International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(1): 587-592
© 2018 IJCS
Received: 18-11-2017
Accepted: 21-12-2017

Direct and residual effect of zinc and boron on growth parameters of rice and wheat grown in sequence in red and alluvial soils of eastern Uttar Pradesh

Achin Kumar and AP Singh

Achin Kumar
Department of Soil Science & Agricultural Chemistry, Institute of Agricultural Sciences Banaras Hindu University, Varanasi, U.P, India

AP Singh
Department of Soil Science & Agricultural Chemistry, Institute of Agricultural Sciences Banaras Hindu University, Varanasi, U.P, India

Correspondence
Achin Kumar
Department of Soil Science & Agricultural Chemistry, Institute of Agricultural Sciences Banaras Hindu University, Varanasi, U.P, India

Abstract

A pot experiment was conducted in net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during *kharif* 2014 and *rabi* 2014-15 to evaluate the direct effect of zinc (Zn) and boron (B) fertilizers on plant growth parameters of rice and their residual effect on subsequent wheat crop grown in red and alluvial soils. Four levels of Zn equivalent to 0, 1, 2 and 4 mg kg^{-1} soil and four levels of B equivalent to 0, 0.5, 1 and 2 mg kg^{-1} soil were applied in combinations as treatments in a factorial completely randomized design (FCRD) with three replications. The result showed that among the levels of zinc the direct application of 4 mg Zn kg^{-1} soil along with RDF to rice was most beneficial and brought highest improvement in growth parameters and similarly on succeeding wheat crop also in both the soils. Among the levels of boron the direct application of 1 mg B kg^{-1} soil along with RDF recorded highest improvement in growth parameters of rice and 2 mg B kg^{-1} soil in succeeding wheat crop. However the combined application of Zn and B was found non-significant of rice and succeeding wheat crops in red and alluvial soils of the study area.

Keywords: zinc, boron, growth characters, cropping sequence, rice-wheat

Introduction

With the demand of ever-increasing population, the present day agriculture has become more intensive and has resulted in mining of available nutrients including micronutrients from soil over years. Proper nutrition of plants with micronutrients depends on many factors. These factors include the ability of soil to supply these nutrients, rate of absorption of nutrients by the plants, distribution of nutrients to functional sites and nutrient mobility within the plant. Micronutrient deficiency in soil including that of Zn and B is quite widespread in Asian countries including India due to prevalent soil and environmental conditions.

Due to widespread deficiencies of zinc and boron in soils of Uttar Pradesh and their direct influence on the growth and yield of cereals and other crops, importance of both the nutrients has increased considerably. Deficiencies of B and Zn emerge because of intensive cropping, use of high analysis fertilizers and adoption of high yielding varieties (Rashid and Fox, 1992; Rafique *et al*., 2006) [35, 33]. Boron is involved in many biochemical and physiochemical processes for optimal plant growth and its requirement vary markedly with crop plants (Gupta, 1993; Shelp, 1993) [10, 39]. Zinc is involved in several enzymatic and metabolic processes (Marschner, 1995). The deficiency of zinc is well documented in flooded rice soils (Yoshida and Tanaka, 1969) [45]. Rice–wheat cropping system (RWCS) is a major cropping system contributing one third of cereal production in the country. However, the system is not sustainable due to the decline in soil fertility and also in organic matter. The factor productivity of fertilizers has also decreased leading to higher requirement of plant nutrients to be applied to obtain the same yield.

Interactions occur among the micronutrients and also with some macronutrients and have profound effect on crop yield. Interaction is an influence, a mutual or reciprocal action, of one element upon another in relation to plant growth. Thus, the two elements combine to produce an added effect when they are applied simultaneously which is not obtained due to one of them alone (Olsen, 1972). Such interaction may take place in the soil and also within the plant. These interactions should be taken into account while formulating recommendation for ensuring adequate micronutrient supply to plant. Growth attributes viz. plant height and chlorophyll content (SPAD value) were significantly affected by the treatments consisting of Zn and B alone as well as their combinations. Plant height is one of the important characteristics which serve as an indicator of the vegetative growth potential of a crop and is both genetically and environmentally determined and is linked to nutrient absorption capacity as well as health of the plants. A healthy plant removes more amounts of nutrients from soil than weak plants and develops well and plant health is likely to be influenced by nutrient interaction. However, there are limited reports dealing with nature of Zn × B interaction in crop plants. Keeping these facts in view, an experiment was conducted to assess the individual and combined effect of boron and zinc on rice-wheat in terms of plant growth parameters and crop yield in red and alluvial soils of eastern Uttar Pradesh.

