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The impact of silica and urea fertilization to yield characters and seed quality of IPB 3S rice varieties in lowland swamp ecology

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Abstract

IPB 3S rice has high yield potential, but was reported low productivity is caused by high empty grain, lodging, and unbalancing nutrient. Lowland swamp ecology to be an alternatif to increase rice production, but has low pH, high Fe, and unbalancing nutrient for rice cultivation in its ecology. The low productivity could be overcome by fertilization of N, P, K, and Silica (Si). This study aims to determine the impact of the silica and urea fertilization to yield characters and seed quality of IPB 3S rice varieties in lowland swamp ecology. The research was carried on June to September 2017 in Banyuasin, South Sumatera. The experiment was arranged in a Factorial Randomized Block Design consisting with doses of Silica (1.33L ha^{-1} in twice application, 2L ha^{-1} in once application, and 2L ha^{-1} in twice application), and doses of Urea in twice application (2.5kg ha^{-1}, 3.3kg ha^{-1}, and 5kg ha^{-1}). Silica affected the tiller number (TN), productive tiller number (PTN), grain number $panicle^{-1}$ (GNP), and filled grain number $panicle^{-1}$ (FGNP), and doses of 1.33L showed the highest those characters. Urea affected the GNP, FGNP, filled grain number $clumps^{-1}$ (FGNC), and doses of 5kg ha^{-1} showed the highest those characters. The interaction affected the TN, PTN, GNP, and FGNP, and interaction of 1.33L and 5kg ha^{-1} showed the highest those characters. Neither, silica and urea didn't affect seed quality, but 1.33L and 2.5kg ha^{-1} interaction showed the highest growth rate.

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Introduction

IPB University released IPB 3S rice varieties_a new type rice has high yield potential is 11.23ton ha^{-1}. Nevertheless, that varieties was reported still has constrain to reach the potential yield. The constrain faced among the high empty grain, lodging, and cultivation in different ecology. The high grain empty and lodging cause the low production, and unoptimal condition decrease the growth and yield.

Lowland swamp ecology has a potency to be an alternatif to increase rice production. Sumatera, Kalimantan, and Papua Island has a huge potency of lowland swamp ecology (Swamp Directorat, 1984). South Sumatera is an province that has about 2 millions hectare lowland swamp land and its has not been optimized. Low pH, high Fe, and unbalancing nutrient in lowland swamp land to be the constrain for rice cultivation in its ecology. Its problem could overcome by the fertilization to increase the nutrient balancing.

The low productivity is caused by high empty grain, lodging, and unbalancing of nutrient could be overcome by fertilization of N, P, K, and Silica (Si). Following N, P, K, and Si was ranked as the fourth most important element for rice production in rice-growing Countries of Southeast Asia (Gong *et al.,* 2012). Silica is considered as an important determinant in rice production because it contribution to rice grain yield and quality (Meharg and Meharg, 2015). The supply of silica nutrients, both nano-sized and particulate, has a significant effect on the growth of rice crops (Amrullah *et al.,* 2014). Mulyani (2017) reported that silicon fertilizer application significantly increased the plant height, and influenced to productive number tiller, percentage of filled grain number on IPB 3S rice varieties.

N, P and K nutrients are often restricted in plant growth, for example the role of nitrogen as a macro nutrient gives a significant effect on rice seed production. High N-giving is reported to reduce the number of seeds in rice plants, and Chen *et al.* (2014) reported that plant height, number of tillers, leaf size and number of seeds per panicle may be reduced in case of N deficiency. Kusuma (2015) reported that the treatment of N fertilizer doses significantly affected the percentage of filled grain and empty grain, where increasing the dosage of N fertilizer will cause the decrease of percentage of filled grain and increase percentage of empty grain IPB 3S rice varieties. While the urea fertilizer application is still applied to the soil, whereas foliar application of urea along with soil application is economical and can compensate the yield losses (Saleem *et al.*, 2013).

Information of yield characteristics and seed quality of IPB 3S rice by Urea and silica fertilization in lowland swamp ecology has ever been informed. Therefore, this information was neeeded to increase the yield production and seed quality of rice in lowland swamp ecology for National food resilience. This study aims to determine the impact of the silica and urea fertilization to yield characters and seed quality of IPB 3S rice varieties in lowland swamp ecology.

Materials and methods

Place and time of research, and experiment design

The research was carried on June to September 2017 in Banyuasin, South Sumatera. The experiment used a Factorial Randomized Block Design consisting of 2 factors with 3 replications. First factor was dose of Silica fertilizer, ie 2L ha^{-1} in once application, 2L ha^{-1} in twice application, and 1.33L ha^{-1} in twice application. The second factor was dose of Urea fertilizer in twice application, ie 5kg ha^{-1}, 3.3kg ha^{-1}, and 2.5kg ha^{-1}.

