* (2016).

Harvest Index (%): Ratio of yield over biomass called Harvest index. Zain *et al.* (2015) reported that application of (FeSO4 + ZnSO4 + MnSO4) produced maximum harvest index (42.263) of wheat which was statistically at par with (FeSO4 + MnSO4) treatment. Also Webb and Loneragan (1990) found that significant positive relationship between the micronutrient and biomass production of wheat.

Rani *et al.* (2019) showed that application of micronutrient such as Mn, Zn and Fe alone or in a combination of manganese and iron significantly increased yield and yield attributes of wheat. The application of Zn increases, the concentration of Zn in the shoots and grains of wheat increases significantly. Grain protein content was decreased by salinity, while the utilization of grain protein enhanced and finally improved the growth and yield of wheat by decreasing the effects of salinity, therefore the addition of Zn helped in reducing the unfavorable effects.

Now a days to meet the feed of global population, there is a demand of high yielding crops. To increase the yield production of wheat crop we are using high analysis NPK fertilizers which contain low amount of micronutrients. High yielding results in removing the micronutrients from the soil. Also the advances in fertilizer technology reduce the residual addition of micronutrients. So there is need of balanced nutrition for soil to crop which meets the demands of soils, crops as well as human health.

Micronutrients promote the good, strong and steady growth of plants that produce higher yields and increase the harvest of produce. Balanced application of micronutrient application will significantly improve the yield attributes of wheat crop such as leaf area index (LAI), leaf area duration, crop growth rate, net assimilation rate, relative growth rate plant height, spike length, spikelet's/spike, grains/spike, test weight, tillers m^{-2}, grain yield, chlorophyll content, biological yield as well as harvest index etc.

Conclusion

A balanced use of macronutrients with micronutrients fertilization is very important for high yield crops and good quality products as well as plant nutrition. Micronutrients play a significant role in chlorophyll synthesis, nucleic acid, protein synthesis and formation, different enzymatic activities, photosynthesis as well as respiration. The balance use fertilization also improves yield and quality of crop by application of micronutrient alone or combined forms give better results over control. The Result have show that micronutrient application substantially improve leaf area index (LAI), leaf area duration, crop growth rate, net assimilation rate, relative growth rate, plant height, spike length, spikelet's/spike, grains/spike, test weight, tillers m^{-2}, grain yield, chlorophyll content and biological yield as well as harvest index of wheat. This study will be helpful for farmers and human welfare in understanding the stages of growth, right micronutrients time, dose, and helped the plants grow successfully under unfavorable conditions.