Materials and Methods

A pot experiment was conducted in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between $25^0 14'$ and $25^0 23'$N latitude and $82^0 56'$ and $83^0 30'$E longitude and falls in a semi-arid to sub humid climate. The red and alluvial soils were collected from Rajiv Gandhi South Campus (RGSC), Mirzapur and Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, respectively. The bulk soils were dried in air under shade and crushed with the help of wooden rod to pass through 2-mm sieve. 10 kg of both the soils was filled in polythene lined experimental pots. Soil samples were taken from each pot after completion of the pot experiment for the determination of physico-chemical properties of both the soils. The initial physico-chemical properties of experimental soils (table 2) were analysed by following standard laboratory methods (table 1).

Table 1: Analytical methods followed during investigation are as under.

Parameters	Procedures applied	References
pH (1:2.5)	Glass electrode (pH meter)	Jackson (1973) [16]
EC (1:2.5)	Conductivity meter	Jackson (1973) [16]
Texture	Hydrometer	Bouyoucos (1962)
Bulk density	Pycnometer method	Black (1965) [4]
Water holding capacity	Keen Rackzowski box	Black (1965) [4]
CEC	Neutral 1N NH_4OAC	Kanwar and Chopra (1988) [19]
Organic C	Titrimetric method	Walkley and Black (1934) [44]
Available nitrogen	Alkaline $KMnO_4$	Subbiah and Asija (1956) [43]
Available phosphorus	Bray's method for red soil	Bray and Kurtz (1945) [6]
	Olsen's Method for alluvial soil	Olsen *et al.* (1954) [29]
Available potassium	Flame photometer	Hanway and Heidel (1952) [11]
Available zinc	AAS in DTPA extract	Lindsay and Norvel (1978) [24]
Available boron	Azomethine-H by spectrophotometer	John *et al.* (1975) [18]

Table 2: Initial physicochemical properties of red and alluvial soils.

Properties	Red soil	Alluvial soil
Sand (%)	47.8	54.1
Silt (%)	27.3	25.4
Clay (%)	23.2	20.5
Texture	Sandy loam	Sandy clay loam
Water holding capacity (%)	34.6	42.13
CEC (Cmol (p^+) Kg^{-1})	15.8	20.1
Bulk density (g cm^{-3})	1.44	1.38
pH (1:2.5)	5.78	7.82
EC (1:2.5) (dSm^{-1})	0.12	0.16
Organic carbon (%)	0.24	0.32
Available nitrogen (kg ha^{-1})	154.3	162.6
Available phosphorus (kg ha^{-1})	18.4	21.5
Available potassium(kg ha^{-1})	285	234
Available zinc (mg kg^{-1})	0.62	0.68
Available boron (mg kg^{-1})	0.71	0.64

Four levels of Zn equivalent to 0, 1, 2 and 4 mg kg^{-1} soil and four levels of B equivalent to 0, 0.5, 1 and 2 mg kg^{-1} soil were applied through zinc sulphate and borax, respectively to rice crop (*kharif* 2014) and there residual effect was observed in succeeding wheat crop (*rabi* 2014-15) in a factorial completely randomized design (FCRD. The symbols used for each levels of zinc and boron are given below in table 3.

Table 3. Treatment details.

Levels of zinc (mg kg^{-1} soil)	Treatment symbols	Levels of boron (mg kg^{-1} soil)	Treatment symbols
0	Zn_0	0	B_0
1	Zn_1	0.5	$B_{0.5}$
2	Zn_2	1	B_1
4	Zn_4	2	B_2

The recommended doses of fertilizers (RDF) (N:P:K :: 60:40:30 mg kg^{-1}) were applied through urea, potassium dihydrogen phosphate and mureate of potash, respectively to all the pots and both the crops. The experiment was laid out in factorial completely randomized design (FCRD) with three replications. Rice (*Oryza sativa* L.) Cv. HUR-105 and wheat (*Triticum aestivum* L.) Cv. Malviya-234 were grown in the same pots. Wheat (*rabi* 2014-15) was taken as residual crop after harvesting of rice. The application of Zn and B fertilizers was done before transplantation of rice, and incorporated in the soil. Pots were irrigated as per requirement of the rice crop and continuous submerged condition was maintained up to the physiological maturity. Full dose of P, K, B and Zn and half of the recommended dose of N were applied at surface as basal and incorporated in the soil. The remaining half of the recommended dose of N was applied as top dressing at 30 and 60 days after transplantation/sowing and completion of the first weeding. The plant height was recorded at tillering, flowering and at maturity, whereas chlorophyll content (SPAD value) at tillering and flowering stages. All the data arising out of experiment were statistically analysed (Gomaz and Gomaz, 1984).

