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Full Length Research Paper

Boron, zinc and microtone effects on growth, chlorophyll contents and yield attributes in rice (*Oryza sativa* L.) cultivar

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The micronutrient required in minute quantity and their deficiency leads to diminished growth and yield of crops. The effect of soil application of Zinc (Zn), Boron (B) and Microtone (MT) on growth, chlorophyll contents, mineral profile and yield components were investigated in rice at Chakkanwali Reclamation Research Station District, Gujranwala, Pakistan in the year 2011. Seven treatments which includes Zn 33% at 3 kg/acre, Zn 33% at 6 kg/acre, B 11.3% at 1.5 kg/acre, B 11.3% at 3 kg/acre, Zn + B at 3 + 1.5 kg/acre, Zn + B at 6 + 3 kg/acre and MT + Zn 6% + B + Fe + Mn + Cu 1% each at 500 ml/acre, and F_0 considered as the control were used. The results reveal that foliar application of Zn and B (Zn + B at 6 + 3 kg/acre) were proved as the best balanced fertilizer dose for higher growth and yield response. The plant height, tiller/plant, panicle length, kernels/plant, filled kernel/plant, productive kernel, straw, paddy and biological yield increased up to 29.75, 38.40, 28.19, 25.81, 36.52, 38.52, 32.47, 38.27 and 31.79%, respectively. The chlorophyll contents, B and Zn contents in rice plant also increased significantly as compared to the control. However, the B, Zn and MT application reduced the amylase and protein contents of rice plant at all treatment levels.

Key words: Micronutrients, rice crop, growth, chlorophyll contents, *Oryza sativa* L., yield attributes.

INTRODUCTION

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 major rice producing countries are in Asia, America and Africa regions, and Thailand, United States, Vietnam, Pakistan and India are the leading exporter. Rice production in the world during 2011 has been reported to be 713 million tons including 4823 thousand tons in Pakistan (GOP, 2011). Minerals like calcium, magnesium and phosphorus are present together with some traces of iron, zinc, copper and manganese (Yousaf, 1992). The protein of rice possesses higher digestibility and biological value. Rice bran is also an excellent source of protein (Shaheen and Anjum, 2005). Rice is available in more than 5000 varieties, of which Basmati rice has a leading position due to its long slender grains and distinct aroma, especially grown in different parts of India and Pakistan (Bhattacharjee et al., 2002).

The soils of Pakistan are calcareous alluvium and are low in many essential plant nutrients. The prevalence of free carbonates, low organic matter and high pH of soils, all suggest a risk of micronutrient deficiencies in crops (Rashid, 1996; Perveen et al., 2011; Jamil et al., 2012; Zia ul Haq et al., 2012a, b). Fertilizer used in this country predominantly contains nitrogen (N), phosphorus (P) and potassium (K) with minimum or no use of micronutrients (Rashid and Rafiq, 1998). In Pakistan, micronutrient deficiency, including zinc in rice is causing substantial yield losses (Rashid et al., 2001). Micronutrient

