REVIEW ARTICLE

EFFECT OF MICRONUTRIENT FERTILIZERS APPLICATION ON CROP YIELD AND NUTRIENT CONCENTRATION IN GRAIN

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Abstract: Micronutrients play very specific role like other essential nutrient elements in the plants. Deficiency of these nutrient elements can't be rectified by the application of other nutrient elements. There is a mining of micronutrients in upper fertile soil from agriculture fields. It is due to adoption of high yielding verities, use of micronutrient free high analysis fertilizers, less use of manures, unbalanced fertilizer use etc. Deficiency of micronutrients such as zinc (Zn), manganese (Mn) and iron (Fe) is a worldwide nutritional constraint in crop production. Many approaches have been elected to boost the Zn and Fe content in crops and ameliorate their malnutrition, including breeding, genetic engineering, and agronomic approaches. In the present review of studies it is concluded that micronutrient application through foliar treatment performers better than other application methods. Application of combined soil + foliar application of micronutrient fertilizer significantly increased the grain micronutrient content as compared to other treatments.

Keywords: Crop, Grain, Fertilizers, Malnutrition, Micronutrient

INTRODUCTION

Soil fertility is one of the most promising factors that control crop yield. Micronutrients play very specific role like other essential nutrient elements in the plants and their presence in soil, above critical level in available form is must for a plant to complete their life cycle. Further, deficiency of these nutrient elements can't be rectified by the application of other nutrient elements. Deficiency of micronutrients such as zinc (Zn), manganese (Mn) and iron (Fe) is a worldwide nutritional constraint in crop production particularly in growth, yield, and grain nutrient of crops, especially in cereals such as wheat and rice in calcareous soils. According to the results of study by Kumar and Sangwan (2019), the concentration of Fe in Ex-, OM- and $CaCO_3$- fractions were found to be very small in all the soils of Haryana. It indicates less availability of Fe in Haryana soils and therefore its outside application will be required in near future to sustain crop production. On the other hand, Zn is an important nutrient for the growth and development of animals and humans and shortage in food causes severe damages economically due to malnutrition considerations. Micronutrient malnutrition in humans in developing countries is derived from deficiencies of these elements in staple food.

Many approaches have been chosen to increase the Zn and Fe content in crops and ameliorate their malnutrition, including breeding, genetic engineering, and agronomic approaches. Mulch, no-tillage leads to higher C sequestration than conventional tillage (Kumar and Sangwan, 2019). Li *et al.* (2007) revealed that application of organic matter significantly increased the DTPA-extractable concentrations of Zn, Fe and Mn. So, emphasis on carbon sequestration should be given for proper nourishment of crops. In this study, effects of agronomic biofortification components including different dose, proper stage of application, and effective method of micronutrient application are investigated on quantitative and qualitative yield of crops. The investigations of agronomy showed that micronutrient has an important role in the improvement of quantitative and qualitative crop yield.

Hence, application of micronutrients such as Zn increased the grain yield due to its effect on the number of fertile spikelet per spike, number of grains per spike, and other agronomic traits. Also, this nutrient increased Zn and other micronutrient concentration in grain, grain protein, amino acid contents, and ascorbic acid content in grain but decreased phytic acid (PA) content and PA/Zn molar ratio in grain crops in most cases which increased bioavailability of micronutrients for human. In most cases, micronutrient application through foliar treatment performed better than other application methods. Studies indicated that application of micronutrients especially Zn and Fe led to increase in grain yield as well as positive aspects of seed quality and decrease in seeds' negative qualities.

Effect of Zinc application on crop yield

The results from an experiment conducted on sandy loam soils of Punjab revealed that four foliar application of 0.5% of Zn and Fe separately at different growth stages of wheat significantly increased grain yield of wheat. The results further revealed that application of Zn raised maximum grain yield up to 63.1 q ha^{-1} (PBW 550) and 62.5 q ha^{-1} (PBW 343), which were 8.1 and 4.4% higher than control, respectively. The yield increase in

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wheat with foliar application of Fe varied from 2.5-5.1 % in different cultivars (Dhaliwal *et al.,* 2009).