Results and Discussion

Plant height

Effect of zinc: The plant height showed a significant ($p < 0.05$) response to Zn fertilization along with RDF which increased with increasing Zn dose from 0 to 4 mg Zn kg^{-1} soil (Table 4). The plant height increased with advancement of the crop age. The highest values of plant height of rice were 83.47, 100.67 and 107.7 cm in red soil and 82.22, 99.11 and 106.23 cm in alluvial soil at tillering, flowering and maturity, respectively which were achieved with the application of 4 mg Zn kg^{-1} soil along with RDF. The respective increments were 6.4, 8.6 and 6.4% in red soil and 11.5, 10.9 and 11.7% in alluvial soil at tillering, flowering and at maturity stages over Zn_0 (control). Application of Zn_4 gave the highest plant height in both the soils which was followed by Zn_2 and Zn_1. Plant height of rice in red soil at tillering stage recorded with Zn_4 and Zn_2, remained statistically at par to each other. In wheat, the residual effect of Zn on plant height was showed significant ($p<0.05$) response along with a fresh dose of RDF (Table 4). The highest values of plant height of wheat were 30.53, 63.76 and 72.55 cm in red soil and 32.41, 65.83 and 79.08 cm in alluvial soil at tillering, flowering and maturity, respectively which were further achieved with the application of 4 mg Zn kg^{-1} soil in rice along with RDF. The respective increments were 14.8, 21.4 and 14.5% in red soil and 11.6, 17.4 and 14.8% in alluvial soil at tillering, flowering and at maturity stages, over Zn_0 (control). Application of Zn_4 gave the highest plant height in both the soils which was followed by the Zn_2 and Zn_1. Plant height of wheat at tillering stage recorded with Zn_4 and Zn_2, remained statistically at par to each other in both the soils. The increase in plant height might be due to role of Zn in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthetic towards them which resulted in better flowering and fruiting (Himanshu *et al*., 2013) [13]. The increase in plant height may be attributed to the adequate supply of zinc which could meet the enhanced Zn demand under appropriate fertilizer application. Similarly, Arya and Singh (2001) reported increase in plant height due to application of ZnSO4. Zinc being an important component of various enzymes and hormones, might have favoured increased synthesis of enzymes and hormones along with the metabolization of major nutrients which in turn promoted growth components. Several researchers showed that plant height increased significantly by application of Zn (Islam *et al*., 1999; Genc *et al.,* 2006 and Jain and Dahama, 2006) [15, 8, 17]. Flintham *et al.*, 1997 [7] reported that zinc application increased plant height and this correlated with the increase in grain yield. Above findings shown that plant height was greatly affected by Zn application. Increase in plant height due to increase in fertilizer dose might have been due to proper nutrient availability, which resulted in increase in vegetative growth of the plants. Kausar *et al.* (1993) [20]; Ayoub *et al.* (1994) [2] and Maqsood *et al.* (1999) [26] reported similar results.