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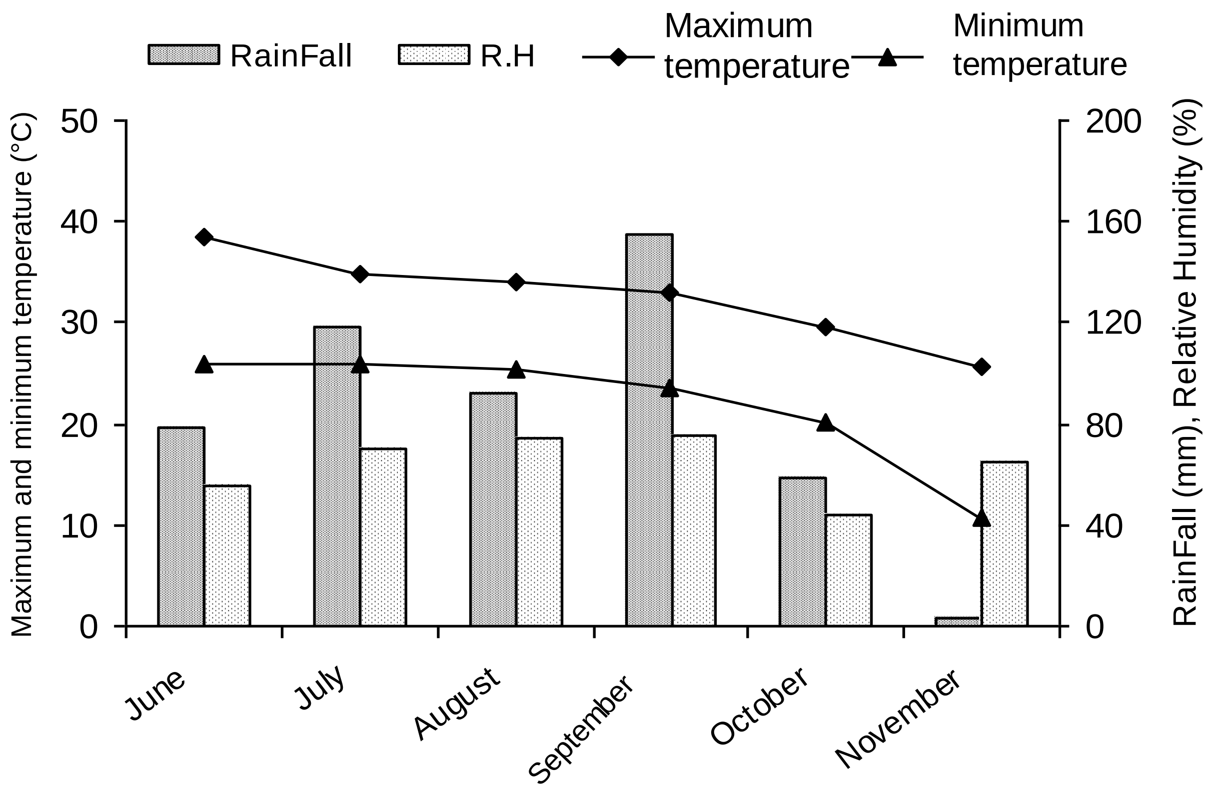

Figure 1. Mean monthly minimum and maximum temperatures, relative humidity and monthly rainfall during crop development.

deficiencies are not only hampering crop productivity but are also deteriorating quality. According to Zia et al. (2004) and Khattak (1995), most of the soil are micro-nutrient deficient and unable to nourish crops properly.

So, keeping in view the importance of micronutrient, the present research study was undertaken to evaluate the effect of Zn, B and microtone (MT) on agronomic and biological attributes in rice crop native to Pakistan.

MATERIALS AND METHODS

The experimental design was a randomized complete block design (RCBD) and the treatments with triplicate run were allocated in the experimental units. Each plot consists of ten rows 25 cm apart, row spacing constituted a net plot size of 6.0 m × 2.5 m. The research work was conducted at Chakkanwali Reclamation Research Station District, Gujranwala to evaluate the effect of Zn, B and MT application on various growth and yield components. Seeds of rice (super basmati) were collected from Ayub Agricultural Research Institute, Faisalabad. The soil texture was loam with cation exchange capacity (14.5 $cmol_c\ kg^{-1}$), CO_3^{2-} (0.2 $mmol_c\ l^{-1}$), HCO_3^- (2.0 $mmol_c\ l^{-1}$), Cl^- (13.2 $mmol_c\ l^{-1}$), Ca^{2+} + Mg^{2+} (9.0 $mmol_c\ l^{-1}$), K^+ (0.02 $mmol_c\ l^{-1}$), Na^+ (16.68), N (0.06%), P (1.68 ppm), $CaCO_3$ (free lime, 5%), boron (0.33 mg kg^{-1}), pH (8.1), saturation (44%), Zn (0.29 mg/kg) and B (0.83 mg/kg) and the weather conditions are shown in Figure 1.

The rice plants were seeded on 20 July, 2011 and six treatments of Zn and B were applied at the time of sowing as a basal dose, while microtone was applied as foliar spray 30 days after transplanting. Treatments comprised F_1 = zinc sulphate monohydrate 33% applied at 3 kg/acre; F_2 = zinc sulphate monohydrate 33% applied at 6 kg/acre; F_3 = borax 11.3% applied at 1.5 kg/acre; F_4 = borax 11.3% applied at 3 kg/acre; F_5 = Zn + B at 3 + 1.5 kg/acre; F_6 = Zn + B at 6 + 3 kg/acre; F_7 = microtone (foliar spray) Zn 6%, B, Fe, Mn and Cu 1% each applied at 500 ml/acre and F_0 considered as control.

