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Effect of boron, zinc and FYM on growth, yield and quality of maize (*Zea mays* L.): A review

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Abstract
Maize is an exhaustible crop that is highly nutritional requirement for their growth. The productivity of the crop depends on nutrient management system. It is a heavy feeder on fertilizer. Hence it should meet its requirement in order to complete its growing period. Highest productivity of crops in sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying appropriate combination of different organic manures and inorganic fertilizers. Boron is one of the essential nutrients for the optimum growth, development, yield, and quality of crops. In the early stages of maize, deficiency of phosphorous, potassium and zinc inhibit the growth due to its small root interface. Prior to the full development of root system the essential nutrients should be supplied to juvenile maize which may likely promote the growth. Zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes in many important biochemical pathways and these are mainly concerned with carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membranes, the resistance to infection by certain pathogens. Due to intensive cultivation, use of hybrid varieties which absorb more nutrients, reduction in application of organic manures like FYM which supply these nutrient and intensive cropping system resulted depletion of Zn and K in soil. The application of FYM also enhanced the availability of plant nutrient as well as improving the soil chemical, biological and physical properties of soil. FYM is a store house of nutrient, which contain all essential plant nutrients.

Keywords: Boron, zinc, FYM, quality, yield, soil productivity, maize

Introduction

Maize (*Zea mays* L.), crop also called as "*queen of cereals*" is the third most important crop in India after rice and wheat. Globally, India stands 5th rank in acreage and 8th rank in production of maize. It is cultivated on 9.86 million hectares with a production of 26.26 million tones having productivity of 26.64 quintals ha^{-1} (Anonymus 2017) [4]. The Maize or corn serves as a basic raw material to thousands of industrial products that may include oil, starch, alcoholic beverages, pharmaceutical, food sweeteners, cosmetic, gum, textile, package and paper industries. Corn is good for digestion due to its fiber content and corn may prevent diabetes and hypertension. The nutritional value of maize is high as it contains 72% starch, 10% protein, 8.5% fibre, 4.8% oil, 3.0% sugar and 1.7% ash (Hokmalipour *et al.*, 2010) [15]. The starch in maize can be hydrolysed and enzymatically treated to produce syrups, particularly high fructose corn syrup, and a sweetener; and also fermented and distilled to produce grain alcohol. Grain alcohol from maize is traditionally the source of Bourbon whiskey (Mohammadi *et al.*, 2012) [21].

In the soil, Boron (B) is found in the form of boric acid or borate; among all the essential elements, the percolation of boron is in the form of uncharged molecules instead of ions (Miwa and fujiwara, 2010) [20]. Boron is one of the essential nutrients for the optimum growth, development, yield, and quality of crops (Brown *et al.*, 2002) [8]. According to a report, in tobacco (*Nicotiana tabacum* L.) and squash (*Cucurbita pepo* L.) plants, 95-98% of B is located in the cell walls of leaves (Hu and Brown, 1994). The enhanced B requirement of young growing tissues proves its critical role primarily in cell division and elongation (Dell and Huang, 1997) [12]. B starvation dramatically inhibits root elongation, with deformed flower and fruit formation due to impaired cell division in the meristematic region, whereas adequate B supply promotes advantageous root development (Gupta and Solanki, 2013) [13]. B deficiency activates enzymatic and nonenzymatic oxidation by using phenol as substrate, resulting in elevated polyphenol oxidase and quinine concentrations, which are hazardous for plant growth and development (Hajiboland *et al.*, 2013) [14]. B plays a pivotal role in nitrogen (N) metabolism and development (Hajiboland *et al.*, 2013) [14]. B plays a pivotal role in nitrogen

(N) metabolism as it enhances nitrate levels and reduces nitrate reductase activity under limited B conditions (Shen *et al.,* 1993) [32]. B deficiency affects photosynthesis indirectly by weakening vascular tissues responsible for ion transport (Wang *et al.,* 2015) [38].

Zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes in many important biochemical pathways and these are mainly concerned with carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membranes, the resistance to infection by certain pathogens (Keram and Singh 2014) [17]. Reduced growth hormone production in Zn-deficient plants causes the shorting of internodes and smaller than normal leaves (Tisdale *et al.,* 2003) [37].