Effect of boron: The plant height showed a significant ($p<0.05$) response to B fertilization along with RDF (Table 4). Plant height increased up to 1 mg B kg^{-1} soil which was applied to rice in rice-wheat sequence and beyond this level a decline in plant height was recorded which was possibly due to the toxic effect of B above 1.0 mg kg^{-1} soil. However, it was still higher than B_0. Application of higher dose of B gave higher response, but indiscriminate use of B may cause toxicity in plants and may also cause deleterious effect of growth of several crops (Kushwaha *et al.,* 1999) [23]. The middle rate of B concentration gave the highest plant height (Khalifa *et al*., 2009) [21]. Hosseini et al. (2007) [14] reported that high levels of B decreased plant height and dry matter production of corn (*Zea mays L.*). The highest values of plant height of rice were 82.43, 98.03 and 106.12 cm in red soil and 79.88, 95.63 and 104.39 cm in alluvial soil at tillering, flowering and maturity, respectively which were achieved with the application of 1 mg B kg^{-1} soil along with RDF. The respective increments were 1.8, 3 and 2.5% in red soil and 3.3, 4.2 and 5% in alluvial soil at tillering, flowering and at maturity stages, over B_0 (control). Tr of B_1 gave the highest plant height in both the soils which was followed by the treatment $B_{0.5}$ and B_2. Plant height of rice recorded with B_1 and $B_{0.5}$, at tillering and maturity stage in red soil and at tillering stage in alluvial soil, remained statistically at par to each other. The presented results are similar with the findings of BINA (1993) who reported that plant height varied significantly by application of 1 kg B ha^{-1}. In wheat, the residual effect of B on plant height was showed significant ($p<0.05$) response along with a fresh dose of RDF (Table 4). The highest values of plant height of wheat were 30.24, 60.10 and 69.97 cm in red soil and 31.76, 63.08 and 76.74 cm in alluvial soil at tillering, flowering and maturity, respectively which were achieved with the application of 2.0 mg B kg^{-1} soil along with a fresh dose of RDF, which was applied to rice in rice-wheat sequence. The respective increments were 10.9, 8.3 and 6.5% in red soil and 5.9, 6.6 and 6.5% in alluvial soil at tillering, flowering and at maturity stages, over B_0 (control). Application of 2.0 mg B kg^{-1} soil gave the highest plant height in both the soils which was followed by B_1 and $B_{0.5}$. Plant height of wheat recorded with B_2 and B_1, at tillering stage in red soil and all growth stages in alluvial soil, remained statistically at par to each other. Soylu *et al.* (2004) [41] and Soylu *et al.* (2005) [41] reported that B application considerably improved the growth and yield parameters of wheat. Many studies had reported a significant increase in plant height (Pradhan and Sarkar, 1993; Rana *et al.*, 2005 and Patel and Ghosh, 2013) [30]. The reasons for increase in plant heights may be attributed to better plant nutrition and balanced interaction among all macro and micronutrients, which may result into better plant growth in terms of plant height. Furthermore, growth inhibition with B deficiency might be due to impairment of plasma membrane functions by reactive quinines or decreased levels of diffusible auxins (IAA), caused by enhanced IAA oxidise activity. The inhibition of growth of the plant in boron deficiency has been attributed to the accumulation of phenolic compounds (Shkolnik, 1974) [40].

However, the interaction effect of Zn and B was found to be non-significant at all the stages in both the soils and both the crops (Table 4).

Chlorophyll content (SPAD Value)

Chlorophyll is one of the major components of plants for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate. The chlorophyll contents in plants may increases or decreases by the effects of micronutrients level in plant and soil (Manivasgaperumal *et* *al.*, 2011) [25]. Combination of B and Zn might have boosted the vegetative growth. Chlorophyll synthesis in plants is directly related to the availability of physiologically active micronutrients in plant available form (Kumar *et al.*, 2011) [22]. Muhammad *et al.* (2012) [28] revealed that the chlorophyll contents of rice plant increased significantly with the application of B and Zn as compared to the control.

Effect of zinc: The SPAD value showed a significant (p<0.05) response to Zn fertilization along with RDF (Table 5) which increased with increasing Zn dose from 0 to 4 mg Zn kg^{-1} soil. The SPAD value increased with progressive application of zinc. The highest SPAD value of rice were 29.21 and 35.75 in red soil and 29.22 and 36.31 in alluvial soil at tillering and flowering, respectively which were achieved with the application of 4 mg Zn kg^{-1} soil along with RDF. The respective increments were 22.1 and 19.3% in red and 15.7 and 19.9%) in alluvial soil at tillering and flowering stages, over Zn_0 (control). Application of Zn_4 gave the maximum SPAD value in both the soils which was followed by Zn_2 and Zn_1. In wheat, the residual effect of Zn on SPAD value was showed significant (p<0.05) response along with a fresh dose of RDF (Table 5). The highest SPAD value of wheat were 33.31 and 40.29 in red soil and 35.68 and 43.58 in alluvial soil at tillering and flowering, respectively which were further achieved with the application of 4 mg Zn kg^{-1} soil in rice along with RDF. The respective increments were 17.5 and 27.17% in red soil and 13.6 and 19.5% in alluvial soil at tillering and flowering stages, over Zn_0 (control). Application of Zn_4 gave the highest SPAD value in both the soils which was followed by Zn_2 and $Zn_{1.}$ The increase in SPAD value may be attributed to the adequate supply of zinc which could meet the enhanced Zn demand under appropriate fertilizer application. Zinc being an important component of various enzymes and hormones, might have favoured increased synthesis of enzymes and hormones along with the metabolization of major nutrients which in turn promoted growth components. Several researchers showed that SPAD value has increased significantly by application of Zn (Islam *et al.*, 1999; Genc *et al.*, 2006 and Jain and Dahama, 2006) [15, 8, 17].