El-Ghamry *et al*. (2009) reported that wheat grain yield increased significantly with foliar application of Zn alone (4.69 t ha^{-1}) as well as mixed application of B+Mo+Zn (5.69 t ha^{-1}) over control (4.38 t ha^{-1}).

Habib (2009) showed that foliar application of Zn and Fe (alone or together with Fe) has significant effect on wheat yield on clay loam soils. Maximum seed yield (8185 kg ha^{-1}) was obtained by using (Fe + Zn) and Zn treatment (7919 kg ha^{-1}). Although seed yield was affected by using Fe fertilizer (increased by 187 kg ha^{-1}), but foliar application of Fe did not increase seed yield significantly compared to control. Similar results have also been reported by Yilmaz *et al.* (1997) and Seilsepour (2006).

Zeidan *et al.* (2010) reported that the grain yield was increased when wheat plants were treated with Zn on sandy soils of low fertility.

Dhaliwal *et al.* (2010) reported that three foliar application of 0.5% Zn and Fe each produced maximum rice yield of 74.0 q ha^{-1} of cultivars PR 114 and PR 115 and 76.3 q ha^{-1} of cultivar PAU 201, respectively on sandy loam soils of Punjab. Similar to Zn, foliar sprays of Fe increased rice yield up to 77.5 (PAU 201), 75.4 (PR 115), 74.7 (PR 114), 74.7 (PR 113) and 74.4 (PR 116) q ha^{-1}, which were 8.5, 7.8, 6.9, 10.3 and 9.3% higher than their control, respectively.

It was reported by Narwal *et al*. (2010) that maximum increase in grain yield was achieved when the recommended dose of $ZnSO_4$@ 25 kg/ha was applied as soil application and 0.5 % solution of $ZnSO_4$ as foliar spray. Habib (2009) also reported similar results of Zn nutrition in wheat.

Dhaliwal *et al.* (2010) conducted experiments at Ludhiana and Hoshiarpur in sandy loam and loamy sand soils respectively and reported that various plant parameters of wheat variety PBW 550 such as plant height, no of tillers/m2 increased with soil application of $ZnSO_4.7H_2O$ @ 62.5kg/ha and foliar spray of Zn chelates which significantly increased grain yield.

Mathpal *et al.* (2015) studied the various methods of zinc application for enrichment of zinc in wheat genotype and reported that the maximum content of Zn in grains was observed under conditions where soil application of Zn fertilizers was followed by foliar spray. He also investigated on interactive effects of Zn and N were investigated on wheat at Peshawar. The experiment consisted of four levels of N (0, 50, 100 and 150 kg/ha) and six levels 16 of Zn (0, 3, 6, 9, 12 and 15 kg/ha). Application of N @150 kg/ha and Zn@15kg/ha resulted in the improved growth, highest yield components and highest grain yield (4044 kg/ha) and straw yield (5067 kg/ha) of wheat.

Afzal *et al*. (2017) from Pakistan studied the effect of different application methods of zinc on various wheat cultivars and reported that the zinc application in soil for wheat before planting along with the foliar application at later stages gave increased yield.

Chattha *et al*. (2017) reported the combination of soil and foliar application of zinc fertilizers to obtain the optimum yield of grain and grain biofortification of wheat.

Effect of Iron application on crop yield

Habib (2009) showed that foliar application of Zn and Fe (alone or together with Fe) has significant effect on wheat yield on clay loam soils. Maximum seed yield (8185 kg ha^{-1}) was obtained by using (Fe + Zn) and Zn treatment (7919 kg ha^{-1}). Although seed yield was affected by using Fe fertilizer (increased by 187 kg ha^{-1}), but foliar application of Fe did not increase seed yield significantly compared to control. Similar results have also been reported by Yilmaz *et al.* (1997) and Seilsepour (2006).

Zeidan *et al.* (2010) carried out field experiments in newly cultivated sandy soil in Nobaria, Egypt to study the effect of foliar application of Fe, Mn and Zn fertilization on wheat yield and quality. Results indicated that the application of these elements significantly increased the grain yield, 1000-grain weight, straw yield and number of grains/spike, Fe, Mn and Zn concentration in grains and flag leaves along with protein content in grain.

