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Soil Science

Response of Boron and Zinc Fertilization to Productivity of Rice in Piedmont Soil of Arunachal Pradesh

P. Debnath[1], S.K. Pattanaaik[1], D. Sah[1], A.K. Pandey[1], Debashish Sen[2*], G. Chandra[3] and S.K. Ghosh[4]

[1] College of Horticulture and Forestry, CAU, Pasighat- 791102, Arunachal Pradesh, India
[2] College of Agriculture Tripura, Lembuchera -799210, West Tripura, India
[3] Division of Forestry Statistics, ICFRE, Dehradun, Uttarakhand, India.
[4] Dept. of Agricultural Chemistry and Soil Science, BCKV, Mohanpur, West Bengal, India.

*Corresponding author: dr.d.sen@gmail.com

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Abstract

A field experiment was conducted in Piedmont plain soil of East Siang of Arunachal, India to predict the responses of rice (*Oryza sativa*) to different levels of boron (B) andzinc (Zn) application. The result showed significance increase in grain and straw yield due to B fertilization. The highest yield response to the tune of 39.25 q/ha grain and 41.25 q/ha straw was recorded with 15 kg level of borax per hectare. Percent increase of grain and straw yield due to 15 kg borax alone over control was found to be 24.52 % and 17.78 % respectively. The soil also showed positive response to different levels of Zn fertilization but maximum response was observedupto 20 kg $ZnSO_4$/ha. Boron and Zn interacted synergistically to boost yield of rice crop resulting in additional yield of 7.1 q/ha of grain and 6.28 q/ha of straw. The increased percent of grain and straw yield of rice with Zn and interaction between B × Zn were 24.87 %, 17.67 % and 47.04, 35.72 %, respectively. The boron concentration and uptake in grain and straw of rice also significantly increases with increase in level of borax upto 15 kg/ha and $ZnSO_4$ 10 kg/ha. However, a negative response was also observed in both grain and straw yield at level of 20kg/ha of borax and 30kg/ha of $ZnSO_4$.

Highlights:

- Physical and chemical properties of Piedmont plain soil of East Siang District, Arunachal Pradesh are presented.
- Significant increase in grain and straw yield was recorded due to B fertilization upto 15 kg of borax/hectare.
- Individual effect of B and Zn as well as interaction effect of B × Zn on grain and straw yield were recorded.
- Positive Correlation observed among grain and straw yield of rice with B concentration.

Keywords: Arunachal Pradesh, boron, piedmont soil, Rice, zinc

Rice (*Oryza sativa* L.) is a leading food grain crop and a staple food for half of the world's population and provides dietary energy and protein up to 2.5 billion people in the world. Rice provides 23% of the global human per capita energy and 16% of the per capita protein (IRRI, 1997). The productivity level in India is low (2.04 t/ha) as compared to Japan (6.25t/ha), China (6.24t/ha) and Indonesia (4.25t/ha). Rice is the major food grain for the tribal population of Arunachal Pradesh. But productivity of rice in this state is very low due to poor nutrient status of soil. Productivity of rice depends upon the adequate and balance amount of all essential nutrients including the micronutrients. The soils of Arunachal Pradesh are poor in macro and micronutrients due to continuous growing of crops in sloppy land without adequate application of fertilizer. The sloppy mountainous landform with high intensity rainfall often causes extensive soil erosion and heavy losses of plant nutrients by runoff/leaching. Moreover, farmers of the state having apathy to use fertilizer in their farming system. Hence, applicationof nutrients particularly micronutrient are of critical importance for sustaining high productivity of rice in Arunachal Pradesh.

Boron and zinc are the essential plant micronutrients and their importance for crop productivity is similar to that of major nutrients (Rattan *et al.* 2009; Padbhushan and Kumar, 2014). Widespread and extensive occurrence of B and Zn deficiency has been reported in the soils of low- land rice cultivation of India, Bangladesh, Pakistan, Philippines, Myanmar, Indonesia, Japan, Korea, Taiwan and Thailand (IRRI, 1997). Paddy soil conditions are usually not favorable for the availability of Zn and hence Zn deficiency has been reported countrywide in rice soils (Singh, 2001). It is therefore, imperative to apply Zn to such soils in addition to major nutrients for obtaining maximum yields. Application of Zn to soil is the most satisfactory way to cure Zn deficiency (Katyal and Agarwala, 1982). Zinc deficiency is the most common nutrient disorder constraining rice productivity