Zinc Oxide is the most common nanoparticle that is applied on maize as it is sensitive to zinc deficiency. Zinc oxide can be used as a foliar spray, seed dipping and can be applied on soil directly. Zinc is considered important among all the micronutrients as it has a major role in metabolism of nitrogen, photosynthesis and promotes the concentration of auxin plants. In the early stages of maize, deficiency of phosphorous, potassium and zinc inhibit the growth due to its small root interface. Prior to the full development of root system the essential nutrients should be supplied to juvenile maize which may likely promote the growth (Raskar *et al.,* 2013) [27].

Farm yard manure (FYM) is the principle source of organic matter in our country and it is a source of primary, secondary and micronutrients to the plant growth. It is a constant source of energy for heterotrophic microorganisms, help in increasing the availability of nutrient quality and quality of crop produce. The application of FYM also enhanced the availability of plant nutrient present in soil. While, FYM applied with Zn and K increased the uptake of deficient nutrients as well as improving the soil chemical, biological and physical properties of soil. FYM is a store house of nutrient, which contain all essential plant nutrients. It is beneficial as apply fertilizer like Zn and K in combination with FYM (Nawab *et al.*, 2011) [24].

Due to intensive cultivation, use of hybrid varieties which absorb more nutrients, reduction in application of organic manures like FYM which supply these nutrient and intensive cropping system resulted depletion of Zn and K in soil. Zinc deficiency virtually an all India problem. On an average, about 48% soils of India are deficient in Zn and in Gujarat also, Zn (24%) deficiency in soils is wide spread. The light textured soils of Gujarat have been reported to be widely deficient in Zn (Dangerwala *et al.,* 1994) [11]. Therefore, it is very essential to check out the response of Zn and fulfill the requirement of Zn to the maize by Zn application in deficient soil.

1. Consequence of boron, zinc and FYM on growth and yield attributing characters of maize

In plants, Boron deficiency symptoms include a drastic shortening of primary root growth and an altered root morphology accompanied by an increased number of root hairs (*hairy* phenotype), root swelling and the disorganization of the root apical meristem (Dell and Huang 1997) [12]. Foliar application of boron was carried out after 20 days of crop emergence at 0, 0.15, 0.30 and 0.45 kg of B ha^{-1}. Boron application at 0.30 kg ha^{-1} increased the plant height, leaf area, stem diameter, cob weight, number of grains per cob, protein and oil contents. The maximum grain yield (7.14 tons ha^{-1}) and biological yield (527.4 tons ha^{-1}) was recorded in where application of boron was carried out at 0.30kg ha^{-1}, however, further increase in boron dose decreased the yields (Tahir *et al.,* 2012) [12]. Application of K_2O @ 60 kg ha^{-1}, Zn @ 20 kg ha^{-1} and FYM @ 10 t ha^{-1} recorded significantly higher plant height, green forage yield and dry matter yield of maize over control. Thus, use of potassium and zinc and FYM increase productivity by maintaining soil health (Chaudhary *et al.,* 2017) [10].

The combined application of T_{13}-75% NPK + Zn 10 kg ha^{-1} + B 10 kg ha^{-1} + 10 t FYM ha^{-1} was recorded higher grain yield (26.42 q ha^{-1}), followed by T_{12}- 75% RDF NPK + Zn 10 kg ha^{-1} + 10 t FYM ha^{-1} (Mued *et al.,* 2017) [23]. The grain yield ha^{-1} as influenced by different treatments revealed that highest grain yield was recorded by T_8-RDF + $ZnSO_4$ + FeSO4 + Borax (4890 kg ha^{-1}) followed by T_9-RDF + Foliar application of Micronutrient (4791 kg ha^{-1}). Thus, for securing maximum grain yield maize crop should be sown by supplying recommended dose of NPK (150:75:75 kg ha^{-1}) along with $ZnSO_4$ 20 kg ha^{-1}, $FeSO_4$ 20 kg ha^{-1} and borax 5 kg ha^{-1} (Borase *et al.,* 2018) [7]. Tariq *et al.,* (2014) [36] the experimental results showed that substantial difference in all physiological and yield parameters except plant height and stem diameter. Statistically maximum grain yield (8.76 t ha^{-1}) was obtained with foliar spray of $ZnSO_4$ at 9 leaf stage (Zn_2) in case of Monsanto-6525. The treatment, which received zinc (4 kg ha^{-1}) through pressmud compost (86 ppm) recorded a maximum yield of 5.96 and 6.85 t $ha^{-1}$of stover and grain respectively (Kumar *et al.,* 2010) [18]. It was reported that T_5 (ZnO 0.42 g kg^{-1} seed + Urea) shows the maximum records of plant height (168 cm), number of leaves (8.55), dry matter accumulation (241.5 g), cob length (24.45 cm), number of grains per cob (412.51), 1000 grain weight (203.33 g), grain yield (2.85 kg pot^{-1}).The least was recorded from control (Sangma *et al.*, 2017) [31].