REFERENCES

1. Abbas, G., Khan, M. Q., Jamil, M., Tahir, M. and Hussain, F. (2009). Nutrient uptake, growth and yield of wheat (*Triticum aestivum* L.) as affected by zinc application rates. *International Journal of Agriculture and Biology* 11: 389-396.
2. Ali, E. A. (2012). Effect of iron nutrient care sprayed on foliage at different physiological growth stages on yield and quality of some durum wheat (*Triticum durum* l.) varieties in sandy soil. *Asian J. of Crop Sci.* 4 (4): 139-149.
3. Ali, S., Shah, A., Arif, M., Miraj, G., Ali, I., Sajjad, M., Farhatullah, Khan, M. Y. and Khan, N. M. (2009). Enhancement of wheat grain yield and yield components through foliar application of Zinc and Boron. *Sarhad J. Agric.* 25(1): 15-19.
4. Asad, A. and Rafique, R. (2002). Identification of micronutrient deficiency of wheat in the Peshawar valley. *Commun. Soil Sci. Plant Anal.* 33: 349-364.
5. Bameri, M., Abdolshahi, R., Mohammadi-Nejad, G., Yousefi, K. and Tabatabaie, S. M. (2012). Effect of different microelement treatment on wheat (*Triticum aestivum*) growth and yield. *Intl. Res. J. Appl. Basic. Sci.* 3(1): 219-223.
6. Blevins, D. G. and Lukaszewski, K. M. (1998). Boron in plant structure and function. *Annual Review of Plant Physiology and Plant Molecular Biolog,* 49: 481 -500. http://dx.doi.org/10.1146/annurev.arplant.49.1.481
7. Cakmak, I. (2000). Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytol.* 146: 185-205.
8. Cakmak, I. (2008). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification?. *Plant Soil* 302: 1-17.
9. Card, S., Cathcart, J. and Huang, J. (2005). The micronutrient and trace element status of crops grown on the Alberta Soil Quality Benchmark Sites. AESA Soil Quality Monitoring Program, *Alberta Agri. Food & Rural Dev., Cons. & Dev. Branch,* pp.20.
10. Chaudry, E. H., Timmer, V., Javed, A. S. and Siddique, M. T. (2007). Wheat response to micronutrients in rainfed areasof Punjab. *Soil & Environ.* 26: 97 -101.
11. Ducic, T. and Polle, A. (2005). Transport and detoxification of manganese and copper in plants. *Braz. J. Plant Physiol.* 17: 103-112.
12. Eskandari, H. (2011). The importance of iron (Fe) in plant Products and Mechanism of Its uptake by plants. *J. Appl. Environ. Biol. Sci.* 1(10): 448-452.
13. Fageria, N. K. (2007). Soil fertility and plant nutrition research under field conditions: Basic principles and methodology. *Journal of Plant Nutrition* 30(2): 203-223.
14. Gomaa, M. A., Radwan, F. I., Kandil, E. E., El-Zweek, S. M. A. (2015). Effect of some macro and micronutrients application methods on productivity and quality of Wheat (*Triticum aestivum* L.). *Middle East J. Agric. Res.* 4(1): 1-11.
15. Hrivna, L., Kotkova, B. and Buresova, I. (2015). Effect of sulphur fertilization on yield and quality of wheat grain. *Food Science and Technology Abstracts Cereal Research Communications.* 43(2): 344-352.
16. Islam, M. R., Islam, M. S., Jahirhuddin, M. and Hoque, M. S. (1999). Effect of sulphur, zinc and boron on yield, yield components and nutrients uptake of wheat. *Pakistan Journal of Science and Industrial Research,* 42: 137-140.
17. Jat, R. C., Sharma, Y., Jakhar, R. K. and Sharma, R. K. (2018). Effect of phosphorus, zinc and iron on yield and quality of wheat in western Rajasthan, India. *Int. J Curr. Microbiol. App. Sci.,* 7(3): 2055-2062.
18. Kandoliya, R. U., Sakarvadia, H. L. and Kunjadia, B. B. (2018). Effect of zinc and iron application on leaf chlorophyll, carotenoid, grain yield and quality of wheat in calcareous soil of Saurashtra region. *International Journal of Chemical Studies,* 6(4): 2092-2095.
19. Kandoliya, R. U., Talaviya, B. P. and Kunjadia, B.B. (2018). Effect soil and foliar application of zinc and iron on growth of wheat plant in calcareous soil of Saurashtra region. *European Journal of Biotechnology and Bioscience,* 6(5): 86-90.

20.Kaya, C. and Higgs, D. (2002). Response of tomato (Lycopersicon esculentum L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. *Sci. Hortic.* 93: 53–64.

21.Kazemi, M. (2013). Effect of Foliar Application of Iron and Zinc on Growth and Productivity of Cucumber. Bull. *Env. Pharmacol. Life Sci.,* 2(11): 11-14.

22.Khan, H. R., McDonald, G. K. and Rengel, Z. (2003). Zn fertilization improves water use efficiency, grain yield and seed Zn content in chickpea. *Plant Soil,* 249: 389-400.

23.Khan, R., Gurmani, A. R., Khan, M. S. and Gurmani, A. H. (2007). Effect of zinc application on rice yield under wheat rice system. *Pakistan Journal of Biological Sciences,* 10: 235-239. http://dx.doi.org/10.3923/pjbs.2007.235.239

24.Khan, R., Gurmani, A. R., Khan, M. S. and Gurmani, A. H. (2009). Residual, direct and cumulative effect of zinc application on wheat and rice yield under rice-wheat system. *Soil and Environment* 28: 24-28.

25.Khan, S., Mirza, K. J., Anwar, F. and Abdin, M. Z. (2010). Development of RAPD markers for authentication of Piper nigrum. *Environment & International Journal of Science and Technology,* 5: 53-62.

26.Kumar, R., Mehrotra, N. K., Nautiyal, B. D., Kumar, P. and Singh, P. K. (2009). Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (Triticum aestivum L.). *J. Environ. Biol.,* 30: 485-488.

27.Liew, C. S. (1988). Foliar Fertilizers from Uniroyal and their Potential in Pakistan. *Proceedings of Seminar on Micronutrient in Soils and Crops in Pak,* 277 (Abstract).