Table 1. Important physio-chemical properties of experimental soil

Sl. No	Properties	Value
1	pH	5.3
2	Organic carbon(g kg^{-1})	23.4
3	Sand (%)	62
4	Silt (%)	21
5	Clay (%)	17
6	Texture	Sandy loam
7	CEC C mol (p+)kg^{-1}	14.5
8	Available -N_2(mg kg^{-1})	151
9	Bray's-P(mg kg^{-1})	12.7
10	Available- K(mg kg^{-1})	74
11	Available B(mg kg^{-1})	0.36
12	DTPA-extractable Zn(mg kg^{-1})	0.78

Table 2. Effect of boron fertilization on yield, B concentration and boronuptake of grain and straw of rice

Level of B-fertilization (kg borax/ha)	Grain Yield			Straw yield		
	Yield (q/ha)	B concentration (mg kg^{-1})	B uptake (g/ha)	Yield (q/ha)	B concentration (mg kg^{-1})	B uptake (g/ha)
0	31.52	3.50	11.03	35.02	1.95	6.83
5	34.04	4.89	16.65	37.20	3.35	12.46
10	37.44	5.80	21.72	39.95	3.85	15.38
15	39.25	5.95	23.35	41.25	3.97	16.37
20	32.34	5.33	17.24	35.54	3.50	12.44
$LSD_{0.05}$ value	1.556	0.114	1.140	1.484	0.061	0.702

Table 3. Computed harvested index of rice influenced by different level of boron fertilization with and without of zinc fertilization

Level of borax applied(kg/ha)	Level of zinc fertilization(kg Zn SO_4/ha)			
	0	10	15	20
0	47.37	48.45	48.85	48.05
5	47.78	48.97	49.24	48.53
10	48.37	49.49	49.73	49.16
15	48.75	49.94	49.37	49.96
20	47.64	45.71	46.39	47.91

Table 5. Interaction effect of grain and straw yield on B concentration and uptake

Sl. No.	Interaction	r-value
1	Grain yield × B concentration	0.8020**
2	Grain yield × B uptake	0.9252**
3	Straw yield × B concentration	0.7676**
4	Straw yield × B uptake	0.8755**

Table 4. Effect of boron fertilization with and without of zinc fertilization on grain and straw yield, B concentration and uptake by rice

Level of B-fertilization (kg borax/ha)	Level of zinc fertilization(kg Zn SO_4/ha)											
	0			10			20			30		
	Yield (q/ha)	B - concentration (mg kg^{-1})	B - uptake (g/ha)	Yield (q/ha)	B concentration (mg kg^{-1})	B - uptake (g/ha)	Yield (q/ha)	B - concentration (mg kg^{-1})	B - uptake (kg/ha)	Yield (q/ha)	B - concentration (mg kg^{-1})	B - uptake (g/ha)
Grain Yield												
0	31.52	3.50	11.03	37.80	4.15	17.01	39.36	4.00	15.74	36.03	4.00	14.41
5	34.04	4.89	16.65	39.54	5.05	19.97	41.85	4.97	20.80	38.53	4.16	16.03
10	37.44	5.80	21.72	43.50	6.00	26.10	45.37	5.85	26.54	41.55	5.20	25.68
15	39.25	5.95	23.35	44.50	6.59	29.32	46.35	6.25	28.96	41.36	6.21	27.07
20	32.34	5.33	17.24	37.15	5.37	19.95	38.98	5.09	19.84	35.82	4.36	15.62
Straw yield												
0	35.02	1.95	6.83	40.21	2.43	9.77	41.21	2.42	9.97	38.95	2.40	9.35
5	37.20	3.35	12.46	41.19	3.60	14.83	43.14	3.46	14.93	40.86	3.00	12.26
10	39.95	3.85	15.38	44.38	4.02	17.84	45.85	3.90	17.88	42.96	3.25	13.96
15	41.25	3.97	16.37	45.52	4.20	19.11	47.53	3.90	18.53	41.42	3.42	14.23
20	35.54	3.50	12.44	44.12	3.70	16.32	45.03	3.62	16.30	38.93	3.00	11.68