FYM and Zn application have significant impact on different growth and yield attributes of maize crop. Mean plant height was observed to be maximum in case of T_3 (120-60-40 Kg ha^{-1} NPK + FYM 4 t ha^{-1} + 4 Kg Zn ha^{-1}) and was 5.10% higher than control T_1 (120-60-40 Kg ha^{-1} NPK + FYM 0 t ha^{-1} + 0 Kg Zn ha^{-1}). Dry matter was highest in T_4 120-60-40 Kg ha^{-1} NPK + FYM 8 t ha^{-1} + 4 Kg Zn ha^{-1} (197.0 g $plant^{-1}$) followed by T_5 120-60-40 Kg ha^{-1} NPK + FYM 8 t ha^{-1} + 6 Kg Zn ha^{-1} (191.2 g $plant^{-1}$) >T_3 120-60-40 Kg ha^{-1} NPK + FYM 4 t ha^{-1} + 4 Kg Zn ha^{-1} (187.5 g $plant^{-1}$) >T_2 120-60-40 Kg ha^{-1} NPK + FYM 4 t ha^{-1} + 0 Kg Zn ha^{-1} (185.0 g $plant^{-1}$) and least in control T_1 120-60-40 Kg ha^{-1} NPK + FYM 0 t ha^{-1} + 0 Kg Zn ha^{-1} (181.8 g $plant^{-1}$). Grain yield (Mg ha^{-1}) was maximum in T_4 120-60-40 Kg ha^{-1} NPK + FYM 8 t ha^{-1} + 4 Kg ha^{-1}Zn (3.94) and least in T_1 120-60-40 Kg ha^{-1} NPK + FYM 0 t ha^{-1} + 0 Kg Zn ha^{-1} (3.47). Soil amendments by FYM alone and in combination with Zn significantly enhanced the plant height, dry matter accumulation, yield character, grain yield, as compared to their respective counter treatments and was thus found to be suitable for maize crop (Kumar *et al.,* 2017) [18]. Sarwar *et al.,* (2012) [29, 30] reported that maximum maize grain yield, *viz.*, 5.18 t ha^{-}1, leaf area index and straw yield were obtained with 75% + 25% (CF + FYM) and 4 kg Zn ha^{-1}. It was statistically at par with treatment having 50% + 50% (CF + FYM) and 4 kg Zn ha^{-1}as well as 75% + 25% and 8 kg Zn ha^{-1}. Zinc application also enhanced maize grain yield by 12% over treatment where no Zn was applied i.e. 4.08 t ha^{-1}. Ramulu *et al.,* (2011) [25] find out that boron and zinc application increasing the higher seed yield along with the recommended dose of fertilizers and farm yard manure. The increase in yield compared to 100% of RDF + FYM (7.5 t ha^{-1}) was to the extent of 8.77 q ha^{-1}, which certainly a higher yield.

