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EFFECT OF BORON APPLICATION ON GROWTH AND DRY MATTER ACCUMULATION IN VEGETATIVE PARTS OF RICE GENOTYPES

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ABSTRACT

A field experiment was conducted to know the effect of foliar spray of boron (B) on dry matter accumulation in seven rice genotypes. B application had a positive impact on LAI at both flowering and maturity stages, however, it was significant at maturity stage. Maximum LAI was obtained at 0.4ppm B spray and genotype IET 21519 recorded maximum LAI at both stages. Similarly the chlorophyll content as indicated by SCMR values increased with the increase in level of B application at both stages. Maximum mean SCMR value was noted in IET 21007. B application did not affect days to 50% flowering and days to maturity. The leaf and culm dry weights of all the tested genotypes responded positively to B application. Maximum mean weights for both leaf and culm were recorded at 0.4ppm B spray, followed by 0.8ppm. Maximum mean leaf and culm weight at flowering and maturity was recorded in IET 21519 and IET 21540 respectively. Overall B spray had a significant role in improving the rice physiology and 0.4ppm was the most suitable level of B spray. Comparatively, genotypes IET 21519, IET 21540 and IET 21007 responded well to B spray.

KEY WORDS
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INTRODUCTION

Rice is India's pre-eminent crop and is the staple food of the people of the eastern and southern parts of the country. During 2012-13 and 2013-14, the world production has increased by 1% (from 472 Million Tonnes to 476 Million Tonnes) accounting for 20% of all world rice production (Annonymous, 2015). B is an essential micronutrient for plant and its availability in soil and irrigation determines agricultural production. In soil solution B exists primarily as boric acid ($B(OH)_3$) and is available in the pH range of 4-6.5. In India B deficiency is widespread and results typically from B leaching in humid areas with coarse-textured soils (Shorrocks, 1997).

B is one of the mineral nutrients that required for normal plant growth. Boron's widespread role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, and regulation of plant hormone levels. Besides it has role in stimulation or inhibition of specific metabolism pathways (Saleem *et al.,* 2011). B application helps to increase the dry matter accumulation in roots, shoots and leaves (Layek *et al.*, 2014). To cope with B deficiency, it can be delivered as soil and foliar application. Foliar applied B plants retain significant phloem mobility to flowering parts from senescing leaves. Therefore, foliar sprays of B not only provide a means to apply B at a particular growth stage, but also remove B deficiency (Rashid *et al,* 2004).

The total leaf area after flowering is closely related to grain production as it affects the amount of carbohydrates in the grain. Increased leaf area index is one of the ways to increase the capture of solar radiation within the can-opy and for production of higher dry matter. It is desirable to have high LAI values for increased spikelet number (Yoshida, 1981). Leaves under B deficient tend to have reduced chlorophyll and soluble protein (largely photosynthetic enzymes) contents, which affected Hill reaction activity and net photosynthesis. The increase in carbohydrate content with the increase in B application could be due to favourable influence of B on various metabolic processes like photosynthesis, respiration, enzyme activity which ultimately increases the concentration of nutrients in seed and stover (Ganie *et al.*, 2014).

Hence, B has received maximum attention over last 15 years. Previously a lot of work has been done to evaluate the response of B application in different crops including rice, however, most of the studies are related to use of different levels of B in rice either as foliar application or in solution form. Foliar spray of B significantly affected total B uptake by rice crop which may be attributed to increased concentration and higher yield attributing characteristics of rice which enhanced the yield and total B uptake (Singh *et al.*, 2015). Overall, for improving rice performance and maximizing the net economic returns, B might be applied at flowering (Hussain *et al.*, 2012).

However, B application at different growth stages of rice through different application methods has rarely been evaluated. The objective of the present study was to find out response of B foliar application for getting higher growth and dry matter accumulation in rice crop.

MATERIALS AND METHODS

A field experiment was laid out in Randomized Block Design (factorial concept) with three replications and spacing of 10 x 20 cm was adopted in an 8.0 x 7.0 m^2 plots to know the effect of B on growth and dry matter accumulation of seven genotypes (IET 20979, IET 21007, IET 21106, IET 21114, IET 21519, IET 21540 and Rasi (check)) against four levels of B spray (control, 0.2 ppm (0.375 kg B ha^{-1}), 0.4 (0.75 kg B ha^{-1}) and 0.8 ppm (1.5 kg B ha^{-1}) given at flowering stage at Indian Institute of Rice Research farm, Rajendranagar, Hyderabad. Experiment was carried out in a textural class of clayey vertisol (Piper, 1966), pH (8.33-alkaline) and EC (0.22 dSm^{-1}) measured with digital pH and EC meters (Jackson, 1967) and also available B (0.327 ppm) estimated by Azomethine method (Bingham, 1982). Leaf area index (LAI) was recorded at flowering and maturity stage. Leaf area was measured with LI-3100 leaf area meter (LICOR-Lincoln, Nebraska, USA) and LAI was calculated by using the following formula (Lan *et al.*, 2009).