28.Ma, D., Sun, D., Wang, C., Ding, H., Qin, H., Hou, J., Huang, X., Xie, Y. and Guo, T. (2017). Physiological responses and yield of wheat plants in zinc-mediated alleviation of drought stress. *Frontiers in Plant Science,* 8:1-12. doi: 10.3389/fpls.2017.00860.

29.Manal, F. M., Thalooth, A. T. and Khalifa, R. K. M. (2010). Effect of foliar spraying with uniconazole and micronutrients on yield and nutrients uptake of wheat plants grown under saline condition. *J. Amer. Sci,.* 6: 398-404.

30.Mandal, A., Patra, A. K., Singh, D., Swarup, A. and Masto, R. E. (2007). Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. *Bioresour. Technol.,* 98: 3585-3592.

31.Maralian, H. (2009). Effect of Foliar Application of Zn and Fe on Wheat Yield and Quality. *African Journal of Biotechnology,* 8: 6795-6798.

32.Modaihsh, A. S. (1997). Foliar application of chelated and non-chelated metals for supplying micronutrients to wheat grown calcareous soils. *Experimental Agriculture* 33: 237-245. http://dx.doi.org/10.1017/S001447979700001X

33.Moghadam, M. J., Sharifabad, H. H., Noormohamadi, G., Sadeghian Motahar, Y. and Siadat, S. A. (2012). The Effect of Zinc, Boron and Copper Foliar Application, on Yield and Yield Components in Wheat (Triticum aestivum L.). *Ann. Biolo. Res*., 3(8): 3875-3884.

34.Nadim, M, A., Awan, I. U., Baloch, M. S., Khan, E. A., Naveed, K., Khan, M. A., Zubair, M. and Hussain, N. (2011). Effect of micronutrients on growth and yield of wheat. *Pak. J. Agri. Sci.,* 48(3): 191-196.

35.Nadim, M. A., Awan, I. U., Baloch, M. S., Khan, E. A., Naveed, K., Khan, M. A. (2012). Response of wheat (Triticum aestivum L.) to different micronutrients and their application methods. *J. Anim. Plant Sci.* 22(1): 113-119.

36.Nataraja, T. H., Halepyati, A. S., Pujari, B. T. and Desai, B. K. (2006). Influence of phosphorus levels and micronutrients on the physiological parameters of wheat. *Karnataka J. Agri. Sci.* 19: 685-687.

37.Noonari, S., Kalhoro, S. A., Ali, A. Mahar, A. Raza, A. Ahmed, M. Shah, S. F. A. and Baloch, S. U. (2016). Effect of Different Levels of Phosphorus and Method of Application on the Growth and Yield of Wheat. *Natural Science,* 8: 305-314.

38.Rani, S., Sharma, M. K., Kumar, N. and Neelam (2019). Impact of salinity and zinc application on growth, physiological and yield traits in wheaT. *Current science* 116(8): 1324-1330. DOI: 10.18520/cs/v116/i8/1324-1330.

39.Rawashdeh, H. and Sala, F. (2013). Effect of different levels of boron and iron foliar application on growth parameters of wheat seedlings. *African Crop Science Conference Proceedings,* 11: 861-864.

40.Rawashdeh, H. and Sala, F. (2013). Effect of different levels of boron and iron foliar application on growth parameters of wheat seedlings. *African Crop Science Conference Proceedings,* 11: 861-864.

41.Rawashdeh, H. and Sala, F. (2015). Effect of some micronutrients on growth and yield of wheat and its leaves and grain content of iron and boron. *Bulletin USAMV series Agriculture,* 72(2).

42.Rawashdeh, H. M. and Sala, F. (2013). The effect of foliar application of iron and boron on early growth parameters of wheat (Triticum aestivum L.). *Research Journal of Agricultural Science,* 45(1): 21-26.

43.Raza, S. A., Ali, S., Chahill, Z. S., Iqbal, R. M. (2014). Response of foliar application of boron on wheat (Triticum aestivum L) crop in calcareous soils of Pakistan. *Acad. J. Agric. Res.,* 2(3): 106-109.

44.Reddy, S. R. (2004). Principles of crop production – growth regulators and growth analysis, 2nd ed. kalyani publishers, Ludhiana, india.

45.Rehm, G. and Albert, S. (2006). Micronutrients and Production of Hard Red Spring Wheat. *Minnesota Crop e News,* 7: 1-3.