The number of tillers/plant, kernels/plant, filled kernels/plant and productive tillers (m^{-2}) were counted visually within each plot randomly in triplicate, while plant height (cm) and panicle length (cm) were measured with the help of carpenter's tape. The straw yield (t ha^{-1}), paddy yield (t ha^{-1}) and biological yield (t ha^{-1})/plot were measured at harvesting stage (14 November, 2011), averaged and converted into tons ha^{-1}. The dried and ground samples were subjected to B analysis. Dry ashed samples were digested in 10 ml of 0.36 N sulfuric acid (H_2SO_4), filtered and volume was made up to 50 ml using deionized water in polypropylene flasks and B was measured spectrophotometrically (Cecil, 7200) (Shehzad et al., 2012). The protein contents were determined by Micro-Kjeldhal method (N × 5.95). Rice kernels were ground in a Retsch Mill equipped with 60-mesh screen for the determination of amylose contents (Inayatullah-Awan et al., 1989). For zinc contents (ppm), the ground sample was digested in mixture of HNO_3 and $HClO_4$. The digest was used for estimation of Zn contents using atomic absorption spectrophotometer (Jackson, 1973). The chlorophyll contents were measured following already reported method (Iqbal et al., 2012) at teaseling stage. Briefly, fresh leaves (0.2 g) were chopped and extracted overnight with 80% acetone at 4°C. The extracts were centrifuged at 10,000 *x* g for 5 min. Absorbance of the supernatant was read at 645 and 663 nm using a double beam spectrophotometer (Cecil, 7200) and the contents of chlorophylls a and b were calculated using

Table 1. The mean squares of nutrient treatments on paddy yield and yield attributes of rice (*Oryza sativa* L.).

Source of variation	df	Mean square									
		Plant height (cm)	Tillers /plant	Panicle length (cm)	Kernels /plant	Filled kernels /plant	Productive tillers (m^{-2})	1000-kernel weight (g)	Straw yield (t ha^{-1})	Paddy yield (t ha^{-1})	Biological yield (t ha^{-1})
Replication (R)	2	7.125	0.713	1.955	90.950	53.198	68.790	2.792	1.200	0.019	3.118
Fertilizers (F)	7	355.327**	9.842	29.984	487.044**	976.451**	2668.66**	32.071	4.243	0.897	6.795
Error (R × F)	14	24.792	0.537	1.255	17.473	32.460	140.550	3.982	1.439	0.063	1.456
Total	23										

**Indicates the significance at 5% levels of probability.

the following formulae:

$$Chl.a\ (mg/g^{-1}) = [12.7(OD_{663}) – 2.69(OD_{645})] \times V=1000 \times W$$
$$Chl.b\ (mg/g^{-1}) = [22.9(OD_{645}) – 4.68(OD_{663})] \times V=1000 \times W$$
$$Total\ Chl.\ (mg/g^{-1}) = [20.2(OD_{645}) – 8.02\ (OD_{663}) \times VW]/1000$$

Statistical analysis

The average value for all measured parameter was analyzed to show the significant effect. Significant means were compared using least significance difference (LSD) test at significance level of P < 0.05 (Steel and Torrie, 1997).

RESULTS

The rice plants raised as a result of B, Zn and MT treatment showed more uniform and faster growth, enhanced biochemical profile, higher chlorophyll contents and ultimately greater yield and other yield components as compared to the control. We have used seven treatments of Zn, B and MT which includes F_1 = Zn 33% at 3 kg/acre, F_2 = Zn 33% at 6 kg/acre, F_3 = B 11.3% at 1.5 kg/acre, F_4 = B 11.3% at 3 kg/acre, F_5 = Zn + B at 3 + 1.5 kg/acre, F_6 = Zn + B at 6 + 3 kg/acre; F_7 = MT + Zn 6% + B + Fe + Mn + Cu 1% each at 500 ml/acre, and their effect on growth, chlorophyll, biochemical and yield attributes has been discussed. The mean squares of nutrient treatments on growth, biochemical and yield components of rice (*Oryza sativa* L.) indicating the significance of treatment is given in Tables 1 and 3.

