OPEN ACCESS
Pakistan Journal of Agricultural Research

Research Article

Dynamics of Soil and Foliar Applied Boron and Zinc to Improve Maize Productivity and Profitability

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Abstract | Zinc and Boron dearth is an imperative soil constraint in Pakistan. Zinc (Zn) and boron (B) deficiency in soil is primary hindrance to achieve yield potential of maize. An experiment was conducted with the objectives to optimize methods of B and Zn application in maize and ultimately enhance profitability. The experiment was laid out in randomized complete block design with factorial arrangement during autumn 2015. Treatments were replicated three times. The treatments were comprised of C = no Zn and B (Control); Zn (S) = soil application of Zn @ of 12 kg ha^{-1}; B (S): soil application of B @ 3 kg ha^{-1}; Zn (F) = foliar application of 1% Zn at 9^{th} leaf stage; B (F) = foliar application of 0.5% B at 9^{th} leaf stage; Zn (S) + B (S) = soil application of Zn @ 12 kg ha^{-1} + B @ of 3 kg ha^{-1} and Zn (F) + B (F) = foliar application of 1% Zn + 0.5% B at 9 leaf stage. Foliar application of Zn and B produced more plant height, cob length, girth, stem girth, shelling percentage, number of grains per cob, 1000-grain weight, harvest index, grain and biological yield. Maximum marginal rate of return was obtained with foliar application of both Zn and B and using foliar Zn alone. Integrated B and Zn application produced more marginal rate of returns both in soil and foliar applications. Use of foliar Zn application also depicted promising results while foliar or soil B application without using Zn enhanced cost of production.

Received | July 07, 2016; **Accepted** | 05 September, 2017; **Published** | September 28, 2017
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Citation | Anjum, S.A., M.F. Saleem, M. Shahid, A. Shakoor, M. Safeer, I. Khan, A. Farooq, I. Ali and U. Nazir. 2017. Dynamics of soil and foliar applied boron and zinc to improve maize productivity and profitability. *Pakistan Journal of Agricultural Research*, 30(3): 294-302.
DOI | http://dx.doi.org/10.17582/journal.pjar/2017.30.3.294.302
Keywords | Application methods, Bio-fortification, Cost of production, Fertilizer use efficiency

Introduction

Maize is positioned third among the cereals in Pakistan after wheat and rice (Govt. of Pakistan, 2016), whereas, maize is the first crop in world amongst the cereals on premise of the production and yield (Paredes et al., 2014). The normal yield of the maize trim in Pakistan is falling behind its potential (Islam et al., 2016). Various elements that lessen maize yield in Pakistan are weeds obstruction, low quality seed and composts (Ahmad et al., 2016). Zinc (Zn) and boron (B) availability for partitioning to grains further declines under alkaline calcareous oils (Zhao et al., 2014). Furthermore, 2/3^{rd} of population all around the globe is facing nutrient deficiencies. Globally, more than 36% of young infants are suffering from B and Zn deficiencies (WHO, 2016). Declined soil Zn availability hampers potential productivity of maize crop and ultimately lessens profits (Velu et al., 2016) while B also dwindles crop productivity by influencing activation of enzymes and growth of reproductive organs (Kayhan et al., 2016).

Deficiency of above listed micronutrients in soils and human population can be attributed to innumerable factors. Most of soils across Pakistan have originated from calcareous alluvium and loess. Hence, poor organic matter contents coupled with excessive carbonates, alkaline pH and poor restoration of nutrients further poses serious threats to crop production (Rafique et al., 2015). Higher Ca prevalence in soil occupies exchange sites of soil colloids (Ali et al., 2016). Additionally, most of the nutrients application is not based on soil and plant analysis (Ali et al., 2015). Among the nutrients, imbalance use of B and Zn is the foremost deterrent factor hindering to attain yield potential (Rehman et al., 2014). Moreover, high degree of adsorption in alkaline calcareous soil conditions further aggravates Zn and B fixation (Abid et al., 2014). Likewise, high temperature mediated diminishment in organic matter contents aggravates B leaching. Hence B deficiency is further accentuated (Kaur and Nelson, 2015). Chemisorption of Zn with calcium carbonate in alkaline calcareous soil depletes soil available Zn (Joy et al., 2016). Similarly, prevalence of shallow soils along with high calcium carbonate further abates Zn availability for plant uptake (Sadeghzadeh et al., 2016). Alkaline calcareous soils rich in montmorillonite which depicts higher potential to fix available Zn (Zhao et al., 2014).