$LSD_{0.05}$ value

	Yield		B -concentration		B -uptake	
	Grain	Straw	Grain	Straw	Grain	Straw
To compare the main effect of B	0.5933	0.6122	0.0345	0.0265	0.4007	0.3001
To compare the main effect of Zn	0.5933	0.6122	0.0345	0.0265	0.4007	0.3001
To compare the interaction effect of B x Zn	1.1860	1.2240	0.0694	0.0532	0.8001	0.5999

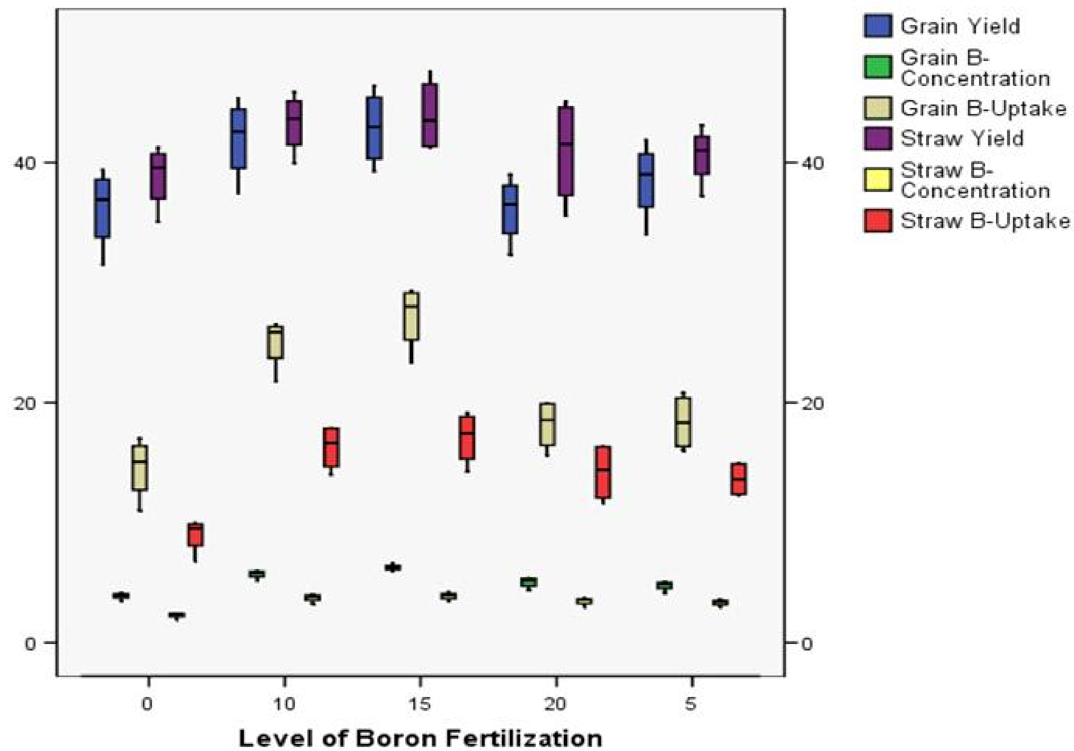

Fig. 1. Box plots for boron fertilization

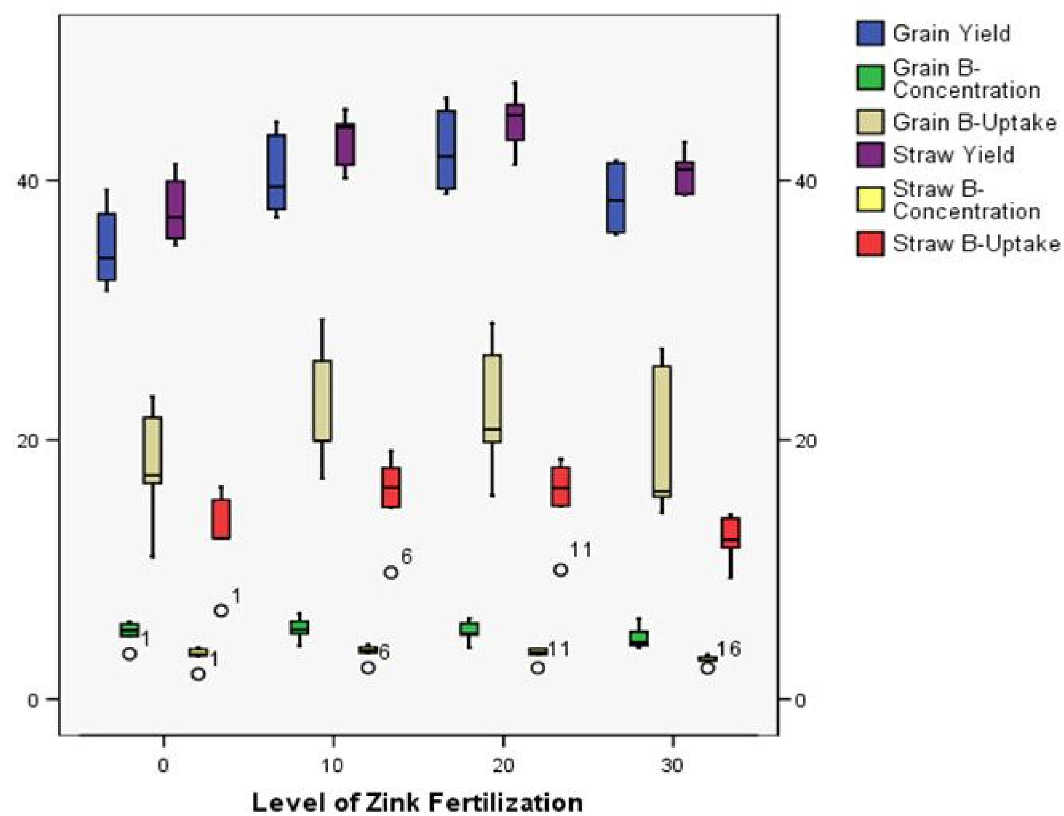

Fig. 2. Box plot for Zn fertilization

worldwide and is effectively controlled by field application of zinc sulphate (Rashid and Fox, 1996). Studies on B and Zn fertilizer proved that the application of B and Zn greatly influences growth, yield and quality of rice (Mahata *et al.* 2013; Raimani and Singh, 2015). The symptoms deficiency of B and Zn has been recorded on rice and other field crops including vegetables crops grown in Northern Hill region. In view of the role of micronutrients in present day agriculture, the study was therefore, being made to assess the level of Zn and B fertilization in rice growing soil of East Siang district of Arunachal Pradesh to get maximum increase in productivity of rice.

Materials and Methods

The field experiment was conducted to predict the responses of rice (Var.CAU R-1) to B in presence of Zn application at the research farm (28 07/ N Latitude and 95 33/E Longitude) of College of Horticulture and Forestry, Pasighat, Arunachal Pradesh, India during two consecutive years 2012 and 2013. The soil belongs to order Entisols .The collected soil sample was air dried, ground and passed through 2 mm size sieve for laboratory analysis. Particle size distribution was done by the standard Bouyoucos hydrometer method (Day, 1965). Soil pH was determined by glass electrode with calomel as standard (Jackson, 1973). Organic carbon was