The plant height was significantly (*P*<0.05) affected by the micronutrient (Zn + B) supplement. Plant height varied from 92 to 121 cm in plant which received nutrient treatments. The plant treated with Zn + B at 6 + 3 kg/acre showed maximum response (121 cm) followed by Zn + B at 3 + 1.5 kg/acre (102 cm) and Zn 33% at 6 kg/acre (100 cm) which was 85 cm in the control. The other treatments like Zn 33% at 3 kg/acre, B 11.3% at 1.5 kg/acre, B 11.3% at 3 kg/acre and MT + Zn 6% + B + Fe + Mn + Cu 1% each at 500 ml/acre also had significant responses as compared to the control. Generally, nutrient supplementation in combination significantly enhanced plant height over the control (Table 2) and 29.75% plant height increased in Zn + B at 6 + 3 kg/acre treated plant (Table 5). The plant height was also significantly (*P*<0.05) affected by the Zn, B and MT application. The tillers varied from 8 to 12.16/plant in treated group of rice plant. The plant treated with Zn + B at 6 + 3 kg/acre showed maximum response of 12.16 tiller/plant as compared to the control (7.49) followed by Zn + B at 3 + 1.5 kg/acre (12.03 tiller/plant cm). The other treatments, Zn 33% at 3 kg/acre, Zn 33% at 6 kg/acre, B 11.3% at 1.5 kg/acre and B 11.3% at 3 kg/acre also increased tillers/plant significantly as compared to the control. However, the effect of MT + Zn 6% + B + Fe + Mn + Cu 1% each at 500 ml/acre was found not to be significant and generally, the maximum number of tiller was observed in plant which was supplied with Zn and B in combination (Table 2). The percentage increment in tillers/plant was 37.06, 37.74 and 38.40% for B 11.3% at 3 kg/acre, Zn + B at 3 + 1.5 kg/acre and Zn + B at 6 + 3 kg/acre, respectively, as compared to the control (Table 5).

The panicle length increased significantly and varied from 24 to 30.40 cm as a result of Zn, B and MT treatment. The plant treated with Zn + B at 3 + 1.5 kg/acre showed maximum response in panicle length of 30.40 cm as compared to the control (21.83 cm) followed by Zn + B at 6 + 3 kg/acre (29.70 cm) and B 11.3% at 1.5 kg/acre (29.67 cm). The other treatments, Zn 33% at 3 kg/acre, Zn 33% at 6 kg/acre, B 11.3% at 3 kg/acre and MT + Zn + B + Fe + Mn + Cu each at 1% at 500 ml/acre also increased in panicle length considerably as compared to control (Table 2). The percentage increment in panicle length was 28.19 and 26.49% for B 11.3% at 1.5 kg/acre, Zn

Table 2. Effect of nutrients treatments on paddy yield and yield attributes of rice (*Oryza sativa* L.).

Treatments	Plant height (cm)	Tillers /plant	Panicle length (cm)	Kernels /plant	Filled kernels /plant	Productive tillers (m^{-2})	1000-kernel weight (g)	Straw yield (t ha^{-1})	Paddy yield (t ha^{-1})	Biological yield (t ha^{-1})
F_0	85.00^{e}	7.49^{c}	21.83^{d}	109.33^{f}	86.33^{d}	155.33^{d}	10.00^{d}	6.53^{c}	2.58^{d}	9.44^{c}
F_1	95.33^{bcd}	11.10^{ab}	28.13^{b}	119.00^{e}	133.50^{a}	222.00^{b}	14.00^{c}	9.03^{ab}	3.05^{c}	12.08^{ab}
F_2	100.67^{bc}	11.00^{ab}	25.10^{c}	147.36^{a}	133.33^{a}	234.00^{ab}	20.00^{a}	8.20^{bc}	3.45^{bc}	10.66^{bc}
F_3	90.00^{de}	10.50^{b}	29.67^{a}	129.67^{d}	130.67^{a}	215.33^{b}	15.33^{bc}	8.06^{bc}	3.13^{c}	11.86^{ab}
F_4	92.00^{cde}	11.90^{a}	24.00^{c}	137.67^{bc}	100.67^{c}	221.67^{b}	15.66^{bc}	9.40^{ab}	3.88^{ab}	13.28^{a}
F_5	102.00^{b}	12.03^{a}	30.40^{a}	140.00^{bc}	114.67^{b}	231.33^{b}	18.67^{ab}	10.33^{a}	3.90^{a}	13.57^{a}
F_6	121.00^{a}	12.16^{a}	29.70^{ab}	142.67^{ab}	136.00^{a}	252.67^{a}	19.33^{a}	9.67^{ab}	4.18^{a}	13.84^{a}
F_7	99.00^{bc}	8.00^{c}	25.00^{c}	134.00^{cd}	115.00^{b}	192.00^{c}	15.67^{bc}	8.10^{bc}	3.05^{c}	11.82^{ab}
LSD (P= 0.05)	8.72	1.28	1.96	7.32	9.97	20.76	3.49	2.10	0.44	2.11