Adequate B availability enhances meristematic growth, cross links cellulose molecules in cell wall and activates enzymes by incorporating diol containing groups in cell membrane (Wimmer and Eichert, 2013). Moreover, B is prerequisite for assembly of rhamnogalacturonan and pectin and thus imparts strength to cell wall (Kunal and Naresh, 2014). Furthermore, declined availability of B consequences into poor translocation rate of assimilates (Saleem et al., 2016). Consequently, yield diminishes and thus potential yield cannot be achieved (Korkmaz and Askin, 2015). Besides, B deficiency mediates ruination in assimilate partitioning, declines indole acetic acid and cytokinin biosynthesis capability of plants. Ultimately, growth of root and shoot apex cells is arrested (Muhammad et al., 2013).

Decline in plant availability of zinc down regulates numerous enzymes and auxin biosynthesis. Consequently, plant capability to survive under stress and maintain its growth rate reduces (Mattiello et al., 2015). Likewise, zinc triggers activation of more than 300 enzymes including carbonic anhydrase, sorbitol dehydrogenase, Zn-SOD (superoxide dismutase) and Cu/Zn-SOD are also negatively regulated (Zhang et al., 2016). Moreover, Zn mediated activation of acid invertase, sucrose synthase and sucrose phosphate synthase diminishes. Consequently, assimilate translocation towards reproductive parts declines with resultant reduction in crop yield (Song et al., 2015). Ultimately, B and Zn deficiency mediates adversities in metabolism of plants and substantially decreases the yield of maize crop.

Applied use efficiency of both Zn and B can be enhanced by employing numerous strategies such as by adding of soil organic matter, foliar application of chelate nutrients and band placement in soil (Ashraf et al., 2016). Eventually, incline in cost of production diminishes profit. Diverse methods are available for application of nutrients (Cool et al., 2016). However, integration of foliar and soil applied micronutrients often surpass other methods of nutrient application in terms of benefits (Das, 2014).

In crux, various studies have explored the role of B and Zn in plant life cycle. While, information regarding the comparative efficacy of foliar and soil applied B and Zn at different pheno-stages for improving maize productivity and benefit cost ration is scarce. The current study supplements the knowledge to optimize B and Zn rates for soil and exogenously applied methods that may ultimately decline cost of production and enhance benefit cost ratio of maize. The study will also suggest economically most feasible method and phenological stage for Zn and B application. Experiment was conducted with following objectives

1. Optimize rate of soil and exogenously applied Zn and B
2. Determine suitable phenological-stage for application of B and Zn
3. Enhance benefits while decrease cost of production and improve maize productivity on sustainable basis

Material and Methods

Experimental site and material

A field trial was laid at Agronomic Research Area, University of Agriculture, Faisalabad (situated at 310, 23˚. 46˚N and 730, 6˚, 7˚S) amid pre-winter season, 2015 to examine the impact of various Zn and B application techniques on use efficiency and cost benefit ratio of maize (Monsanto half and half DK-6714). Before sowing and harvest, ten soil tests were brought with a soil auger at the profundity of 0-15 cm and 15-30 cm from better places in the trial range. A part of the readied soil test was utilized to dissect for different physico-chemical properties. Soil pH was measured in immersed soil saturation paste by utilizing a Beckman pH meter. Electrical conductivity (0.28 dS m^{-1}) was measured in saturation extract by utilizing advanced EC meter. The organic matter content in the soil was 0.62% as indicated by Walkely-Block strategy (Nelson and Sommers, 1982). Soil textural class was dictated by hydrometer technique (Gee and Bauder, 1982) was loamy clay soil.

Experimental treatments and design

The experiment was laid out by using randomized complete block design (RCBD) having net plot size dimension of 4.5 m × 3 m length and width respectively. There were seven treatments of experiment and each treatment was replicated three times. Treatments included, no Zn and B (Control), soil application of Zn as $ZnSO_4$ @ of 12 kg ha^{-1}, soil application of B as Boric acid @ 3 kg ha^{-1}, foliar application of Zn as 1% solution of $ZnSO_4$ at 9th leaf stage, foliar application of B as 0.5% solution Boric acid at 9th leaf stage, soil application of Zn as $ZnSO_4$ @ 12 kg ha^{-1}+ Soil application of B as Boric acid @ of 3 kg ha^{-1} and Foliar application of Zn as 1% $ZnSO_4$ solution + foliar application of B as 0.5% Boric acid solution at 9th leaf stage the percentage of B in boric acid is 17% and the percentage of Zn in zinc sulphate is 33%.

