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A Study of Boron and Silica Foliar Application on Growth and Yield of Rice in High Boron Content Media

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Abstract

The low level of micro nutrients will cause a deficiency in plants, but even the slightest excess will be toxic. This research aimed to know the possible physiology effect of foliar application of boron, silica and their interaction on growth and yield of rice in high boron content media. The research was conducted in the Integrated Green house Field Laboratory, College of Agriculture, University of Lampung from October 2014 to March 2015. The treatments were arranged in a 3 x 5 factorial by applying in a Randomized Complete Block Design (RCBD) with two replications. The first factor was boron applied with concentrations of 0, 10 and 20 ppm, respectively. The second factor was silica applied with concentrations of 0, 50, 100, 150 and 200 ppm, respectively. The homogeneity of variance was tested using Bartlett's test and the non-additivity of model using Tukey's test. The differences of treatment mean were analyzed using orthogonal contrast and polynomial at 5% and 1% probability level. The results showed that the foliar application of boron, silica and their interaction did not affect growth and yield of rice in high boron content media. The high formation of wax in the cuticle layer supported by high levels of boron may cause boron and silica which was applied through the leaves difficult to be absorbed by plants.

Keywords

cuticle layer, micro nutrients, wax

1. Introduction

The low level of micro nutrients will cause a deficiency in plants, but even the slightest excess will be toxic. Boron is one of the micro nutrients that plants need. Boron plays a carbohydrate metabolism and transport of sugar, phenol and auxin metabolism, tissue development and formation of cell walls, reproduction and disease resistance, root elongation and nucleic acid metabolism, nitrogen fixation and nitrate assimilation, and water relations (Saleem et al., 2011).

High levels of boron in the soil cause toxicity symptoms to the plant. It occurs following the pattern from the base to the tip of the leaf causing typical poisoned symptoms of chlorosis or necrosis at the edges of older leaves (Roessner et al., 2006). Cayton (1985) in his IRRI research revealed that levels of boron in the soil is called critical (high) if it contains > 5 mg B/kg based on the hot water extraction analysis.

Silica element is categorized as a supportive nutrient. Although most of the plants can complete their life cycle in a state of shortage of silica, the adequate level of silica in plants is important to support healthy growth, especially on accumulating plants such as rice (Kraska & Breitenbeck, 2010). The role of silica in supporting the growth of plants by pressing biotic stresses such as disease and pests, and abiotic stresses such as drought, salinity and toxicity of metals by performing two ways polymerization of silicate acid which leads to the formation of a dense layer of silica gel (poly-silicate acid) and it has an important role in organic defense compound formation through changes in gene expression (Epstein, 2009).

Nutrients applied through the soil likely to be tied up and form sediment influenced by pH and ions contained in the soil (Lopez-Arredondo et al., 2013). Fertilizer application through the leaves can be an alternative to fulfill the micronutrients need because the response showed by the plants is relatively quick. Absorption of sprayed nutrients through the leaf carried on by the surface of plants which has a hydrophobic membrane, or cuticle (the membrane which limits exchange of water, solutes and gases between plant and the environment), also might through stomata's although those two entrances are debatable (Fernandez et al., 2013). Fernandez et al. (2013) revealed that spraying nutrients which are immobile in the plant is only beneficial for tissues which receive the sprayed nutrients directly. This research aimed to study of foliar application of boron, silica and their effect on growth and yield of rice in high boron content media.

2. Materials and Methods

The research was conducted in the green house at the Integrated Field Laboratory, College of Agriculture, University of Lampung from October 2014 to March 2015. The treatments were arranged in a 3 x 5 factorial by applying in a Randomized Complete Block Design (RCBD) with two replications and each replication there were two sub replications. The first factor was the application of boron with concentrations of 0, 10 and 20 ppm, respectively. The second factor was the application of silica, of 0, 50, 100, 150 and 200 ppm, respectively. Treatments combination or experimental unit was in the form of plastic buckets filled with a red-yellow podzolic mud soil media as much 8 kg/bucket. The homogeneity of variance was tested using Bartlett's test and the non-additivity of model using Tukey's test. The difference of means were analyzed using orthogonal contrast and polynomial at 5% and 1% probability level.