Means with the same letters within the same column are not significantly different at P = 0.05. F_1= Zinc sulphate monohydrate 33% applied at 3 kg/acre; F_2 = zinc sulphate monohydrate 33% applied at 6 kg/acre; F_3 = borax 11.3% applied at 1.5 kg/acre; F_4 = borax 11.3% applied at 3 kg/acre; F_5= Zn + B at 3 + 1.5 kg/acre; F_6 = Zn + B at 6 + 3 kg/acre; F_7 = microtone (foliar spray) Zn 6%, B, Fe, Mn and Cu 1% each applied at 500 ml/acre.

Table 3. The mean squares of nutrients treatments on biochemical attributes of rice (*Oryza sativa* L.).

Source of Variation	df	Mean square						
		Chl. a (mg/g)	Chl. b (mg/g)	Total chl. (mg/g)	Amylose content (%)	Protein content (%)	Boron content (ppm)	Zinc content (ppm)
Replication (R)	2	0.003	0.001	0.005	4.542	0.001	0.023	0.070
Fertilizers (F)	7	0.215	0.024	0.401	29.851**	0.371	1.268	2.371
Error (R × F)	14	0.009	0.001	0.011	2.637	0.003	0.046	0.063
Total	23							

**Indicates the significance at 5% levels of probability.

+ B at 3 + 1.5 kg/acre and Zn + B at 6 + 3 kg/acre treatments, respectively as compared to the control (Table 5). The kernel number/plant was also affected significantly (P<0.05) by the Zn, B and MT application and the number varied from 119 to 147.36/plant in the treated group of rice plant. The plant treated with Zn 33% at 6 kg/acre showed maximum response of 47.36 kernels/plant as compared to the control (109.33) followed by Zn + B at 6 + 3 kg/acre (142.67 kernel/plant) and Zn + B at 3 + 1.5 kg/acre (140 kernels/plant). The treatments like Zn 33% at 3 kg/acre, B 11.3% at 1.5 kg/acre, B 11.3% at 1.5 kg/acre and B 11.3% at 3 kg/acre also enhanced tillers/plant considerably as compared to the control. However, the effect of MT + Zn + B + Fe + Mn + Cu each at 1% at 500 ml/acre was found to be not significant and generally, the maximum number of tiller was observed in plant which was supplied with Zn and B in combination (Table 2). The percentage increment in panicle length was 25.81 and 23.37% for Zn 33% at 6 kg/acre and Zn + B at 6 + 3 kg/acre treatments, respectively as compared to the control (Table 5).

The filled kernel and productive kernel were significantly (P<0.05) increased by the Zn, B and MT supplement. The filled kernel and productive kernels number varied from 115 to 136/plant and 192 to 252.67 m^{-2}, respectively. The plant treated with Zn + B at 6 + 3 kg/acre showed superior

Table 4. Effect of nutrients treatments on biochemical attributes of rice (*Oryza sativa* L.).

Treatments	Chlorophyll content (mg/g)			Quality parameter		Nutrient content	
	Chl. a	Chl. b	Total Chl.	Amylose content (%)	Protein content (%)	Boron content (ppm)	Zinc content (ppm)
F_0	1.11^e	0.39^f	1.48^e	31.00^a	8.25^a	1.16^e	6.06^d
F_1	1.32^d	0.44^{ef}	1.76^d	22.33^{cd}	7.57^c	2.70^{bc}	8.33^b
F_2	1.47^{cd}	0.52^{cd}	1.96^c	21.67^d	7.94^b	2.53^{cd}	8.63^{ab}
F_3	1.34^d	0.45^e	1.75^d	26.00^b	7.53^{cd}	2.24^d	7.46^c
F_4	1.53^c	0.48^{de}	2.04^c	22.00^d	7.46^d	3.00^{ab}	7.30^c
F_5	1.63^{bc}	0.56^{bc}	2.24^b	24.33^{bcd}	7.23^e	2.86^{bc}	7.56^c
F_6	1.95^a	0.66^a	2.60^a	22.00^d	7.45^d	3.33^a	8.86^a
F_7	1.77^b	0.58^b	2.36^b	25.00^{bc}	8.04^b	2.67^{bc}	7.60^c
LSD (P= 0.05)	0.17	0.06	0.18	2.84	0.10	0.37	0.44