Crop husbandry

Before sowing, field was irrigated with canal water. At proper moisture condition, field was ploughed with tractor drawn tillage implements. Ridges were made to draw boundaries between adjacent plots. Two seeds per hole (made by dibbler) were sown manually. Recommend doses of N, P and K @ 250, 125 and 125 kg ha^{-1} in the form of N, P_2O_5 and K_2O, were uniformly applied at sowing in all plots the source of nitrogen, phosphorus and potassium was urea, DAP and SOP respectively. Soil application of zinc and boron was done at the time of sowing. Twenty days after sowing, thinning was performed in order to have uniform number of plants in all the plots and also to maintain row-to-row and plant to plant distance of 75 cm and 30 cm, respectively. Earthing up of maize plants was performed thirty days after sowing. Weeds were manually eradicated and Imadiacloprid was sprayed to control the attack of maize stem borer. The calculated amount of zinc and boron were mixed in fair quantity of sand and was broadcasted uniformly. The foliar application was performed at the 9th leaf stage by using a knapsack sprayer. Plants were grown till maturity, after which cobs were separated from the plants and air dried. After oven drying in a forced air oven at 70°C dry weight of cobs was recorded. Grains were separated manually from the cobs and their dry weight was also recorded.

Data collection

From each plot, selected five plants were tagged for their height, number of cobs, cob length, cob girth and stem girth was measured and then average of these parameters was determined. Ten randomly selected number of cobs were taken; grain rows of each cob and grains per row of each cob were counted and then averaged to get grain rows of each cob and grains per row. In order to take 1000-grin weight, three samples were taken randomly from the seed lot of each subplot, weighed and then averaged. Grain yield was recorded on subplot basis and then converted into tons per hectare (t ha^{-1}). Biological yield comprised of grain, stover and pith yield. Crop from each subplot was harvested manually, sun dried and weighed to determine the biological yield in kg $plot^{-1}$ and then converted to t ha^{-1}. The ratio of grain yield and biological yield (harvest index) was calculated by using formula (Gardner et al., 1985):

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Shelling percentage was calculated by using the following relation

$$\text{Shelling percentage (\%)} = \frac{\text{Grain weight}}{\text{Cob weight}} \times 100$$

All the expenses occurred during the research were recorded and cost of production involved in growing the crop and gross income was calculated.

Gross benefits were calculated as

$$\text{Net field benefits} = \text{Gross income} - \text{Variable cost}$$

Benefit cost ratio for each treatment was calculated by using the following formula:

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Gross expenditure}}$$

Marginal rate of return was calculated by using the following formula (CIMMYT, 1988).

$$\text{Marginal rate of return} = \frac{\text{Marginal net benefits}}{\text{Marginal cost}}$$

Statistical analysis

Data were statistically analyzed using Fisher's analysis of variance technique. Mean values were compared by using least significant difference at 5% probability level (Steel et al., 1997).

Results

Application of B and Zn generally improved yield and yield components of maize. However, distinct response of treatments was evident for numerous attributes. Application of B and Zn significantly improved all yield and growth components of maize. Contrarily, number of cobs per plant were not improved under B and Zn nutrition (Table 1). Yet, application of foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage produced higher biological yield (BY) 21.23 t ha^{-1} (Table 2) and shelling percentage 71.13% (Table 1). While, BY of foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage was statistically similar to all other treatments except control where BY was observed minimum. Application of foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage depicted more stem girth 1.60 cm (Table 1) and harvest index 42.61% (Table 2).

Application of foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage provided more number of grains per row 42.46 (Table 2) and plant height 231.00 cm (Table 1). However, statistically comparable values for these attributes were observed in 12 kg ha^{-1} soil applied Zn + 3 kg ha^{-1} soil applied B, foliar applied 0.5% B + foliar applied 1% Zn at 9 leaf stage, 3 kg ha^{-1} soil applied B and 12 kg ha^{-1} soil applied Zn. Relatively more cob length 22.60 cm (Table 1), 1000-grain weight (313.33 g) and grain yield 9.03 t

Table 1: *Effect of zinc and boron application methods on plant height, stem girth, cob length, number of cobs per plant cob girth and shelling percentage of maize*