Effect of boron: The SPAD value showed a significant (p<0.05) response to B fertilization along with RDF (Table 5) which increased up to 1 mg B kg^{-1} soil which was applied to rice in rice-wheat sequence and beyond this level a decline in SPAD value was recorded which was possibly due to the toxic effect of B above 1.0 mg kg^{-1} soil. However, it was still higher than B_0. The highest SPAD value of rice were 27.02 and 33.98 in red soil and 28,25 and 35.02 in alluvial soil at tilleringand flowering, respectively which were achieved with the application of 1 mg B kg^{-1} soil along with RDF. The respective increment were 4.6% at tillering and non-significant at flowering stage in red soil and 5.5 and 6.4% in alluvial soil at tillering and flowering stage respectively, over B_0 (control). SPAD value of rice received B_1 and $B_{0.5,}$ in red soil at tillering stage and in alluvial soil at both stage, remained statistically at par to each other. In wheat, the residual effect of B on SPAD value was showed significant (p<0.05) response along with a fresh dose of RDF (Table 5). The highest SPAD value of wheat were 32.10 and 37.56 in red soil and 34.64 and 41.60 in alluvial soil at tillering and flowering, respectively which were achieved with the application of 2.0 mg B kg^{-1} soil along with a fresh dose of RDF, which was applied to rice in rice-wheat sequence. The respective increments were 5.8 and 8.3% in red soil and 6.1 and 6.1% in alluvial soil at tillering and flowering stages, over B_0 (control). Application of 2.0 mg B kg^{-1} soil gave the highest SPAD value in both the soils which was followed by B_1 and $B_{0.5}$. SPAD value of wheat recorded with B_2 and $B_{1,}$ in red soil at both stage and in alluvial soil at flowering stage, remained statistically at par to each other. The improvement in growth attributes as a result of B application may be due to the enhanced photosynthetic and metabolic activity which leads to an increase in various plant metabolic pathways responsible for cell division and elongation (Hatwar *et al.*, 2003) [12] because the chlorophyll contents increased considerably in Zn and B treated plants. The photosynthesis enhanced in the presence of B indicates that it helps to activate the synthesis of tryptophan and precursor of indole acetic acid (IAA) which is responsible for stimulation of plant growth and accumulation of biomass. The micronutrient being a component of ferrodoxin and electron transport are also associated with chloroplast. The acceleration in photosynthesis is evident for better vegetative growth (Patil *et al.*, 2008) [31].

However, the interaction effect of Zn with B was found to be non-significant at both the stages in both the soils (Table 5). SPAD value gradually increased with increasing dose of Zn and B, which might be attributed to greater photosynthetic activity and chlorophyll synthesis due to zinc and boron fertilization resulting into better vegetative growth. Salet *et al.* (1990) [36] and Shaaban *et al.* (2004) [21] also reported similar results. Zinc deficiency enhanced B concentration in younger and older leaves, indicating thereby an antagonistic relationship between them. Hatwar *et al.* (2003) [12] reported that the chlorophyll content increased considerably in Zn and B treated group of plants.

Conclusion

This study examined the application of Zn and B that had positive effect on growth parameters and boosted the vegetative growth of rice and wheat in both the soils. The result showed that among the levels of zinc the direct application of 4 mg Zn kg^{-1} soil along with RDF to rice was most beneficial and brought highest improvement in growth parameters and similarly on succeeding wheat crop also in both the soils. High dose of Zn could be even more beneficial. Among the levels of boron the direct application of 1 mg B kg^{-1} soil along with RDF recorded highest improvement in growth parameters of rice and 2 mg B kg^{-1} soil of succeeding wheat crop. However the combined application of Zn and B was found non-significant on growth parameters of rice and succeeding wheat crops in both the soils of the study area. The application of Zinc and boron in either way increased the growth parameters of rice and wheat over control, which showed the response of rice and wheat to zinc and boron. However, the responses of different crops to multiple nutrient combinations are required to be studied in long term basis for better understanding of the nutrient dynamics in red and alluvial soils of eastern U.P., India.