Means with the same letters within the same column are not significantly different at P = 0.05. F0= Control (no fertilizer); F1= Zinc sulphate monohydrate 33% applied @ 3 kg/acre; F2= Zinc sulphate monohydrate 33% applied @ 6 kg/acre; F3= Borax 11.3% applied @ 1.5 kg/acre; F4= Borax 11.3% applied @ 3 kg/acre; F5= Zn + B @ 3 + 1.5 kg/acre; F6= Zn + B @ 6 + 3 kg/acre; F7= Microtone (foliar spray) Zn 6%, B, Fe, Mn and Cu 1% each applied @ 500 ml/acre.

response for both filled kernel and productive kernel. The other treatment are, Zn 33% at 3 kg/acre, Zn 33% at 6 kg/acre, B 11.3% at 1.5 kg/acre, B 11.3% at 3 kg/acre, Zn + B at 3 + 1.5 kg/acre and B 11.3% at 3 kg/acre + MT + Zn + B + Fe + Mn + Cu each at 1% at 500 ml/acre also had excellent response as compared to the control (Table 2). The percentage increase in filled kernel/plant and productive kernel/m^2 were observed to be up to 36.52 and 38.52% for Zn + B at 6 + 3 kg/acre treatment as compared to the control (Table 5). The 1000-kernels mass also increased parallel to other yield parameters significantly (P<0.05) by the Zn, B and MT application and the mass of 1000-kernels varied from 14 to 20 g in micronutrient treated plants. The plant treated with Zn 33% at 6 kg/acre increased with maximum mass of 20 g/1000 kernels followed by Zn + B at 6 + 3 kg/acre treatment (19.33 g/1000-kernels) which was recorded as 10 g in the case of the control. Other treatments like Zn 33% at 3 kg/acre; B 11.3% at 1.5 kg/acre; B 11.3% at 3 kg/acre; Zn + B at 3 + 1.5 kg/acre and B 11.3% at 3 kg/acre + MT + Zn + B + Fe + Mn + Cu each at 1% v 500 ml/acre also had increase in the 1000-kernels mass significantly (P<0.05) (Table 2). The percentage increment in 1000-kernel mass was 50 and 48.26%, respectively for Zn 33% at 6 kg/acre and Zn + B at 6 + 3 kg/acre treatments as compared to control (Table 5). The paddy and biological yield are the main focus of any treatment and the treatment under study significantly affected both parameters positively. The paddy and biological yield (t ha^{-1}) varied from 3.05 to 4.18 and 10.66 to 13.84 t ha^{-1}, respectively. The treatment Zn + B at 6 + 3 kg/acre showed maximum response of 4.18 and 13.84 t ha^{-1} of paddy and biological yield, respectively followed by Zn + B at 3 + 1.5 kg/acre and B 11.3% at 3 kg/acre. All other treatments were also found to be significant for paddy and biological yield, except Zn 33% at 6 kg/acre for biological yield (Table 2). The paddy yield and biological yield increased up to 38.27 and 31.79%, respectively for the treatment Zn + B at 6 + 3 kg/acre (Table 5).

Ultimate response of growth and yield parameter depends upon the photosynthetic rate which in turn is dependent on chlorophyll contents. In the present study, a significant (P<0.05) increment in chlorophyll contents (a, b and total chlorophyll) was recorded in Zn, B and MT treatments. The chlorophyll "a" and "b" contents was found to be correlated with each other example the treatment Zn + B at 6 + 3 kg/acre showed highest and Zn 33% at 3 kg/acre lowest chlorophyll contents. The chlorophyll "a" and "b" contents varied from 1.95 to 1.32 mg g^{-1} and 0.66 to 0.44 mg g-1, respectively. The highest chlorophyll consents (a, b and total) was recorded in Zn + B at 6 + 3 kg/acre treated plant. However, all other treatments also had increased chlorophyll contents significantly (P<0.05) (Table 4). The chlorophyll "a", "b" and total chlorophyll contents increased up to 43.07, 40.91 and 43.07%, respectively for the treatment Zn + B at 6 + 3

Table 5. Percentage change (positive/negative) on various parameters of rice (*Oryza sativa* L.) after micronutrients application.