Shilpashree *et al.*, (2012) [33] recorded the maximum stover yield (11.00 t ha^{-1}) with the application of (100% N + 7.5 t ha^{-1} FYM) and followed by (150% N + 7.5 t ha^{-1} FYM) which recorded the Stover yield of 10.20 t ha^{-1}. Ajaz *et al.*, (2013) [3] application of farm yard manure (FYM) at 6 t ha^{-1} in combination with 150% recommended dose of fertilizer (225 N: 90 P_2O_5: 60 K_2O kg ha^{-1}) reveled maximum cob yield (without husk) of 20.60 q ha^{-1} associated with maximum number of cobs plot^{-1} (326). However application of FYM at 6 t ha^{-1} in combination with state recommended dose of Nitrogen: Phosphorus: Potassium (N: P: K) at 90: 60: 40 kg ha^{-1} was statistically at par with the best treatment and gave a cob yield of 19.85 q ha^{-1}. Application of 150% of Recommended Dose of Fertilizer (RDF) without FYM reveled increased cob length (10.90 cm), whereas, 125% of RDF resulted in maximum cob girth without husk (18.30 mm). Similar trend of enhanced green fodder yield (26.39 t ha^{-1}) was observed with application of 6 t ha^{-1} FYM + 150% of RDF).

2. Consequence of Boron, Zinc and FYM on quality characters of Maize

Application of 100% RDF *i.e.*, 180-60-50 kg N, P2O5 and K2O ha-1 supplemented 30 kg S ha-1 along with foliar application of ZnSO4 + FeSO4 @ 0.5% each at booting and silking stage is the optimum nutrient strategy for obtaining higher productivity of hybrid maize with improved seed quality (in terms of higher concentration of zinc, iron and protein) and as well as the maximum economic returns. From this, it might be noted that nutrients do not work in isolation and therefore balanced nutrition is required to enhance the productivity and quality of hybrid maize (R. Rakesh Naik, 2016) [26]. Seed priming is a pragmatic, easy approach and an effective technique in the quality production of maize with solution of boron and zinc. Rasool *et al.*, (2019) [28] revealed that for priming maize seeds were soaked for 8 hours in various solutions of zinc (0.5%), boron (0.01%), manganese (0.01%), boron + zinc (0.01% + 0.5%), boron + manganese (0.01% + 0.1%), and boron + zinc + manganese (0.01% + 0.5% + 0.1%). For comparison, seeds were also soaked in simple water (distilled), i. e. hydro=priming, and untreated seeds were taken as control. Seed priming in all the treatments substantially induced the early emergence of maize compared to control. Likewise, highest grain yield, biological yield, cob length, grain rows per cob, grains per cob and 1000-grain weight were observed in plants raised from primed seeds, while boron + zinc + manganese (0.01% + 0.5% + 0.1%) was the best treatment. Similarly, maximum boron (77.60 mg/kg) and protein contents (10.82%) were observed in boron + zinc + manganese (0.01% + 0.5% + 0.1%) primed seeds, followed by boron + zinc (0.01% + 0.5%).

3. Consequence of boron, zinc and FYM on nutrient uptake and content of maize

The application of boron at low Zn levels had no significant effect on the NPK concentrations in the grain, but at high Zn levels, increased NPK concentrations in the grain. Therefore, a high Zn content in the soil helped increasing the N, P and K concentrations and P uptake in the grain by boron application (Aref 2011) [6]. The highest N uptake, *viz.*, 98.7 kg ha^{-1}was observed with 50% + 50% (Chemical Fertilizer + Farm Yard Manure) and 8 kg Zn ha^{-1} than 25% or 100% N with FYM. Similarly, maximum Zn uptake, *viz.*, 250.7 g ha^{-1}was observed with 75% + 25% (CF + FYM) and 4 kg Zn ha^{-1}application (Sarwar *et al.*, 2012) [29, 30]. Aref (2012) [5] revealed that N and P concentration in the leaf were below the critical level but P concentration was sufficient for corn: There was a synergism between Zn-P and between B-K and an antagonism between B-P. The response of a high amount of B in the soil assisted to increasing of leaf P content by Zn application. The higher rate of B was needed for increasing K concentration in the leaf by B application. Tariq *et al.*, (2014) [36] as regard to quality parameters, Pioneer-32F 10 and Hycorn-8288 accumulated more zinc contents in grains but Monsanto-6525 attained more zinc concentration in straw. Foliar spray of $ZnSO_4$ at 9 leaf stage produced 19.42% more zinc contents in grains as compared to other $ZnSO_4$ treatments. Foliar spray of $ZnSO_4$ at 9 leaf stage in Monsanto-6525 hybrid produced higher grain yield.