Materials used in this study were Mekongga rice seed variety released by Indonesian breeders, distilled water, urea, SP-36, KCl, monosilica sodium ($Na_2SiO_3.9H_2O$), boric acid (H_3BO_3), bactericides and insecticides. Potential yield of Mekongga varieties reached 8.4 tons/ha, resistant to pests (brown planthopper biotype 2 and 3) and diseases (bacterial leaf blight strains IV), so widely grown by farmers. Boric acid (H_3BO_3) needed to create boron solutions with concentration of 10 and 20 ppm those were equivalent to 0.06 and 0.11 g, respectively. Silica fertilizer needed to make 1 liter of solution with concentration of 50, 100, 150 and 200 ppm was equivalent to 0.51; 1.01; 1.52; 2.03 g of Si, respectively. Based on the analysis result of N, P and K levels with a colorimetric method (staining), fertilizer added was equivalent to 200 kg urea/ha (1.25 g/buckets), 75 kg SP-36/ha (0.47 g/buckets), and 50 kg KCl/ha (0.31 g/buckets).

Media was flooded for 30 days to reach a pH of 6-7. Rice seeds were soaked in water for 24 hours, and then wrapped using gauze for 48 hours, so that the seed germinated uniformly. The germinating seed were then sown in seedbed. When seedlings were 21 days old (days after sowing) then seedlings were transferred the seedbed to the bucket. The seedlings were planted right in the middle of circle of bucket, two seedlings per bucket, at a depth of 3-5 cm. After one week old, one less vigor of the seedling was removed and leaving the vigorous one to grow in the bucket. Boron and silica was applied when the plants were 28, 35 and 42 Days After Planting (DAP). Watering was done by flushing water in the bucket to the brim each began to dry with the aim of giving an opportunity to oxidation. Weeding was done physically if there were weeds growing. Basic fertilization was performed at the age of 7 DAP for half dose of urea fertilizer, as well as full dose of SP-36 and KCl. Rest of half dose of urea fertilizer was added after the plant was 36 DAP. Controlling of pest and disease was carried out if during the observation was found the symptoms. Harvesting was done at the time the plant was 120 days, marked by race grain and flag leaf yellowing and water content ranging from 17%-23%. Furthermore, the drying of seeds were done until the seeds moisture content around 11%.

Observations to components of growth included plant height (at 9 weeks after planting), productive tiller number (at 13 weeks after planting), tiller angle (at 49 days after planting), greenness leaves level (at 42 days after planting) and plant dry weight (at 65 days after planting); and yield components observed after the harvest: filled grain number, total grains number, unfilled grain number, filled grain weight, unfilled grain weight, 1000 grain weight, and yield potential.

Plant height measured from the ground to the tip of the highest leaf. Productive tiller number was calculated as the number of tillers those produced filled panicles. Tiller angle was an angle formed between the main stem with tiller. Greenness leaves level observation was performed with chlorophyll meter. Plant dry weight was made by weighing the stover of rice plant dried in the oven at a temperature of 80°C for 3 x 24 hours. Filled grain number was determined by counting the filled grains number per plant. Total grain number was calculated by adding up all the filled grain and unfilled grain per plant. Filled grain weight was calculated by weighing the whole filled grain weight per plant. Weight of 1000 grains was calculated with the provisions of ISTA. Potential yield was calculated by weighing the pithy grain per plant, then converted it into ton/ha at moisture content of seed around 11%.

3. Results and Discussion

The results showed that the application of boron through the leaves did not affect the rice growth and yield. Increasing the concentration of silica applied through the leaves did not affect the rice growth and yield. Rice plant responses to increased concentration of silica were independent on the increased concentration of boron (data were not given).

Standard error of the mean of the effect of boron on the rice growth and yield showed no differences on the application of 0, 10 and 20 ppm boron, respectively (Tables 1 and 2). This was also shown on the application of silica which showed no difference in the growth and yield of the application 0, 50, 100, 150 and 200 ppm silica, respectively (Tables 3 and 4).

Table 1. Standard Error of the Mean (SEM) of the Effect of Boron on Plant Height (PH), Productive Tiller Number (PTN), Tiller Angle (TA), Greenness Leaves Level (GLL) and Plant Dry Weight (PDW)

Treatments	PH ± SEM	PTM ± SEM	TA ± SEM	GLL ± SEM	PDW ± SEM
	9 WAP	13 WAP	49 DAP	42 DAP	65 DAP
0 ppm Boron	103.20 ± 1.40	12.1 ± 0.55	25.52 ± 0.97	38.32 ± 0.42	42.45 ± 1.58
10 ppm Boron	105.40 ± 1.99	12.1 ± 0.44	25.28 ± 1.88	38.31 ± 0.32	42.53 ± 2.85
20 ppm Boron	103.75 ± 3.48	11.8 ± 0.40	25.26 ± 1.40	38.29 ± 0.44	41.08 ± 2.08

Note. WAP = Weeks After Planting; DAP = Days After Planting.