Acknowledgements

I would like to gratefully acknowledge to the Ministry of Science and Technology, Department of Science and Technology (DST-INSPIRE) for financial assistance.

Table 4: Effect of Zn and B application on plant height (cm) of rice - wheat sequence in red and alluvial soils

Treatments	Red soil						Alluvial soil					
	Rice			Wheat			Rice			Wheat		
	Tillering	Flowering	Maturity	Tillering	Flowering	Maturity	Tillering	Flowering	Maturity	Tillering	Flowering	Maturity
Factor I Zinc (mg kg^{-1})												
Zn_0	78.43	92.67	101.24	26.60	52.53	63.37	73.70	88.23	95.11	29.03	56.04	68.90
Zn_1	81.84	95.01	104.15	28.71	56.26	66.02	77.85	91.41	101.08	30.74	59.90	74.12
Zn_2	82.82	97.96	106.35	29.62	59.66	69.31	80.50	95.38	104.66	31.55	63.28	76.92
Zn_4	83.47	100.67	107.70	30.53	63.76	72.55	82.22	99.11	106.23	32.41	65.83	79.08
SEm±	0.26	0.34	0.39	0.34	0.28	0.34	0.37	0.51	0.49	0.30	0.40	0.49
LSD (p = 0.05)	0.74	0.99	1.13	0.99	0.81	0.98	1.06	1.47	1.42	0.86	1.14	1.40
Factor II Boron (mg kg^{-1})												
B_0	80.98	95.13	103.47	27.26	55.49	65.70	77.35	91.72	99.37	29.99	59.14	72.02
$B_{0.5}$	82.08	97.00	105.59	28.53	57.65	67.13	79.51	93.78	102.34	30.73	60.88	74.52
B_1	82.43	98.03	106.12	29.43	58.97	68.44	79.88	95.63	104.39	31.25	61.94	75.74
B_2	81.08	96.15	104.27	30.24	60.10	69.97	77.53	93.01	100.98	31.76	63.08	76.74
SEm±	0.26	0.34	0.39	0.34	0.28	0.34	0.37	0.51	0.49	0.30	0.40	0.49
LSD (p = 0.05)	0.74	0.99	1.13	0.99	0.81	0.98	1.06	1.47	1.42	0.86	1.14	1.40
Zn × B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Effect of Zn and B application on chlorophyll content (SPAD Value) of rice - wheat sequence in red and alluvial soils

Treatments	SPAD Value in Red soil				SPAD Value in Alluvial soil			
	Rice		Wheat		Rice		Wheat	
	Tillering	Flowering	Tillering	Flowering	Tillering	Flowering	Tillering	Flowering
Factor I Zinc (mg kg^{-1})								
Zn_0	23.91	29.97	28.35	31.68	25.26	30.28	31.40	36.46
Zn_1	25.32	33.33	30.95	35.25	26.94	33.52	33.20	39.84
Zn_2	26.82	34.58	32.45	37.95	28.11	35.04	34.19	41.86
Zn_4	29.21	35.75	33.31	40.29	29.22	36.31	35.68	43.58
SEm±	0.25	0.31	0.24	0.22	0.28	0.33	0.22	0.42
LSD (p = 0.05)	0.73	0.90	0.70	0.63	0.82	0.95	0.64	1.21
Factor II Boron (mg kg^{-1})								
B_0	25.84	32.80	30.33	34.68	26.77	32.91	32.63	39.19
$B_{0.5}$	26.52	33.63	31.00	35.92	27.59	34.18	33.38	40.06
B_1	27.02	33.98	31.62	37.01	28.25	35.02	33.80	40.88
B_2	25.88	33.22	32.10	37.56	26.91	33.05	34.64	41.60
SEm±	0.25	0.31	0.24	0.22	0.28	0.33	0.22	0.42
LSD (p = 0.05)	0.73	NS	0.70	0.63	0.82	0.95	0.64	1.21
Zn × B	NS	NS	NS	NS	NS	NS	NS	NS