LAI = (Total leaf area/cm^2)/(Unit leaf area/cm^2)

SCMR Values (Soil Plant Analytical Development Chlorophyll meter readings) were measured with chlorophyll meter (SPAD 502 Minolta Corp., Tokyo) at flowering and maturity stage (Poli *et al.*, 2013). Phenological data such as days to flowering and days to maturity was recorded from the date of transplanting. Leaf dry weight and Culm dry weight was measured using three randomly selected plants at flowering and tillering stages. The sampled plants were separated into leaves and stems and dried in an oven at 80º C until a constant weight was attained. Dry weights were recorded using electronic balance and were expressed in g m^{-2} dry weight.

RESULTS AND DISCUSSION

LAI

At maturity stage treatmental, genotypes and their interaction effects differed significantly (Table 1). Maximum mean LAI (3.23) was recorded in treatment where B was sprayed at 0.4 ppm. Maximum mean LAI was recorded in IET 21519 and minimum in IET 21007 at both the stages. IET 21519 recorded maximum values at both flowering (5.38) and maturity stages (4.57) with interaction of 0.4ppm and 0.2ppm respectively. Similarly, soil and foliar application of B at flowering and grain formation stages showed high LAI at 60 and 75 DAT against the low LAI that was recorded in the control and soil application of B at the transplanting and tillering stages (Hussain *et al.*, 2012). Whereas, Shukla and Warsi (2000) reported that the B did not influence the growth and LAI of wheat genotypes.

SCMR values

At flowering stage significant differences were noted among

Table 1: Leaf Area Index of rice influenced by B application at flowering and maturity stage.

	Flowering					Maturity				
Treatments	B spray concentrations (ppm)					B spray concentrations (ppm)				
Genotypes	Control	0.2	0.4	0.8	Mean	Control	0.2	0.4	0.8	Mean
IET 20979	3.19	3.69	4.36	3.97	3.80	2.47	2.73	3.64	2.52	2.84
IET 21007	3.17	2.17	2.97	2.80	2.78	2.67	1.45	2.66	2.40	2.29
IET 21106	3.49	3.75	3.20	4.00	3.61	2.67	2.77	2.82	2.87	2.78
IET 21114	2.99	3.08	3.01	3.48	3.14	2.13	2.15	2.50	2.76	2.38
IET 21519	5.22	4.69	5.38	4.93	5.05	4.24	4.57	4.42	4.28	4.38
IET 21540	4.69	4.26	4.81	3.83	4.40	4.13	3.72	4.31	3.52	3.92
Rasi (Check)	3.57	3.01	2.42	3.22	3.05	2.53	2.66	2.27	2.50	2.49
Mean	3.76	3.52	3.74	3.75		2.98	2.86	3.23	2.98	
	SEm		CD (p = 0.05)			SEm			CD (p = 0.05)	
Treatments (T)	0.15			NS		0.08			0.22	
Genotypes (G)	0.20			0.57		0.10			0.29	
Interaction	0.40			NS		0.20			0.58	

Table 2: SCMR values of rice as influenced by B application at flowering and maturity stage

	Flowering					Maturity				
Treatments	B spray concentrations (ppm)					B spray concentrations (ppm)				
Genotypes	Control	0.2	0.4	0.8	Mean	Control	0.2	0.4	0.8	Mean
IET 20979	31.8	32.9	30.4	31.8	31.7	24.9	26.0	26.7	26.7	26.1
IET 21007	47.0	45.3	48.3	46.9	46.9	25.4	27.1	27.4	27.3	26.8
IET 21106	39.3	40.0	40.5	41.7	40.4	24.9	25.3	25.0	26.0	25.3
IET 21114	38.6	39.1	39.3	39.9	39.2	22.3	22.9	23.3	23.0	22.9
IET 21519	38.1	34.2	33.9	35.4	35.4	25.4	25.8	26.1	25.8	25.8
IET 21540	35.5	31.2	32.0	33.9	33.2	23.2	22.1	22.1	23.5	22.7
Rasi (Check)	42.3	43.5	44.0	40.4	42.6	23.4	23.1	23.1	23.7	23.3
Mean	39.0	38.0	38.4	38.6		24.2	24.6	24.8	25.2	
	SEm			CD (p = 0.05)		SEm			CD (p = 0.05)	
Treatments (T)	0.57		NS			0.15			0.41	
Genotypes (G)	0.76		2.15			0.20			0.55	
Interaction	1.52		NS			0.40			1.09	