Treatments/response	F_1	F_2	F_3	F_4	F_5	F_6	F_7
Agronomic parameters							
Plant height (cm)	10.83	15.56	5.5	7.61	16.67	29.75	14.14
Tillers/plant	32.52	31.91	28.66	37.06	37.74	38.40	6.37
Panicle length (cm)	22.39	13.03	26.42	9.04	28.19	26.49	12.68
Kernels/plant	8.13	25.81	15.68	20.58	21.91	23.37	18.41
Filled kernels/plant	35.33	35.25	33.93	14.24	24.71	36.52	24.93
Productive tillers (m^{-2})	30.03	33.62	27.86	29.93	32.85	38.52	24.12
1000-kernel weight (g)	28.57	50.00	34.76	36.14	46.44	48.26	36.18
Straw yield (t ha^{-1})	27.68	20.36	18.98	30.53	36.78	32.47	19.38
Paddy yield (t ha^{-1})	15.41	25.21	17.57	33.50	33.86	38.27	15.41
Biological yield (t ha^{-1})	21.85	11.44	20.40	28.91	30.43	31.79	20.13
Biochemical attributes							
Chl. a (mg/g)	15.91	24.48	17.16	27.45	31.90	43.07	37.28
Chl. b (mg/g)	11.36	25.00	13.33	18.75	30.35	40.91	32.75
Total Chl. contents (mg/g)	15.91	24.48	15.43	27.45	33.93	43.07	37.28
Amylose contents (%)	-38.83	-43.05	-19.23	-40.91	-27.41	-40.91	-24.00
Protein contents (%)	-8.98	-3.90	-9.56	-10.58	-14.11	-10.73	-2.61
Boron contents (ppm)	57.04	54.15	48.21	61.33	59.44	65.16	56.55
Zinc contents (ppm)	27.25	29.77	18.76	16.98	19.84	31.60	20.26

F_1= Zinc sulphate monohydrate 33% applied @ 3 kg/acre; F_2= Zinc sulphate monohydrate 33% applied @ 6 kg/acre; F_3= Borax 11.3% applied @ 1.5 kg/acre; F_4= Borax 11.3% applied @ 3 kg/acre; F_5= Zn + B @ 3 + 1.5 kg/acre; F_6= Zn + B @ 6 + 3 kg/acre; F_7= Microtone (foliar spray) Zn 6%, B, Fe, Mn and Cu 1% each applied @ 500 ml/acre.

kg/acre (Table 5). Negative effect of Zn, B and MT application was observed in amylose and protein contents. The amylase and protein contents values were 31 and 8.25%, respectively in the control, and ranged from -21.67 to -26% and -8.04 to -7.23%, respectively in nutrient treated plant. The lowest decrease was for treatments B 11.3% at 1.5 kg/acre and B 11.3% at 3 kg/acre + MT + Zn + B + Fe + Mn + Cu each at 1% at 500 ml/acre for amylase and protein contents and all other treatments further had decrease in the amylase and protein contents of rice treated plant with Zn, B and MT as compared to the control (Table 4).

The effect of Zn, B and MT application was also evaluated on the basis of these nutrients absorption in plant tissue. The contents of B and Zn significantly increased in rice plant as a result of Zn and B application. In the present study, a significant (P<0.05) increment in Zn and B contents were recorded and values varied from 2.24 to 3.33 ppm and 7.30 to 8.86 ppm in treated plant which was 1.16 and 6.06 ppm in the control. The considerable higher value of Zn and B in rice plant indicates their absorption possibility. The maximum values of B and Zn contents were observed for higher B and Zn treatment, for example Zn + B at 6 + 3 kg/acre as compared to all other treatments such as Zn 33% at 3 kg/acre, Zn 33% at 6 kg/acre, B 11.3% at 1.5 kg/acre, B 11.3% at 3 kg/acre, Zn + B at 3 + 1.5 kg/acre and B 11.3% at 3 kg/acre + MT + Zn + B + Fe + Mn + Cu each at 1% at 500 ml/acre (Table 4). The B and Zn content in rice plant increased up to 65.16 and 31.60%, respectively as a result of Zn + B at 6 + 3 kg/acre treatment (Table 5).