estimated by wet digestion method of Walkey and Black (Jackon, 1973). The cation exchange capacity was determined by leaching the soil with 1 N NH_4^+ OAC and subsequently displacing the adsorbed NH_4^+ methods of Schollenberger and Simon (Gupta, 2007). The available nitrogen, available potassium and Bray's P was determined by the standard methods described in Jackson (1973). The soils samples were extracted for available B by the method of Wear (1965). Activated charcoal was used so as to obtain colourless extract. Boron was estimated in clear filtrate colorimetrically using azomethine– H-method (Wolf, 1971). Available Zncontent of the soil samples were extracted with DTPA-TEA (pH 7.3) extractant following the method of Lindsay and Norvell (1978) and the concentration of Zn in the extracted solution were estimated with the help of Atomic Absorption Spectrophotometer (AAS).

The experiment was laid in symmetrical factorial experiment for studying the individual (main) effects of B fertilization (0, 5, 10, 15 and 20 kg borax/ha) and Zn fertilization (0, 10, 20 and 30 kg $ZnSO_4$/ha) and their interaction with net field size of 3mx2m. There were total 20 treatments and each treatment was replicated thrice in Randomized Block Designed (RBD). Recommended doses of nitrogen, phosphorus and potassium @ 80, 60 and 40 kg/ha N, P_2O_5 and K_2O, respectively were applied as reagent grade of Urea, Single supper phosphate and KCl. Borax and $ZnSO_4$ were applied at the levels corresponding to each treatments about 7 days after basal fertilization of NPK. Three 21 days old rice seedlings (variety CAU R-1)) were transplanted in each plot with 15cm x 15cm spacing in kharif season. Irrigation and intercultural operations like weeds control and plant protection measures were adopted uniformly in each plot as and when required.