Treatments	Plant height (cm)	Cob length (cm)	No. of cobs per plant	Cob girth (cm)	Stem girth (cm)	Shelling percentage (%)
C	214.67 b	19.66 d	1.40	5.0 e	1.23 b	65.20 b
Zn (S)	220.40 ab	20.76 c	1.46	5.26 d	1.33 b	69.50 a
B (S)	229.73a	21.73 ab	1.53	5.40 bc	1.36 ab	70.90 a
Zn (F)	223.00 ab	20.13 cd	1.46	5.36 bcd	1.40 ab	69.50 a
B (F)	215.27 b	20.80 bc	1.40	5.30 cd	1.36 ab	69.33 a
Zn (S) + B (S)	226.33 ab	22.00 a	1.46	5.46 ab	1.43 ab	70.00 a
Zn (F) + B (F)	231.00 a	22.60 a	1.60	5.56 a	1.60 a	71.13 a
LSD ≤ 0.05	13.559	0.116	NS	0.116	0.235	2.009

C = Control; Zn (S) = Soil applied Zn @ 12 kg ha^{-1}; B (S) = Soil applied B @ 3 kg ha^{-1}, Zn (F) = Foliar applied Zn @ 1% at 9th leaf stage, B (F) = Foliar applied B @ 0.5% at 9th leaf stage; Zn (F) + B (F) = Foliar application of 1% Zn + 0.5% B at 9th leaf stage; Zn (S) + B (S) = Soil application of Zn @ 12 kg ha^{-1} + B @ 3 kg ha^{-1}

Table 2: *Effect of zinc and boron application methods on yield and yield related attributes of maize*

Treatments	No. of grains per cob	No. of grains per row	1000-grain weight (g)	Grain yield t ha^{-1}	Biological yield (t ha^{-1})	Harvest index (%)
C	574.67 c	37.13 c	280.33 d	8.13 d	20.30 b	40.10 b
Zn (S)	604 b	41.13 ab	297.00 c	8.36 c	20.63 ab	40.55 b
B (S)	603.33 b	39.53 abc	307.00 ab	8.86 ab	22.26 a	41.69 ab
Zn (F)	605.33 b	39.03 cd	299.33 bc	8.73 bc	21.16 a	41.27 ab
B (F)	609.67 b	39.40 abc	286.33 d	8.54 d	20.93 ab	40.77 ab
Zn (S) + B (S)	616.67 ab	40.26 abc	304.67 abc	8.93 a	21.20 a	42.09 ab
Zn (F) + B (F)	62733 a	42.46 a	313.33 a	9.03 a	21.23 a	42.61 a
LSD ≤ 0.05	15.171	3.231	15.171	0.379	0.379	2.009

For treatment details, see Table 1.

ha^{-1} (Table 2) were manifested by foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage. Although, foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage was statistically analogous to 12 kg ha^{-1} soil applied Zn + 3 kg ha^{-1} soil applied B and 3 kg ha^{-1} soil applied B. Higher cob girth (55.56 cm) (Table 1) and number of grains per cob 627.33 (Table 2) were exhibited by foliar applied 0.5% B + foliar applied 1% Zn at 9th leaf stage. Though, statistically identical cob girth and number of grains per cob were manifested in 12 kg ha^{-1} soil applied Zn + 3 kg ha^{-1} soil applied B.

Application of foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage produced maximum benefit cost ratio and it was followed by foliar applied 1% Zn at 9th leaf stage and 3 kg ha^{-1} soil applied B (Table 3). However, marginal analysis depicted highest profit in foliar applied 1% Zn at 9th leaf stage (1596) and it was followed by foliar applied 1% Zn + foliar applied 0.5% B at 9th leaf stage (1235) and 12 kg ha^{-1} soil applied Zn + 3 kg ha^{-1} soil applied B (632) (Table 4).

Discussion

Boron and Zn mediated increment in plant height, stem girth and biological yield over control can be attributed to role of B and Zn in photosynthesis. Application of B and Zn might have activated enzymes and thereafter enhanced carbon fixation. Thus, improved photosynthesis under B and Zn nutrition might have promoted dry matter accumulation in vegetative parts. Moreover, B and Zn nutrition might have aggravated biosynthesis of indole-3- acetic acid (IAA) and subsequently of IAA improved stem height and biological yield. Indole-3- acetic acid might have caused acidification of cell wall. Henceforth, degradation of pectin and cellulosic fibers in cell wall ultimately enhanced plat height and biological yield. Likewise, Zn might have triggered activity of carbonic anhydrase. Consequently, carbonic anhydrase boosted bicarbonates availability for phosophoenol pyruvate and hence photosynthesis was increased. Moreover, B and Zn provoked enhancement in cob girth and 1000-grain weight established the role of B and Zn in activation of enzymes and photosynthesis. Application of Zn enhanced growth and yield of barley. Similarly, B application might promote radial cell division and hence improved stem girth over control. Furthermore, B mediated radial cell division was also confirmed from B mediated increment in cob girth.