Shinde *et al.*, (2014) [34] reported that application of 100% RDF + 10 t FYM ha^{-1} was at par with application of 100% RDF + 5 t FYM ha^{-1} and both of them recorded significantly higher grain yield than other integrated nutrient management practices. The highest values of protein percent, protein yield and protein production efficiency were recorded with application of 100% RDF + 10 t FYM ha^{-1}. Zinc uptake by maize significantly increased due to applied zinc sources except zinc oxide. Further, application of zinc (4 kg ha^{-1}) through organic sources [FYM (197 ppm), vermicompost (128 ppm) and pressmud (86 ppm) respectively] was found to increase uptake of in N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn significantly (Kumar *et al.*, 2010) [18]. Application of K_2O @ 60 kg ha^{-1}, Zn @ 20 kg ha^{-1} and FYM @ 10 t ha^{-1} recorded significantly higher N, P, and K uptake by plant over control. The highest K content in plant was recorded with the application of K2O @ 60 kg ha^{-1} than rest of the levels of K_2O at 30 DAS and harvest. However, the application of FYM @ 10 t ha^{-1} and zinc @ 20 kg ha^{-1} recorded significantly higher N content at 30 DAS and at harvest (Chaudhary *et al.*, 2017) [10].

4. Consequence of boron, zinc and FYM on economic of maize

Combined application of T_{13}- 75% NPK + Zn 10 kg ha^{-1} + B 10 kg ha^{-1} + 10 t FYM ha^{-1} was recorded highest, gross returns (Rs.49595.00), net return (Rs. 30300.00) and B:C ratio (1.57) followed by T_{12}-75% RDF NPK + Zn 10 kg ha^{-1} + 10 t FYM ha^{-1} (Mued *et al.*, 2017) [23]. Cultivation of baby corn variety *VL-78* under temperate conditions with an application of N: P: K a 90 N: 60 P: 40 K, kg ha^{-1} in combination with 6 t ha^{-1} FYM revealed a maximum B: C ratio of 1: 1.59 (Ajaz *et al.*, 2013) [3]. Ahmad *et al.*, (2013) [1] showed that combining FYM with 50% of recommended NPK fertilizers produced the highest grain and biological yields of maize over the 50% NPK treatment and were statistically at par with those receiving 100% NPK fertilizers. Moreover, the net return was greatest when organic sources were combined with 50% of recommended NPK fertilizers.

5. Consequence of boron, zinc and FYM on soil microbial population and physical chemical properties

Highest productivity of crops in sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying appropriate combination of different organic manures and inorganic fertilizers (Chandrashekhara *et al.*, 2000) [9]. There are soils with high

pH and low organic matter (OM) minimizes the microelements availability such as boron (B), zinc (Zn) and iron (Fe) to crops (Ahsan *et al.*, 2011) [2].
Mousavi (2011) [22] observed that Zinc is playing principal metabolically role in plant. This micronutrient have an important role on most enzymes structure such as: dehydrogenises, al dolase and isomerases. Also Zinc is effective in energy production and crebs cycle. In most of the Iranian soil pH is high and they are also calcareous. In this type of soil solvability of micronutrient is less and cause decline uptake these element and finally requirement of plants to this element is increasing. Crop yields and quality are reduced by Zinc inadequate in soil. Zinc absorption capacity is reduced by high phosphorus utilization and Zinc in plant and soil has an antagonism state with phosphorus (negative interaction). The study revealed that substitution of 25 or 50% N with FYM + 4 kg Zn ha^{-1} performed better than 100% N fertilizer alone, with respect to, soil organic matter content and nutrient uptake (Sarwar *et al.*, 2012) [29, 30].

Conclusion

To eliminate zinc and iron deficiency, foliar feeding is an excellent and low cost technology as it not only enhanced the productivity and also found to be an important strategy for increasing the zinc and iron content in seeds, which may alleviate the hunger and malnutrition especially in the children, as maize is used as an important source of dietary protein and a mineral nutrient.
Experiment shows that farm yard manure with boron and zinc can be used as complement nutrients for good quality yield of maize. FYM is a store house of nutrient, which contain all essential plant nutrients. FYM also enhanced the availability of plant nutrient as well as improving the soil chemical, biological and physical properties of soil.

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