References

1. Arya KC, Singh SN. Productivity of maize (Zea mays) as influenced by different levels of phosphours, zinc and irrigation. Indian Journal of Agricultural Sciences. 2001; 71(1):57-59.
2. Ayoub M, Guertin S, Lussier S, Smith DL. Timing and level of nitrogen fertility effects on spring wheat yield in eastern Canada. Crop Science. 1994; 34:748-756.
3. BINA (Bangladesh Institute of Nuclear Agriculture). Effect of different levels of boron application on the growth and yield of wheat. Ann. Rep. (1991-92). Bangladesh Inst. Nuclear Agric., Mymensingh. 1993; 159.
4. Black CA. Methods of Soil Analysis: Part I Physical and Mineralogical properties. American Society of Agronomy Madison, Wisconsin, USA.1965
5. Boyoucous G J. Hydrometer method improved for making particle size analysis of soils. Agronomy Journal. 1962; 54:464-465.
6. Bray RH, Kurtz LT. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 1945; 59:39-45.
7. Flintham JE, Borner A, Worland AJ, Gale MD. Optimising wheat grain yield: effects of Rht (gibberellin-insensitive) dwarfing genes. J Agric. Sci. 1997; 128:11-25.
8. Genc Y, McDonald GK, Graham RD. Contribution of different mechanisms to zinc efficiency in bread wheat during early vegetative stage. Plant and Soil. 2006; 281:353-367.
9. Gomez KA, Gomez AA. Statistical procedures for agriculture research. Wiley Press, New York, 1984.
10. Gupta UC. Boron and its role in crop production. CRC Press, Boca Raton, FL. USA. system. International, J. Agric. Biol. 1993; 8(6):805-808.
11. Hanway, J, Heidal HS. Soil analysis and methods used in Iowa State College Soil Testing Lab, Iow a Agriculture. 1969; 57:1-31.
12. Hatwar GP, Gondane SV, Urkude SM. Effect of micronutrients on growth and yield of chilli. Soil Crop, 2003; 13:123-1254.
13. Himanshu, Ali Javed, Singh SP, Singh Sandeep. Response of fababean to boron, zinc and sulphur spplication in alluvial soil. Journal of the Indian Society of Soil Science. 2013; 61(3):202-206
14. Hosseini SM, Maftoun M, Karimian N, Ronaghi A, Emam Y. effect of zinc × boron interaction on plant growth and tissue nutrient concentration of corn. Journal of Plant Nutrition. 2007; 30(5):773-781.