46.Rehman, S. U., Hussain, N., Tariq, M., Hussain, M., Nasir, M., Ayaz, M. (2012). Response of wheat to exogenous boron supply at various growth stages. *Sarhad J. Agric.,* 28(3): 411-414.

47.Saeed, B., Gul, H., Khan, A. Z., Badshah, N. L., Parveen, L. and Khan, A. (2012). Rates and methods of nitrogen and sulfur application influence and cost benefit analysis of wheat. *Journal of Agricultural & Biological Science* 7(2): 81-85.

48.Sale, R. B., Nazirkar, R. B., Thakare, R. S. and Kondvilkar, N. B. (2018). Effect of foliar spray of zinc, iron and seed priming with molybdenum on growth and yield attributes and quality of soybean in the rainfed condition of Vertisol. *Int. J of Chemical Studies* 6(1): 828-831.

49.Shukla, S. K. and Warsi, A. S. (2000). Effect of sulphur and micronutrients on growth, nutrient content and yield of wheat (Triticum aestivum L.). *Indian J. Agri. Res.* 34:203-205.

50.Suleimani, R. (2006). The effects of integrated application of micronutrient on wheat in low organic carbon conditions of alkaline soils of Western Iran. *Proc. 18th World Congress of Soil Sci.* Philadelphia, USA.

51. Sultana, N., Ikeda, T. and Kashem, M. A. (2001). Effect of foliar spray of nutrient solutions on photosynthesis, dry matter accumulation and yield in seawater-stressed rice. *Environ. Exp. Bot.* 46: 129-140.
52. Sultana, S., Naser, H. M., Shil, N. C., Akhter, S. and Begum, R. A. (2016). Effect of foliar application of zinc on yield of wheat grown by avoiding irrigation at different growth stages. *Bangladesh J. Agril. Res.* 41 (2): 323-334.
53. Tahir, M., Tanveer, A., Shah, T. H., Fiaz, N. and Wasaya, A. (2009). Yield response of wheat (*Triticum aestivum* L.) to boron application at different growth stages. *Pak. J. Life Soc. Sci.* 7: 39-42.
54. Uddin, M. N., Islam, M. S. and Islam, A. B. M. S. (2008). Effect of boron on wheat at different boron application methods. *J. Subtrop. Agric. Res. Dev.* 6: 483-486.
55. Webb, M. J. and Loneragan, J. F. (1990). Zinc translocation to wheat roots and its implications for a phosphorus/zinc interaction in wheat plants. *Journal of Plant Nutrition* 13: 1499-1512. http://dx.doi.org/10.1080/01904169009364171
56. Yadav, S. K., Singh, G., Kumar, R., Kumar, P. and Mohan, B. (2017). Effect of Phosphorus, Sulphur and Zinc on Growth, Yield and Yield Attributes of Wheat (*Triticum aestivum*). *Int. J. Curr. Microbiol. App. Sci.* 6(8): 2581-2584. https://doi.org/10.20546/ijcmas.2017.608.306.
57. Zain, M., Khan, I., Qadri, R. W. K., Ashraf, U., Hussain, S., Minhas, S., Siddique, A., Jahangir, M. M. and Bashir, M. (2015). Foliar application of micronutrients enhances wheat growth, yield and related attributes. *American Journal of Plant Sciences,* 6: 864-869.
58. Zayed, B. A., Salem, A. K. M. and Sharkawy, H. M. (2011). Effect of different micronutrient treatments on rice (Oriza sativa L.) growth and yield under saline soil conditions. *World J. Agric. Sci.* 7(2): 179-184.
59. Zeidan, M. S., Manal, F. and Hamouda, H. A. (2010). Effect of foliar fertilization of Fe, Mn and Zn on wheat yield and quality in low sandy soils fertility. *World J Agric Sci.* 6(6): 696-699.
60. Ziaeian, A. H. and Malakouti, M. J. (2001). Effect of micronutrient application on wheat production in calcareous soils. Prepared for the Second National Conference on Optimum Utilization of Chemical Fertilizers and Pesticide in Agriculture, Karaj, Iran.
61. Ziaeian, A. H. and Malakouti, M. J. (2001). Effects of Fe, Mn, Zn and Cu fertilization on the yield and grain quality of wheat in the calcareous soils of Iran. *Food Security and Sustainability of Agro-Ecosystems,* pp.840-841.