DISCUSSION

In agreement with previous reports, Zn, B and MT applications significantly increased growth parameter, chlorophyll contents, yield components and mineral profile of rice crop (Tables 1 and 2). It is well known that rice is extremely sensitive to Zn application and its deficiency leads to low growth and ultimately decreased yield. Furthermore, B is associated with the development of cell wall and cell differentiation and hence, helps in root elongation and shoot growth of plant. Patil et al. (2008) has also reported the importance of B for normal growth of plant. 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) because the chlorophyll contents increased considerably in Zn and B treated group of 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).

The increases in rice biological yield by Zn application were relatively high, indicating the necessity of Zn application to plants. Irrespective of the Zn application, the effect of Zn on all yield components was correlated with each other and growth parameter as well as chlorophyll contents. However, the effect on yield components was marginally higher than growth parameters. These results indicate that the importance of Zn nutrition for yield is greater than for vegetative growth. Brown et al. (1993) reported that anther and pollen grain development in Zn-deficient wheat plants were largely impaired, possibly as a result of reduced levels of IAA and proteins (Cakmak et al., 1989; Yilmaz et al., 1997) and B deficiency hamper plant growth by reduced photosynthate translocation through vascular bundles of petioles, causing stunted growth and abnormal reproductive development (Wang et al., 1992). Secondly, the micronutrient acts as catalyst in the uptake and use of certain other macronutrients (Phillips, 2004).

The increase in growth parameter, chlorophyll contents, biochemical profile and yield components were improved with micronutrient use and found to be dose dependent. This dose dependent trend was in accordance with previous studies (Ali et al., 2011) and 2 to 5 kg Zn and 0.75 to 1.0 kg B per hectare may be adequate for 2 to 4 crop rice seasons, however, this varies from crop to crop and species to species as well as soil condition (Rashid and Ryan, 2004). For example, cotton, sunflower, legumes, clover, canola and pine have higher B requirements than cereals (Rashid, 1998). Abid et al. (2007) observed significant improvement in yield and fruiting efficiency with B application. Rashid and Rafiq (2002) obtained 14 percent increase in yield due to B and Zn application on 15 sites. Similar results have also been reported by various researchers for other crops (Malik et al., 1990; Rashid, 1996; Soomro et al., 2001; Howard et al., 2000; Sadana and Takkar, 1983). In our study, we obtained a good yield at low level of Zn application. The wide variability in response might be due to agroclimatic condition difference and mode of application. Rice response to Zn fertilization rates varied with soil texture, available Zn status and rice variety. The optimum level seems to be 5.6 kg Zn ha^{-1}. The level of Zn for sodic soil was reported to be quite high (11.0 to 22.0 kg Zn ha^{-1}) (Singh and Abrol, 1985; Swarup, 1991). Furthermore, the Zn application also depends on application timing. For example, application of 25 kg $ZnSO_4$ h^{-1} at transplanting and tillering proved to be effective, while applications at transplanting and panicle initiation was not effective (Savithri et al., 1999) or Zn-deficient crops can be improved by applying Zn. Results reported by Sadana and Takkar (1983) and Takkar et al. (1989) indicated that rice yield was more limited by Zn deficiency during rabi than kharif season due to variation in temperature and radiation. In contrast, the B effect was found to be less as compared to Zn because in treatment where Zn alone or in combination with B was applied, there were similar results.

Conclusion

Boron and Zn application significantly increased the growth parameter, chlorophyll contents and yield components as well as Zn and B assimilation in rice plants. Generally, Zn at higher level alone or in combination with B gave better response. The treatment of Zn and B with microtone did not significantly affect the growth and yield parameters. The Zn + B at 6 + 3 kg/acre treatment was found to be more effective followed by Zn + B at 3 + 1.5 kg/acre and Zn 33% at 6 kg/acre. Form the results, the use of B and Zn is suggested for better yield in rice crop practically.

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