Random samples of 5 whole plant from net area of each plot were harvested separately and sundried. Finally all the plants in each plot were harvested leaving half meter on each side for border effect. The weight of grain and straw from each plot were recorded for determination of yield per hectare of each component. The straw and grain samples of each pot were separately powdered in a warring stainless steel grinder. Dry powdered straw and grain samples were ashed in a muffle furnace at 600ºC and then ash was extracted in 10 ml 0.36 N H_2SO_4 for 1 hr at room temperature. The concentration of B was determined colorimetrically using azomethine– H-method (Gaines and Mitchell, 1979). The special advantages of the method of Gaines and Mitchell (1979) are that it is less time consuming with low interference of organic matter and more colour persistence. Treatment and replication wise data of grain and straw yield and B concentration of each plot were collected and two years pooled data were analysed statistically using the standard procedure described by Gomez and Gomez (1983).

Results and Discussion

Soil properties

The data of relevant physical and chemical properties of experimental field in Piedmont plain soil of East Siang of Arunachal Pradesh are presented in table 1. The data revealed that the texture of experimental soil is sandy loam. The soil had pH value 5.3 which is strongly acidic in reactions. The organic carbon content, CEC, available-N, available-P and K were 23.4 g kg^{-1}, 14.5 C mol (p+) kg^{-1}, 151(mg kg^{-1}), 12.7(mg kg^{-1}) and 74 (mg kg^{-1}), respectively. The available B and DTPA-extracted Zn were 0.36 (mg kg^{-1}) and 0.78 (mg kg^{-1}), respectively which indicate low in their content. The results are in agreement with earlier work of Thakur *et al.* (2011).

Effect of B on grain and straw yield of rice

Boron is an important micronutrient greatly influences the yield of rice due to its nutritional value in metabolism (Berger and Truog, 1940). Significance increase in grain and straw yield was recorded due to B fertilization upto 20 kg level of borax/hectare over control (Table 2). However, the maximum yield responses of rice grain and straw to B fertilization was observed at 15 kg level of borax/ha. Assuming the responses of B fertilization on grain and straw yield upto the level at which maximum response was recorded as linear, the magnitude of increase in grain and straw yield (kg) per kg of borax fertilization was 51.53 kg of grain and 41.5 kg for straw. The percent response of grain and straw yield due to 15 kg borax alone over control found to be 24.52 % and 17.78 % (Debnath and Ghosh, 2011 and Choudhary *et al.* 2015). The harvested index of rice in control was 47.37 % which increases to 48.75 % at 15 kg level of borax/ha (Table 3). Hence, farmer of the region can substantially augment their productivity of rice through B fertilization not exceeding with 15 kg borax/ha.

Combined effect of B and Zn on rice yield

The interrelationship of B with Zn in rice growing soil is a synergistic effect (Das, 2003). In view of the inadequate information available for interaction of B and Zn for piedoment soil of Arunachal Pradesh, the effect of B fertilizer has been tested in the same field in presence of different levels of Zn fertilization. The data are presented as two ways table of means computed from the actual yield of rice recorded in the three replications for grain and straw (Table 5). The results clearly revealed that the separate main effect of B and Zn as well as interaction effect of B x Zn on grain and straw yield were significant (compared with $LSD_{0.05}$ value), indicating that individual effect of different levels of B and Zn fertilization are independent. The results showed 7.9, 18.7, 24.5 and 2.6 percent increase in grain yield over control at 5, 10 15 and 20 kg borax/ha, respectively. Corresponding increase in straw yield accounted for a slightly lower than the percent increase in grain (6.2, 14.0, 17.78 and 1.4 over control) but had the same sequence of $B_{20} < B_5 < B_{10} < B_{15}$. The result thus indicates maximum yield responses at 15 kg level of borax fertilization per hectare. Whereas, in absence of B fertilization, the maximum percent increase in grain (24.8 %) and straw (17.6 %) yield recorded at 20 kg $ZnSO_4$/ha over no Zn fertilization (Mahata *et al.* 2013). This indicates that soil despite of being B deficient, the area are good responsive to Zn fertilization and therefore, the existence of hidden hunger for Zn in the soil cannot be ruled out. Naik and Das (2010) reported that the application of zinc as Zn-EDTA @ 1 kg/ha to low land rice soil of West Bengal resulted the 37.8% and 20.9 % greatest increase in grain and straw yield of rice respectively, over the control. However, a negative response were also observed in both grain and straw yield at level of 20 kg/ha of borax and 30kg/ha of $ZnSO_4$. The decrease in grain and straw yield at higher B and Zn levels may be ascribed to B and Zn toxicity in plant tissue (Debnath and Ghosh, 2011 and Chauhan *et al.* 2014). The response due to B fertilization on yield of rice was found to be further boosted when B fertilization is made along with Zn fertilization. The highest yield response was observed in the treatment receiving both borax @15 kg/ha and $ZnSO_4$ @ 20 kg/ha. The percent increase in the treatment giving highest yield ($B_{15}Zn_{20}$) over control (B_0Zn_0) amounting 47 % for grain and 35.72 % for straw. Thus, it indicates that B and Zn interacted synergistically to boost the yield of rice crop in acid soil of Arunachal Pradesh.