Table 2. Standard Error of the Mean (SEM) of the Effect of Silica on Plant Height (PH), Productive Tiller Number (PTN), Tiller Angle (TA), Greenness Leaves Level (GLL) and Plant Dry Weight (PDW)

Treatments	PH ± SEM	PTN ± SEM	TA ± SEM	GLL ± SEM	PDW ± SEM
	9 WAP	13 WAP	49 DAP	42 DAP	65 DAP
0 ppm Silica	104.00 ± 0.93	11.92 ± 0.41	25.71 ± 1.95	38.21 ± 0.62	40.35 ± 1.57
50 ppm Silica	102.67 ± 3.28	12.67 ± 0.37	26.42 ± 0.83	38.49 ± 0.31	41.58 ± 1.85
100 ppm Silica	107.50 ± 1.45	12.08 ± 0.37	25.76 ± 1.20	38.74 ± 0.36	44.83 ± 1.58
150 ppm Silica	101.42 ± 1.01	12.00 ± 0.47	25.47 ± 1.02	38.12 ± 0.11	41.71 ± 3.32
200 ppm Silica	105.00 ± 2.89	11.33 ± 0.27	23.42 ± 1.44	37.96 ± 0.21	41.62 ± 1.95

Note. WAP = Wees After Planting; DAP = Days After Planting.

The application of boron through the leaves did not affect growth and yield of rice. It might be caused by the high boron concentration in the planting media. Based on the analysis before planting, the content of boron in the soil used as planting media was 9.571 mg/g or 0.001% (10 ppm). Nutrients and water absorbed by plants through the roots both entered to the mass flow in apoplast and followed the symplast path. Afterward the nutrients and water went to the endodermis, flowed through xylem tissues following the transpiration stream towards the top of the plant. Miwa and Fujiwara (2010) revealed that boron in the soil absorbed by plants in form of boric acid soluble in water and largely distributed through the transpiration stream. Water was absorbed by roots and CO_2 through the leaves. They were used by plants to produce photosynthate in carbohydrate forms. Boric acid in plants is easy to bind into a complex with polyhydroxyl compounds (Camacho-Crist'obal, 2008). Furthermore, boron plays a role in regulating the transport and translocation of sugar through the plant cell membranes (Stangoulis et al., 2010).

High levels of boron in the soil resulted in increased distribution of carbohydrates thus increased cell respiration. Respiration in plants occurs in aerobic (requiring O_2) and anaerobic (not requiring O_2). Through a series of aerobic respiration, glycolysis process converts glucose into pyruvic acid to form tyrosine phosphatase involved in the synthesis of fats, proteins and other compounds. The next process, in the Kreb's cycle transfers electrons to mitochondria to change to energy. The energy is also formed from the excess of lactic acid and other fermentation (anaerobic respiration). The energy created is used for the formation of new cells in all parts of the plant. This energy is also used to remodel pyruvic acid (in the aerobic respiration) in forming of fat, proteins and other compounds. Fat then forms a layer of wax (which costs the energy) in the leaf cuticle which acts as a barrier membrane between plants and the environment which limits the exchange of water, solutes and gases (Aslan et al., 2014; Fernandez et al., 2013). Increased distribution of carbohydrate supported by high levels of boron may cause the increase of pyruvic acid and fat synthesis, which results in high wax synthesis.

Table 3. Standard Error of the Mean (SEM) of the Effect of Boron on Filled Grain Number (FGN), Total Grain Number (TGN), Unfilled Grain Number (UGN), Filled Grain Weight (FGW), Unfilled Grain Weight (UGW), 1000 Grain Weight (1000 GW) and Yield Potential (YP)

Treatments	FGN ± SEM	TGN ± SEM	UGN ± SEM	FGW ± SEM	UGW ± SEM	1000 GW ± SEM	YP ± SEM
	120 DAP	120 DAP	120 DAP	120 DAP	120 DAP	120 DAP	120 DAP
0 ppm Boron	1853.60 ± 51.70	1718.25 ± 44.05	135.35 ± 25.49	45.53 ± 1.08	0.54 ± 0.11	26.21 ± 0.29	7.28 ± 0.17
10 ppm Boron	1874.85 ± 37.56	1724.95 ± 41.80	149.90 ± 11.15	44.73 ± 1.19	0.59 ± 0.03	26.06 ± 0.25	7.19 ± 0.22
20 ppm Boron	1772.75 ± 78.65	1654.30 ± 61.29	118.45 ± 22.30	42.63 ± 0.92	0.47 ± 0.10	26.02 ± 0.49	6.80 ± 0.19

Note. DAP = Days After Planting.