Dhaliwal *et al.* (2010) reported that three foliar application of 0.5% Zn and Fe each produced maximum rice yield of 74.0 q ha^{-1} of cultivars PR 114 and PR 115 and 76.3 q ha^{-1} of cultivar PAU 201, respectively on sandy loam soils of Punjab. Similar to Zn, foliar sprays of Fe increased rice yield up to 77.5 (PAU 201), 75.4 (PR 115), 74.7 (PR 114), 74.7 (PR 113) and 74.4 (PR 116) q ha^{-1}, which were 8.5, 7.8, 6.9, 10.3 and 9.3% higher than their control, respectively.

Zhang *et al.* (2010) carried out the experiment to study concentrations of iron and zinc in wheat grain affected by foliar application Fe & Zn. Fe concentration in grain was increased significantly by application of $FeSO_4$ (37.8 mg kg^{-1}), ferric citrate plus $ZnSO_4$ (35.9 mg kg^{-1}) and ferric citrate (34.9 mg kg^{-1}) as compared to control (29.5 mg kg^{-1}). Zn concentration in grain was also found to be increased by application of ferric citrate plus ZnSO4 (45.7 mg kg^{-1}) and a complex of micronutrients (39.6 mg kg^{-1}) in comparison to (29.0 mg kg^{-1}). He also conducted the pot experiment to study the growth and productivity of wheat after foliar application of Cu, Zn and Fe and showed increased grain yield along with other parameters like leaf number, branch number, leaf area, total dry weight for shoots and roots etc.

Zhao *et al.* (2011) conducted the experiment to investigate the effect of iron and zinc supply. Plant dry weight was found to be increased with the supply of Fe (5 mg l^{-1}) and Zn (0.1 mg l^{-1}). Wheat Fe concentrations were decreased (by an average of 8%) by Zinc supply (10 mg l^{-1}).

Nadim *et al.* (2012) studied the response of wheat to different micronutrients along with the methods of application. They reported that side dressing method at 4 weeks after sowing showed better results when combined with iron in terms of higher grain yield, higher number of tillers, and LAI.

Shahrokhi *et al.* (2012) carried out the experiment to study the effects of spraying the iron sulfate in three cultivars of dry land wheat. Data analysis indicated that the grain yield was significantly enhanced by spraying treatment. Out of 4 treatments, concentration of 6/1000 showed the maximum grain yield of 8125 kg/ha.

Rawashdeh and Sala (2015) studied the effect of Fe, B and combination of Fe & B on the growth and yield of wheat. They reported that the spray of Fe & B increased the grain yield but the combination gave the highest yield along with highest plant height, chlorophyll content and flag leaf area.

Sher *et al.* (2018) conducted the experiments in Pakistan to study the response of wheat to nitrogen, zinc and iron application. Three levels of N (90, 120 and 150 kg ha^{-1}), and three concentrations of Fe and Zn (i.e. 1, 2, 3 kg ha^{-1}) were included in treatments along with two controls i.e. no water & no micro nutrients (control-I) and water + no micro nutrients (control-II). They concluded that the combination of the N - 150 kg ha^{-1}, Zn - 3 kg ha^{-1} and Fe -1 kg ha^{-1} showed the best results in terms of increase biomass and leaf area.

Effect of Manganese application on crop yield

Sadana *et al.* (2005) reported that an increase of Mn solubility by microbial or chemical mobilization would increase Mn uptake by wheat. Low Mn efficiency of some wheat cultivars was related to their reduced root growth at low soil Mn supply. For correcting Mn deficiency in wheat, $MnSO_4.H_2O$ proved more efficient than Mn-frits, MnO_2 and other multi micronutrient mixtures. Three to four foliar sprays of 0.5% $MnSO_4.H_2O$ solution initiated before the first irrigation proved more effective and economical compared to soil application of Mn in increasing yield.