15. Islam MR, Islam MS, Jahirhuddin M, Hoque MS. Effect of sulphur, zinc and boron on yield, yield components and nutrients uptake of wheat. Pakistan J. Sci. And Ind. Res. 1999; 42(3):137-140.
16. Jackson ML. Soil chemical analysis.prentice Hall of India, pvt. Ltd. New Delhi. 1967; 498.
17. Jain NK, Dahama AK. Direct and residual effects of phosphorus and zinc fertilization on productivity of wheat (Triticum aestivum)-pearl millet (Pennisetum glaucum) cropping system. College of Agriculture, Rajasthan Agricultural University, Bikaner 334 006, India. New Delhi, India: Indian Society of Agronomy. Indian J Agronomy. 2006; 51(3):165-169.
18. John MK, Chuah HH, Neufeld JH. Application of improved azomethine-H method to the determination of boron in soils and plants. Analytical Letters. 1975; 8:559-568.
19. Kanwar JS, Chopra SL. Analytical agricultural chemistry, Kalyani publishers, New Delhi India, 1982.
20. Kausar K, Akbar M, Rasul M, Ahmad AN. Physiological response of nitrogen, phosphorus and potassium on growth and yield of wheat, Pakistan Journal of Agricultural Research. 1993; 14:126-130.
21. Khalifa RKHM, Shaaban SHA, Rawia A. Effect of foliar application of zinc sulphate and boric acid on growth, yield and chemical constituents of IRIS plants. Ozean J. Applied Sciences. 2009; 4(2):132.
22. Kumar A, Sharma KD, Gera R. Arbuscular mycorrhizae (Glomus mosseae) symbiosis for increasing the yield and quality of wheat (Triticum aestivum). Indian J. Agric. Sci. 2011; 81:478-480.
23. Kushwaha BL. Studies on response of fenchbean to zinc, boron and molybdenum application. Indian J Pulses Res. 1999; 12:44-48.
24. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Am. J. 1978; 42:421-428.
25. Manivasgaperumal RS, Balamurugan G, Thiyagarjan, Sekar J. Effect of Zinc on Germination, Seedling growth and Biochemical Content of Cluster Bean (Cyamopsis tetragonoloba (L.) Taub). Current Botany. 2011; 2(5):11-15.
26. Maqsood M, Akbar M, Yousaf N, Mehmood MT, Ahmad S. Effect of different rate of N, P and K combinations on yield and components of yield of wheat. Int. J. Agri. Biol. 1999; 1:359-361.
27. Marschner H. Mineral Nutrition of Higher Plants. 2nd ed. Academic Press London, 1995.
28. Muhammad Arif, Muhammad Asif Shehzad, Fiaz Bashir, Muhammad Tasneem, Ghulam Yasin, Munawar Iqbal. Boron, zinc and microtone effects on growth, chlorophyll contents and yield attributes in rice (Oryza sativa L.) cultivar. African Journal of Biotechnology. 2012; 11(48):10851-10858.
29. Olsen SR, Cole CV, Watanable FS, Dean LA. Estimation of Available Phos-phorus in Soils by Extraction with Sodium Bicarbonate. USDA Circular. 1954; 939.
30. Patel SK, Ghosh SKG. Effect of different levels of boron and sulphur on growth of chickpea with mustard intercropping system. Trends in Biosciences. 2013; 6(2):188-189.
31. Patil BC, Hosamani RM, Ajjappalavara PS. Effect of Foliar application of micronutrients on growth and yield components of tomato (Lycopersicon esculentum Mill.), karnataka J Agric. Sci. 2008; 21:428-430.
32. Pradhan AC, Sarkar SK. Growth and yield of rape-seed mustard varieties as influenced by sulphur and boron application, Indian Agriculturist. 1993; 37(1):21-26.
33. Rafique E, Rashid A, Ryan J, Bhatti AU. Zinc deficiency in rainfed wheat in Pakistan: magnitude, spatial variability, management, and plant analysis diagnostic norms. Commun. Soil Sci. Plant Anal. 2006; 37:181-197.
34. Rana KS, Rana DS, Gautam RC. Influence of phosphorus, sulphur and boron on growth, yield, nutrient uptake and economics of Indian mustard (Brassica juncea) under rainfed conditions, Indian Journal of Agronomy. 2005; 50(4):314-316.
35. Rashid A, Fox RL. Evaluating internal zinc requirements of grain crops by seed analysis. Agron. J. 1992; 84:469-474.
36. Salet RL, Aude MI, da S, Santos OS. Response of wheat to seed treatments with zinc and boron. Revista do seed treatments Rurais, Universidade Federal de Santa Maria. 1990; 20(1-2):89-99.
37. Shaaban MM, El-Fouly MM, Abdel-Maguid AWA. Zinc-boron relationship in wheat plants grown under low or high levels of calcium carbonate in the soil. Pakistan Journal of Biological Sciences. 2004; 7(4):633-639.
38. Sharma PN, Kumar N, Bisht SS. Effect of zinc deficiency on chlorophyll contents, photosynthesis and water relations of cauliflower plants. Photosynthetica. 1994; 30:353-359.
39. Shelp BJ. Physiology and Biochemistry of Boron in Plants. 1993; 53-85.
40. Shkolnik MY. General conception of the physiological role of boron in plants, Fiziol. Rast. 1974; 21:174-186.
41. Soylu S, Sade B, Topal A, Akgun N, Gezgin S. Responses of irrigated durum and bread wheat cultivars to boron application in a low boron calcareous soil. Turk. J. Agric. 2004; 29:275-286.
42. Soylu S, Sade B, Topal A, Akgun N, Gezgin S, Hakkiand EE, et al. Responses of irrigated durum and bread wheat cultivars to boron application in a low boron calcareous soil. Turkish J. Agri. Forest. 2005; 29(7): 657- 663.
43. Subbiah BV, Asija A. Rapid procedure for the determination of available nitrogen in soils, Current Sciences. 1956; 25:259-260.
44. Walkley A, Black CA. Estimation of organic carbon by chromic acid and titration method, Soil Science. 1934; 37:28-29.
45. Yoshida S, Tanaka A. Zinc deficiency of the rice plant in calcareous soils. Soil Sci. Plant Nut. 1969; 15:75-80.