Table 3: Phenology of rice genotypes influenced by B application

Treatments	Days to 50per cent Flowering B spray concentrations (ppm)					Days to Maturity B spray concentrations (ppm)				
Genotypes	Control	0.2	0.4	0.8	Mean	Control	0.2	0.4	0.8	Mean
IET 20979	105	101	103	94	101	136	133	135	135	135
IET 21007	77	77	77	76	77	107	107	108	107	107
IET 21106	91	91	89	89	90	123	123	122	120	122
IET 21114	88	87	88	89	88	121	121	121	121	121
IET 21519	104	102	103	104	103	136	135	135	131	134
IET 21540	103	102	101	103	102	132	131	131	131	131
Rasi (Check)	82	81	81	82	82	113	112	112	113	112
Mean	93	92	92	91		124	123	123	123	
	SEm			CD (p = 0.05)		SEm			CD (p = 0.05)	
Treatments (T)	0.78			NS		0.46			NS	
Genotypes (G)	1.03			2.93		0.61			1.72	
Interaction	2.06			NS		1.21			NS	

Table 4: Leaf dry weight (g m^{-2}) of rice influenced by B application at flowering and maturity stage

Treatments	Flowering B spray concentrations (ppm)					Maturity B spray concentrations (ppm)				
Genotypes	Control	0.2	0.4	0.8	Mean	Control	0.2	0.4	0.8	Mean
IET 20979	206	228	243	241	230	125	118	128	141	128
IET 21007	161	177	192	190	180	81	97	112	110	100
IET 21106	182	195	212	208	199	102	115	132	128	119
IET 21114	155	170	190	189	176	75	90	110	109	96
IET 21519	275	289	296	292	288	165	179	176	172	173
IET 21540	232	247	266	263	252	122	137	146	143	137
Rasi (Check)	156	168	196	192	178	76	88	116	112	98
Mean	195	211	228	225		106	118	131	131	
	SEm			CD (p = 0.05)		SEm			CD (p = 0.05)	
Treatments (T)	0.66			1.87		0.66			1.88	
Genotypes (G)	0.87			2.47		0.88			2.48	
Interaction	1.74			4.94		1.75			4.97	

the SCMR values for the genotypes studied. IET 21007 (46.9) recorded the mean maximum value. IET 21106 (40.4) was on par with check variety Rasi (42.9) and this was followed by IET 21114 (39.2). SCMR values at maturity stage (Table 2) showed significant differences. SCMR values ranged from 23.5 to 22.1 for B treatments. IET 21007 recorded the mean maximum value of 27.1. Two other genotypes IET 20979 (25.6) and IET 21519 (25.8) were found on par and were followed by IET 21114. From the results it can be inferred that maximum SCMR values were recorded in IET 21007 at all stages with B application and there was no increase in SCMR values in other genotypes. Hence, the increase in SCMR values may be due to genotype not due to treatment effect. Besides NPK, zinc and B fertilizers are needed to improve grain yield and quality with respect to physicochemical properties, irrespective of varieties (Abbas *et al*., 2013).

Table 2. SCMR values of rice as influenced by B application at flowering and maturity stage

Phenological parameters

The physiological age of the crop has been characterized by the formation of the various organs and their appearance. Subedi *et al*. (1997) reported that days to maturity were influenced by sowing date and genotype. Based on the crop growth duration,recorded in table 3 genotypes were categorized into long duration types (IET 20979, IET 21519 and IET 21540), medium duration (IET 21106, IET 21114) and early duration (IET 21007 and Rasi). The growth duration was highly heritable, highly location and season specific because of interactions between the variety's photoperiod and temperature sensitivity and weather conditions (Yoshida, 1981).

Hence, phenology was not affected by B application in our results. B deficient rice plants were generally healthy with green leaves except for twisting and white tips and banding. Flowering stage was delayed by one month in B deficient sand cultured rice resulting in few and smaller panicles that decreased yields (Yu and Bell, 2002). Increasing crop growth period progressively increases Crop Growth Rate (CGR) due to increased dry matter accumulation up to 60 DAT and then starts declining, in addition to this soil application of B at flowering stage improved both LAI and CGR (Hussain *et al*., 2012).

Leaf dry weight

Leaf dry weight showed significant variation in flowering upon B spray at different concentrations (Table 4). Maximum values were recorded at 0.4 ppm B (228 g m^{-2}) concentration which significantly differed from 0.8 ppm B concentration (225 g m^{-2}). Among the genotypes mean maximum values were recorded in IET 21519 (288 g m^{-2}) and were followed by IET 21540 (252 g m^{-2}) and IET 20979 (230 g m^{-2}) which were significantly different from each other. Interaction was also found to be significant, where maximum values were recorded in IET

Table 5: Culm dry weight (g m^{-2}) of rice influenced by B application at flowering and maturity stage