Kumar *et al.* (2009) conducted a pot experiment at six graded levels of Mn 0, 0.5, 1.0, 1.5, 2.0 and 2.5 mg kg^{-1} to test the response of wheat plants grown in a Mn-responsive alluvial soil (Entisol) under glass house conditions. The growth attributes like plant height, fresh and dry matter yield, percent dry matter enhanced with increasing Mn levels and was maximum at 1.5 mg kg^{-1} Mn while the number of tillers was minimum at this level. The grain yield at 1.5 mg kg^{-1} Mn was enhanced by 62.9% over the control. The increase in weight of 1000 grains ranged from 33.93 to 41.35 g in comparison to control (32.58 g). Harvest index also increased and ranged from 39.42 to 47.73 in different treatments in comparison to control (35.92).

The results from an experiment conducted on sandy loam soils of Punjab revealed that four foliar applications of 0.5% of Mn separately at different growth stages of wheat significantly increased wheat grain and straw yield. The application of Mn raised maximum grain yield up to 63.1 q ha^{-1} and 42.5 q ha^{-1} which were 8.1 % higher than control, respectively (Dhaliwal and Manchanda., 2008).

Ashok *et al.* (2009) reported significant increase in grain and straw yield and uptake of N, P, K and Mn by wheat with the application of K and Mn at recommended rates.

Zeidan *et al.* (2010) studied the effect of Mn, Fe & Zn foliar fertilization on wheat yield in low sandy soil fertility. Two field experiments were conducted which indicated the significant increase in grain yield, 1000-grain weight, straw yield and number of grains/spike, protein content in grain; and Fe, Mn and Zn concentration in grains and flag leaves on application of these elements.

Abbas *et al.* (2011) obtained a positive and significant response of wheat to Mn application. The highest grain yield of 4.59 t ha^{-1} was achieved with the highest application of 16 kg ha^{-1} Mn along with NPK against 3.96 t ha^{-1} from NPK alone. Maximum wheat straw yield of 6.11 t ha^{-1} was obtained with $MnSO_4$ of 16 kg ha^{-1} while lowest (5.67 t ha^{-1}) with the NPK alone. The uptake of N, K and Mn was significantly increased with the application of $MnSO_4$.

Stepien and Wojtkowiak (2016) performed the experiments in Poland to study the effect of foliar application of Cu, Zn, and Mn on yield of wheat grain. Mn supplemented mineral fertilizers increased the content of Fe (14.3%), protein (3.8%) and gluten (4.4%) in wheat grain. Foliar Mn application increased the ω, α/β, and γ gliadin fractions (19.9%, 9.5%, and 2.1%, respectively).

Jarecki *et al.* (2017) carried a field experiment determine the response of spring wheat cultivar Arabella to foliar application and to different levels of soil NPK fertilization. Increase in the total protein, Cu, K and Mn contents in grain was found after the higher level of NPK fertilization.

Dimkpa *et al.* (2018) in USA studied the effects of manganese nanoparticle exposure on wheat yield and nutrient acquisition in wheat comparative to bulk and ionic-Mn. Nano-Mn resulted in a higher grain Mn translocation efficiency (22%), as compared to bulk-Mn (21%), salt-Mn (20%), and control (16%).

Effect of micronutrients fertilizers application on their concentration and their uptake in wheat

Wissua *et al.* (2008) reported that foliar Zn application (equivalent to 1.5 kg Zn ha^{-1}) at three different growth stages of rice *viz.* booting, flowering and early seed development significantly increased average grain concentration in low Zn lowlands of Philippines from 30.1 to 36.4 mg kg^{-1}. In high Zn uplands, average grain concentrations were 41.6 and 44.7 mg kg^{-1} for the non-sprayed and sprayed plots, respectively.

Varshney *et al.* (2008) reported that highest Zn concentration in rice grain and straw registered was 18.6 mg kg^{-1} and 35.8 mg kg^{-1} with application of Zn at once (20 kg Zn ha^{-1}) or twice application (10.0 kg Zn ha^{-1} to rice + 2.5 kg Zn ha^{-1} to wheat) during 1st year in hybrid rice-wheat sequence. While, in 2nd year highest Zn content in straw was recorded with 5.0 kg Zn ha^{-1} (to each rice crop). However, Zn content in wheat grain ranged from 29.4 to 39.5 and 24.2 and 33.2 mg kg^{-1} during both the years. The concentration of Zn was more in wheat grain as compared to straw while reverse was true for rice; however, total Zn removal by hybrid rice was more than twice as compared to wheat.