Table 4. Standard Error of the Mean (SEM) of the Effect of Silica on Filled Grain Number (FGN), Total Grain Number (TGN), Unfilled Grain Number (UGN), Filled Grain Weight (FGW), Unfilled Grain Weight (UGW), 1000 Grain Weight (1000 GW) and Yield Potential (YP)

Silica	FGN ± SEM	TGN ± SEM	UGN ± SEM	FGW ± SEM	UGW ± SEM	1000 GW ± SEM	YP ± SEM
Treatments (ppm)	120 DAP	120 DAP	120 DAP	120 DAP	120 DAP	120 DAP	120 DAP
0	1837.67 ± 91.96	1695.08 ± 61.36	142.58 ± 39.16	44.69 ± 1.19	0.57 ± 0.18	25.88 ± 0.46	7.13 ± 0.33
50	1855.50 ± 37.76	1710.75 ± 41.05	144.75 ± 11.05	44.67 ± 1.32	0.59 ± 0.04	26.27 ± 0.37	7.04 ± 0.28
100	1887.33 ± 33.47	1758.25 ± 28.21	129.08 ± 8.12	44.90 ± 1.14	0.52 ± 0.04	25.86 ± 0.40	7.18 ± 0.18
150	1782.17 ± 98.24	1658.83 ± 81.31	123.33 ± 28.46	44.27 ± 2.40	0.47 ± 0.11	26.29 ± 0.14	7.08 ± 0.38
200	1806.00 ± 45.26	1672.92 ± 36.94	133.08 ± 19.71	42.95 ± 0.60	0.52 ± 0.07	26.19 ± 0.35	7.01 ± 0.11

Note. DAP = Days After Planting.

The entry of nutrients applied through the leaves in the morning is mostly happen in the leaf cuticle through wax epicuticular surface (wax is the outermost and the most hydrophobic component on the leaf surface; Wojcik, 2004). The high formation of wax in the cuticle layer causes boron and silica which is applied through the leaves in this study is difficult to be absorbed by plants. High levels of boron in the media led to the adequacy of boron in the plant are met, as a result of boron through the leaves actually cause the formation of wax, so that Si from the leaves can't sign cause the absence of interaction with the influence of Si and B is applied through the leaves. Given the boron was applied in the morning while the silica in the afternoon. This was indicated by all the variables of growth which were not different. Wahyuti et al. (2012) shown greenness leaves level was positively correlated with yield of rice. This is appropriate with the results which showed that the foliar application of boron, silica and their interaction do not affect growth and yield of rice in high boron content media. The possible physiology effect of boron and silica foliar application in high boron content media can be seen in Figure 1.

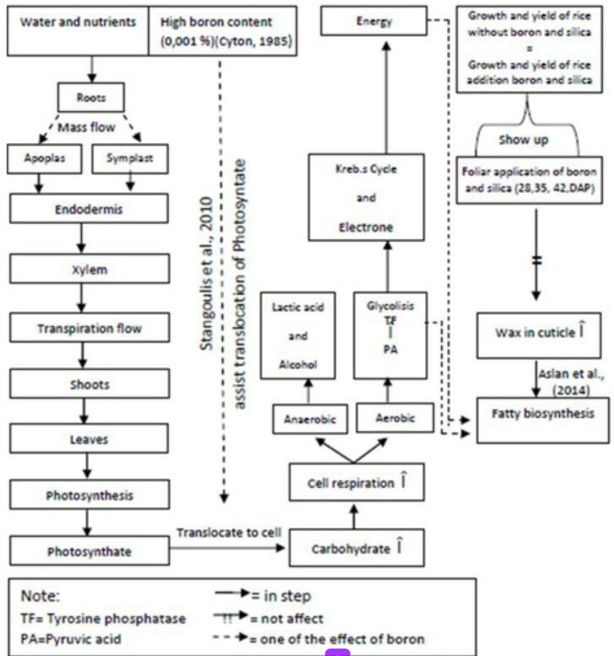

Figure 1. Diagram the Possible Physiology Effect of Boron and Silica Foliar Application in High Boron Content Media

4. Conclusion

The results showed that the foliar application of boron, silica and their interaction do not affect growth and yield of rice in high boron content media. The high formation of wax in the cuticle layer supported by high levels of boron may causes boron and silica which is applied through the leaves in this study is difficult to be absorbed by plants.

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