Table 3: *Effect of zinc and boron application methods on the economic analysis of maize*

Treatments	Grain Yield (t ha^{-1})	Value (Rs. ha^{-1})	Straw yield (t ha^{-1})	Value (Rs. ha^{-1})	Gross Income (Rs. ha^{-1})	Variable cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	Benefit cost ratio
C	8.13	203250	12.16	12167	215417	000	95959	119458	2.24
Zn (S)	8.36	209000	12.26	12267	221267	2800	98759	122508	2.24
B (S)	8.86	221500	12.40	12400	233900	2350	98309	135591	2..37
Zn (F)	8.73	218250	12.43	12433	230683	900	96859	133824	2.38
B (F)	8.54	213500	12.40	12400	225900	1212	97171	128729	2.32
Zn (S) + B (S)	8.93	223250	12.30	12300	235550	4750	100709	134841	2.33
Zn (F) + B (F)	9.03	225750	12.16	12167	237917	2112	98071	139846	2.42

For treatment details, see Table 1.

Table 4: *Effect of zinc and boron application methods on marginal analysis*

Treatments	Gross income (Rs. ha^{-1})	Variable cost (Rs. ha^{-1})	Marginal cost (Rs. ha^{-1})	Net field benefits (Rs. ha^{-1})	Marginal net benefit (Rs. ha^{-1})	MRR (%)
C	215417	0	-	215417	-	-
Zn (F)	230683	900	900	229783	14366	1596
B (F)	225900	1212	312	224688 D	D	D
Zn (F) + B (F)	237917	2112	900	235805	11117	1235
B (S)	233900	2350	238	231550 D	D	D
Zn (S)	221267	2800	450	218467 D	D	D
Zn (S) + B (S)	235550	4750	1950	230800	12333	632

For treatment details, see Table 1.

Increment in yield was consequence of Zn mediated incline in phloem translocation rates and photosynthesis (Sadeghzadeh et al., 2106). Zinc application augmented the photosynthetic activity and dry matter accumulation of maize. Enhancement in activity of photosynthesis was an outcome of boost in carbonic anhydrase activity (Soltangheisi et al., 2014). Likewise, B application enhances biomass accumulation of plant. Green leaf area was enhanced under B nutrition and thus higher assimilates were available for improving attributes related to biomass accumulation (Wang et al., 2015).

Comparatively more cob length and cob girth than control can be divulged in context of B and Zn activated enzymes involved in photosynthesis. Boron and Zn application might upsurge cofactors for enzymatic activation. Consequently, photosynthesis might have enhanced in plants applied with Zn and B treatments over their control. Thereafter, inclined partitioning towards reproductive parts might have improved cob length and girth. Moreover, excessive availability of B and Zn might have enhanced translocation from source organs to sink organs of plants. Furthermore, B and Zn incited photosynthtases translocation was affirmed increment of biological yield and plant height. Since, B and Zn improved plant height and biological yield, so increased cob girth and length might augment assimilate partitioning to cob. Therefore, cob length and cob girth was enhanced under B and Zn nutrition over control. Besides, augmentation in cob length and girth can also be designated to B and Zn triggered number of grains per cob and per row. Increment in carbohydrates partitioning to grains might exert positive influence on cob length and girth. Enhancement in cob girth and length was resultant of raise of assimilate partitioning under B and Zn nutrition. Application of Zn and B improved vegetative growth and leaf area. Ultimately, B and Zn triggered photosynthetic area enhanced yield of maize (Fountain et al., 2015). Application of Zn enhanced yield, growth and nutrient accumulation capability of maize (Manzeke et al., 2014).