In general, bread wheat (*Triticum aestivum*) is more tolerant of Zn deficiency than durum wheat (*Triticum durum*). Very recently, new wild emmer wheat accessions have been identified showing simultaneously both very high concentrations of Zn (up to 139 mg kg^{-1}), Fe (up to 88 mg kg^{-1}) and protein (up to 380 g kg^{-1}) in seed and high tolerance to drought stress and Zn deficiency in soil (Cakmak, 2008).

Zhang *et al*. (2010) reported that combined application of foliar Fe (II)-AA and B recorded highest concentration of Fe in polished rice as compared to the control. Addition of B in foliar Fe-containing solutions spray did not increase Fe content in polished rice. However, whether B was added in Fe containing solutions or not, foliar Fe(II)-AA spray increased significantly the concentration of Fe in polished rice.

Dhaliwal *et al.* (2009) reported that four foliar application of Zn raised concentration of Zn to maximum 43.3 µg g^{-1} (PDW 291) and 42.8 µg g^{-1} (PBW 502), which were 38.8 and 37.75 % higher over control, respectively. Also the application of Fe raised maximum concentration of Fe to 50.9 µg g^{-1} (PBW 343) and 47.9 µg g^{-1} (PBW 502), which was 24.8 and 23.1% more over control, respectively. However, the highest per cent increase in Fe concentration was reported in PDW 274 (30.3%) variety of wheat.

Habib (2009) showed that foliar application of Zn and Fe (alone or together with Fe) has significant effect on wheat seed Zn concentration on clay loam soils. Zn application increased grain Zn approximately up to threefold in comparison with control (from 18.7 to 50.9 mg kg^{-1}). Foliar application of (Fe+Zn) at tillering and heading stage increased Zn concentration up to 20.27 from 12.17 mg kg^{-1}. Iron application increased grain Fe approximately up to twofold, in comparison with control (from 84.93 to 146.7 mg kg^{-1}).

Grain Zn concentration of wheat was increased to 62.1 mg kg^{-1} (99% increases) with its foliar application (0.5%) in sandy loam soils (Pahlavan and Pessarakli, 2009). Similarly, foliar application of Fe significantly increased its concentration by 21% in grains. It was also noticed that foliar application of Fe increased content of Zn and vice versa, while Fe application decreased Mn concentration. The highest Zn concentration was in the foliar treatment of Zn and Fe, which was 67.5 mg kg^{-1}.

Dhaliwal *et al.* (2009) observed that four foliar sprays of 0.5% each of Mn applied at different growth stages of wheat resulted in increase in their concentration in durum wheat varieties *viz.* PDW 274 and PDW 291 as well as aestivum varieties *viz.* PBW 343, PBW 502 and PBW 550 on sandy loam soils of Punjab. It was also observed that aestivum varieties showed more increase in micronutrients concentration than durum varieties under Mn sprays.

Zahan *et al.* (2009) studied Mn-efficiency and manganese uptake kinetics of raya, wheat and oat grown in nutrient solution as well as soil. They reported that raya was more Mn-efficient in soil than wheat or oat. This resulted from higher shoot Mn concentration due to a higher Mn uptake but not from a large root system**.** The higher Mn uptake of raya was related to its ability to increase the solubility of Mn in the rhizosphere, while in wheat it was rather decreased. In solution culture Mn uptake of all species was similar at the lowest Mn concentration.

On the contrary, Cakmak *et al.* (2010) noticed that when compared with bread wheat, durum wheat tends to accumulate more Zn, Mn and Fe. Durum wheat has also a higher protein concentration than bread wheat with grain protein representing a sink for Zn, Fe and Mn.