Treatments	Flowering					Maturity				
		B spray concentrations (ppm)					B spray concentrations (ppm)			
Genotypes	Control	0.2	0.4	0.8	Mean	Control	0.2	0.4	0.8	Mean
IET 20979	685	723	746	745	725	533	533	536	535	534
IET 21007	413	420	432	433	425	293	300	312	313	305
IET 21106	472	490	509	506	494	352	370	389	386	374
IET 21114	459	469	479	477	471	339	349	359	357	351
IET 21519	682	708	721	715	706	524	588	601	515	557
IET 21540	768	784	795	790	784	572	584	585	580	580
Rasi (Check)	533	547	560	553	548	413	427	440	433	428
Mean	573	592	607	603		432	450	460	446	
	SEm		CD (p = 0.05)			SEm			CD (p = 0.05)	
Treatments (T)	1.95			5.54		1.82			5.15	
Genotypes (G)	2.58			7.33		2.40			6.81	
Interaction	5.17			14.65		4.80			13.63	

21519 (296 g m^{-2}) at 0.4 ppm and IET 21519 (292 g m^{-2}) at 0.8 ppm were on par.

At maturity significant variation was recorded among different B concentrations in leaf dry weights (Table 4). Mean maximum values of 131g m^{-2} were recorded at 0.4 and 0.8 ppm concentrations, followed by 0.2 ppm (118 g m^{-2}). Genotypes differed with respect to leaf weight. IET 21519 showed mean maximum value (173 g m^{-2}) followed by IET 21540 (137 g m^{-2}) and IET 20979 (128 g m^{-2}). Interaction revealed maximum leaf weight in IET 21519 genotype at 0.2 ppm (179 g m^{-2}), at 0.4 ppm (176 g m^{-2}) and at 0.8 ppm (172 g m^{-2}). B application has a positive influence on growth of the crop (Sharma *et al.*, 2013).

Culm dry weight

Significant variation for culm weight was recorded upon spray of B at different concentrations, genotypes and interactions at both flowering and maturity in Table 5. At flowering maximum culm weight values recorded at 0.4 ppm (607 g m^{-2}) was on par with 0.8 ppm (603 g m^{-2}) B spray. Genotype IET 21540 recorded mean maximum value (784 g m^{-2}) followed by IET 20979 (725 g m^{-2}) and IET 21519 (706 g m^{-2}). Maximum significant interaction was recorded in IET 21540 at 0.4 ppm B (795 g m^{-2}) and IET 21540 (790 g m^{-2}) at 0.8 ppm which were on par. At maturity mean maximum culm weight values recorded at 0.4 ppm (460 g m^{-2}) was on par with 0.2 ppm (450 g m^{-2}) B spray and in genotypes IET 21540 (580 g m^{-2}) followed by IET 21519 (557 g m^{-2}) and IET 20979 (534 g m^{-2}) recorded maximum values. Interaction between B concentrations and genotypes revealed IET 21519 at 0.4 ppm (601 g m^{-2}) showed maximum culm weight and was followed by IET 21519 at 0.2 ppm (588 g m^{-2}).

At maturity shoot carbohydrates would be translocated into grains, as a result the culm weight decreased due to subsequent increase panicle weight. Leaves turned into yellowish green. Shah *et al.*, 2011 reported that application of 1 kg ha^{-1} B increased the straw yields. 18 μM B produced 42 mg $plant^{-1}$ culm weight in Nipponbare genotype (Uraguchi and Fujiwara, 2010). Kabir *et al.* (2007) reported that micronutrient application that includes 2 kg B ha^{-1} improved the straw yields. Application of B at 1.0 kg ha^{-1} enhanced straw yields of rice (Shah *et al.*(2011), application of 1.0 per cent B solution increases dry weight of rice (Ahmad *et al.*, 2012).

B has been postulated to increase the rate of transport of sugars to actively growing regions and also in to developing fruits. IET 20979, IET 21003 and IET 21014 had better source potentials in terms of dry weights of culm and leaf. Mean sink potential was 248 g m^{-2} and genotypes IET 20979 and IET 21007 were found to be superior at this stage (DRR annual progress report, 2009). Grain and straw yields were increased under 0.1 ppm B foliar spray along with 100 per cent N in rice (Singh *et al.*, 2015). Among the B levels, the highest seed yield was observed with 1.0 and 1.5 kg B ha^{-1} in soya bean (Layek *et al.*, 2014), similarly these B levels increased the yield attributes of French bean (Ganie *et al.*, 2014).

The present investigation revealed that maximum LAI and leaf dry weight was in IET 21519. Highest SCMR value (responsible for higher rate of photosynthesis) was recorded in the genotype IET 21007 and maximum culm weight was in IET 21540 where B was sprayed at 0.4 ppm. This clearly indicates that IET 21519, IET 21540 and IET 21007 are superior genotypes comparatively and perform better with the application of B.

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