The symmetry about the median and possible outliers of yield, B-concentration and B uptake of both grain and straw at various levels of B fertilization and Zn fertilization are presented in Fig. 1 and Fig. 2 respectively. There is lack of symmetry has been observed for B-concentration values compared with the other two parameters under study. Some outliers have also been observed for B-concentration of straw of Zn fertilization.

Boron concentration and its uptake

The data presented in Table 4 revealed that the B concentration and its uptake in grain and straw increased with increased level of B fertilization upto 15 kg borax/ha. Further increase in B fertilization caused a decrease in B concentration in the plant possibly indicating a toxic influence at higher level (20 kg borax/ha). The maximum response of B fertilization on B concentration due to borax fertilization (B_{15}) over the B_0 control, in absence of Zn fertilization was 2.45 $mgkg^{-1}$ in grain and 2.02 $mgkg^{-1}$ in straw. The same due to Zn fertilization (Zn_{10}) over Zn_0 control in absence of B fertilization was 0.65 $mgkg^{-1}$ in grain and 0.48 $mgkg^{-1}$ in straw. Therefore, due to interaction between B × Zn on B concentration in the crop, the response level at $B_{15}Zn_{10}$ would have been 3.1 $mgkg^{-1}$ (2.45+0.65) in grain and 2.5 $mgkg^{-1}$ (2.02+0.48) in straw. But the actual response on B concentration observed in $B_{15}Zn_{10}$ treatment was 3.0 $mgkg^{-1}$ in grain and 2.25 $mgkg^{-1}$ in straw, showing a slightly suppressive effect of Zn on B concentration in rice crop. Hence, maximum responses of B fertilization on B concentration and uptake in rice grain and straw were observed in $B_{15}Zn_{10}$ treatment. Similar results were also reported by Naveen and Stalin (2014). Further application of Zn fertilization above 10 kg/ha ($ZnSO_4$)

showed a decreasing in concentration of B in both grain and straw. This may be due to antagonistic effect of Zn with B at higher level of Zn. However, Shuka *et al.* (1983) reported that the combined effect of Zn and B application though tended to increase B uptake, seed yield, oil and protein content of mustard in Alluvial soil of Kanpur, UP, but fail to show synergism expect in grain protein content.

Correlation among yield of rice and B concentration

The grain yield exhibit a significant positive correlation with B concentration (r = 0.8020 **), and B uptake (r = 0.9252*) by the grain (Table 4). A positive relationship was also observed between straw yield and B content(r =0.7676**) and B uptake(r=0.8755**).This suggest that application of B in soil will increase the concentration of B in plant tissue which having direct effect on grain and straw yield of rice. Similar correlation was also reported by Ram *et al.* (2013).

Conclusion

The study concluded that the maximum percentage of yield increase in the treatment ($B_{15}Zn_{20}$) over control (B_0Zn_0) amounting 47 % for grain and 35.72 % for straw. Hence, farmer of the region can substantially augment their productivity of rice through application of B fertilizer @15kg borax/ha and Zn @20 kg $ZnSO_4$/ha. It also indicates that B and Zn interacted synergistically to boost the yield of rice crop in acid soil of Arunachal Pradesh.

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