The accumulation of Zn and Fe in rice, irrespective of cultivars ranged from 28.5-30.4 mg kg^{-1} and 52.3-54.8 mg kg^{-1} with three foliar applications of 0.5% Zn and Fe, respectively on sandy loam soils of Punjab. The three sprays of Zn raised its concentration to 30.42 mg kg^{-1} (PAU 201) and 30.3 mg kg^{-1} (PR116), which were 19.3 and 18.6% higher than their controls, respectively. It was also observed that foliar application of Fe also helped to enhance concentration of Fe to maximum of 54.8 mg kg^{-1} (PR 116) and 57.7 mg kg^{-1} which was higher by 48.5% and 43.5% over respective controls. However, the highest increase in Fe concentration was reported for PR 116 (48.5 mg kg^{-1}) followed by PAU 201 (48.4 mg kg^{-1}) cultivars of rice (Dhaliwal *et al.*, 2010).

Aciksoz *et al*. (2011) reported that highest iron concentration in grain with the application of $FeSO_4$ + Urea and at par with FeEDTA + Urea and Fe EDDHA + Urea as compare to over treatments.

Wei *et al.* (2012) reported that the concentration of Zn in brown rice was increased from 30.28 mg kg^{-1} in the control, to 33.75 mg kg^{-1} by foliar Zn-EDTA application, to 35.07 mg kg^{-1} by foliar Zn-Citrate application, to 38.45 mg kg^{-1} by foliar $ZnSO_4$ application, to 39.84 mg kg^{-1} by foliar Zn-AA application. It might be due to the different capacity of leaf penetration of different forms of foliar applied Zn fertilizers. Foliar fertilizer with low molecular weight like Zn-AA and $ZnSO_4$ might be easily penetrated into the leaves than those have higher molecular weight like Zn-EDTA and Zn- Citrate fertilizers.

Bharti *et al*. (2013) reported that the application of combined soil + foliar application of Zn fertilizer significantly increased the grain Zn content as compared to other treatments. It might be due to increasing the Zn levels and also obtained lowest values of phytic acid because phytic acid is a P storage compound and therefore a greater P uptake might be a reason for an antagonistic relationship between phytic acid and Zn nutrition.

Singh *et al*. (2013) reported that three foliar sprays of $FeSO_4.7H_2O$ with 0.5 per cent and 1 per cent levels at different growth stages of rice crop (maximum tillering, pre-anthesis and post-anthesis stages) significantly increased Fe concentration in brown rice of different rice cultivars as compared to control but results shown by PR113 cultivar were non-significant.

Yadav *et al*. (2013) in an experiment found that application of 3 foliar sprays of 2.0% $FeSO_4$ recorded higher Fe concentration and with significant improvement in uptake in grain as well as in straw of aerobic rice. Fe application increased the Fe concentration 5.4 to 19.9% and 5.8 to 13.3% in grain and straw of aerobic rice.

Shivay and Prasad (2014) found that the combined soil + foliar treatment, and always significantly superior to all other treatments. Soil application as Zn-coated urea was nearly always statistically higher than application as Zn sulphate. All Zn treatments for agronomic biofortification of Zn in corn grain as well as in stover were in the following order: 5 kg soil + 1 kg foliar > 1 kg foliar > 2.83 kg as Zn-coated urea to soil > 5 kg soil.

Shivay *et al*., (2015) reported that soil application of ZnSHH or Zn–EDTA significantly increased the Zn concentration in grain of rice crop over NPK fertilization, which were at par with two or three applications of 0.2% solutions of ZnSHH or Zn–EDTA or one or two applications of 0.5% solutions of ZnSHH or Zn-EDTA. A single application of 0.2% of ZSHH or Zn-EDTA was inferior to soil application of Zn and did not significantly increase Zn concentration in rice grain.

CONCLUSION

Foliar application of 0.5% of micronutrients separately or in mix at different growth stages of crop significantly increases grain yield. Increase in grain yield is achieved when the recommended dose of micronutrient is applied as soil application and 0.5 % solution of micronutrient as foliar spray. Foliar application of these elements significantly increased the grain yield, 1000-grain weight, straw yield and number of grains/spike, Fe, Mn and Zn concentration in grains and flag leaves along with protein content in grain. Application of combined soil + foliar application of micronutrient fertilizer significantly increased the grain micronutrient content as compared to other treatments.

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