Non-significant changes in number of cobs per plant can attributed to genetic potential of plant. Since same genotype was used in all treatments so varying environmental conditions did not alter number of cobs per plant significantly. Whereas, improvement of yield components grain yield, shelling percentage, number of grains per cob and per row, 1000-grain weight and harvest index) under B and Zn application over control can be defined in terms of B and Zn triggered activation of numerous enzymes.. Subsequently, higher carboxy peptidase might maintain adequate carbohydrate availability by catalyzing irreversible reactions in glycolysis. Ultimately, sufficient carbohydrates partitioning towards grains improved grain yield. Moreover, Zn availability might have triggered activities of pyrophosphates over control. Subsequently, pyrophosphates might increase energy availability for enzymatic reactions and hence improved carbon fixation. Additionally, enzymatic catalyzed increment in shelling percentage expressed B and Zn role in improvement of maize yield. Moreover, Zn and B mediated increase in IAA activity might enhance green area. Different rates of Zn improved various yield, growth components and biomass accumulating attributes of maize. Improved yield and growth attributes were consequence of Zn triggered enzymes and carboxylation (Jiang et al., 2013). Soil applied Zn improved photosynthetic green leaf area of maize and ultimately boosted yield components (Eteng et al., 2014). Likewise, exogenous application of zinc sulfate aggravated carbohydrate supply to sink organ. Enhanced carbohydrate was consequence of increased sucrose synthase and sorbitol dehydrogenase activity (Zhang et al., 2016). Likewise, B application enhanced membrane stability of wheat. Increased stability was result of B mediated negative regulation of NADH-oxidase activity (Masood et al., 2012). Application of B enhanced phloem translocation rate from pre-anthesis stored reserves of stems. Consequently, yield and quality of sunflower was enhanced under B application over no B nutrition (Saleem et al., 2016).

Improvement of yield and growth was more remarkable under foliar applied B and Zn than soil application can be elucidated in context of secondary active transport of B and Zn from soil (Shukla et al., 2014). Utilization of ATPs from plant metabolism might decline nutrient uptake from soil medium (Kaur and Nelson, 2015). Contrarily, foliar applied nutrients might have absorbed without utilization of ATPs through passive transport from leaf plasmodesmata pores that extend from leaf cuticle to phloem (Davarpanah et al., 2016). Hence, improvement in yield contributing attributes were more pronouncing than soil application. Moreover, alkaline calcareous soils of Pakistan coupled with low organic matter might have aggravated B and Zn fixation (Joy et al., 2016). Therefore, B and Zn availability might decline from soil solution than from foliar application (Uraguchi et al., 2014). Foliar applied micronutrients enhanced yield by 61% while soil applied micronutrients boosted yield only by 36% (Zhao et al., 2014).

More marginal rate of return under foliar application of Zn alone and Zn and B together can be attributed cation form of Zn that is absorbed by plants. Since cations are easily absorbed when foliar applied than anions. Whereas, borate being negatively charged ions might have not taken up by plant in quantity sufficient to improve yield components. Higher uptake of cations over anions during foliar application might have enhanced negative charge density in leaf cross section. Therefore, continuously increasing negatively charged hydroxyl ions density from leaf cuticle to phloem might have aggravated repulsive forces for borate anions. Hence, alone B foliar application aggravated wastage and thus cost was enhanced. Contrarily, enhancing negative charged density in leaf cross section might attract cations more strongly. Whereas, more marginal rate of return in case of foliar applied nutrients can ascribed to passive transport of nutrients in foliar application. While, alkaline calcareous soil conditions with lesser organic matter might did not improved plant nutrient status upto sufficient level to improve growth and yield components. Foliar applied micronutrients depicted more promising results than soil applied micronutrients. Additionally, foliar application of cationic nutrients produced more promising results than foliar application of anionic nutrients regarding yield enhancement (Bybordi, 2014).

Conclusion

Foliar application of 1% Zn + foliar application of 0.5% B at 9th leaf stage also depicted more pronouncing results regarding profit, yield and growth of maize crop than other treatments and it was closely followed by soil application of Zn @ 12 kg ha^{-1} + soil application of B @ of 3 kg ha^{-1} for growth yield and yield attributes and marginal rate of return declined. Alone soil or foliar B application and soil application of Zn aggravated nutrient loss and enhanced cost of production.

Authors Contribution

SAA and MFS designed the experiments. MS peovided experimental inputs. AF collected data and performed the experiments. AS and AF wrote the manuscript and MS helped them. IK, IA and UN provided technical input in data entry and analysis

Acknowledgements

We applaud the services provided by Agro-Biology Laboratory, Department of Agronomy, University of Agriculture Faisalabad, Pakistan to complete this research work.

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