Seed production in field

Seeds were sown for 40 days in twice seeding. The first seeding was done for 15 days, while the second seeding was done for 25 days. 40 days old seedlings after sowing was planted in plot (120m^2 per treatment) using spacing 25 cm x 25cm, and each hole was planted 3 seedlings. Basic fertilization was given on 3 times, ie on the second seeding (5kg ha^{-1} Phonska fertilizer), on 12 days after planting (150kg ha^{-1} Phonska fertilizer), and on 20 days after planting (150kg ha^{-1} Phonska fertilizer). Application of Silica and Urea fertilizer through leaves (sprayed) was done when the plants were 6 and / or 7 weeks after planting (WAP).

The parameters observed were plant height (cm), flag leaf length (cm), tiller number (tiller), productive tiller number (tiller), panicle length (cm), grain number panicle^{-1} (seed), filled grain number panicle^{-1} (seed), filled grain weight clump^{-1} (g), 1000 grain weight (g), and silicate content in the stem. Observation of plant height, tiller number, productive tiller number, and filled grain weight clump^{-1} was done on 5 sample plants in each experimental plot. Observation of panicle length, grain number panicle^{-1}, filled grain number panicle^{-1} was done by measuring 1 panicle per sample plant. The collected data were analyzed using analysis of variance (α = 0.05), and will be continued Duncan's Multiple Range Test (DMRT) if showed significant effect by Statistical Tools Agricultural Research (STAR).

Seed viability and vigor testing

Seed viability and vigor testing was done by a rolled paper test method using stencil paper substrate. 50 seed were sown in one roll. For each sample, eight rolls were used for testing 400 seeds. The rolls were placed in IPB 73-2A/B type Ecogerminator. Seed germination was recorded at 5 and 14 days after sowing. Normal seedling, abnormal seedling, and dead seeds were counted separately and expressed in percentage. Normal seedling percentage at 5 days after sowing was recorded as vigor index. Growth rate was recorded by counting normal seedling on each 24 hours until 14 days after sowing. Normal seedling criteria was observed by ISTA Rules (2014). The collected data were analyzed using analysis of variance (α = 0.05), and will be continued Duncan's Multiple Range Test (DMRT) if showed significant effect by Statistical Tools Agricultural Research (STAR).

Results and discussion

The rice yield was estimation by the yield characters such as tiller number, productive tiller number, panicle length, grain number panicle^{-1}, filled grain number panicle^{-1}, filled grain number per clumps^{-1}, and 1000 seed weight. There is a positive interaction between the yield characters and yield. Cultivation ecology very affected the vegetative and generative growth. The poor growth in both phase lead the low production and poor seed quality in seed production.

Yield characters

The fertilization was applied to support rice growth in lowland swamp ecology. Silica fertilization significant to characters of tiller number, productive tiller number, grain number panicle^{-1}, filled grain number panicle^{-1}, but did not significant to other characters (Table 1). Dobermann *et al.* (2000) reported that silicon was the only non-essential nutrient included in the guidelines for rices fertilization. Pati *et al. (*2016) was reported Si plays an enhancement rice growth. Si deficiency lead to decrease seed quality (Makarim *et al.,* 2014), and tiller number (Timotiwu and Dewi*,* 2014).

Doses of silica 1.33L (twice application) showed the highest tiller number, productive tiller number, grain number panicle^{-1}, and filled grain number panicle^{-1}. Hossain *et al.* (2002) reported that silicon, which is mainly absorbed by the roots in the form of silicic acid (H_4SiO_4) and is distributed extensively throughout rice plant tissues, can effectively stimulate the growth of rice plants. Results also revealed that Silica addition helped plant growth, which might be due to the increased photosynthetic efficiency upon Silica addition, and it was exerted through the numbers of productive tillers, panicle length, the percentage of filling grains, 1000-grain weights, and the reduction of pest and disease infestation. This corroborated the findings (Buck *et al.,* 2008; Prakash *et al.,* 2011; Gholami and Falah, 2013; Pati *et al.,* 2016; Timotiwu *et al.,* 2017). Applying slag-based fertilizer to Si-deficient paddy soil is necessary for improving both rice productivity and brown spot resistance (Ning *et al.,* 2014). Dharmika (2016) observed that silicon fertilizer application could increased the number tiller, productive number tiller, percentage of filled grain number and also resistancy to stem rot disease on IPB 3S rice varieties.

Table 1. The effect of silica and urea fertilization yield characters of IPB 3S rice varieties in lowland swamp ecology.

Silika	Urea			Average
	2.5kg ha-1	3.3kg ha-1	5kg ha-1	
	Plant height (cm)			
1.33 L ha-1 (twice application)	67.1 ab	69.7 ab	69.4 ab	68.7
2 L ha-1 (once application)	63.5 b	67.5 b	71.1 a	67.4
2 L ha-1 (twice application)	69.3 a	72.0 a	66.3 b	69.2
Average	66.6 b	69.7 a	68.9 ab	
	Flag leaf length (cm)			
1.33 L ha-1 (twice application)	38.7	37.5	40.7	38.9
2 L ha-1 (once application)	38.2	33.0	39.7	36.9
2 L ha-1 (twice application)	40.1	36.2	34.9	37.1
Average	39.0	35.6	38.4	
	Tiller number (tiller)			
1.33 L ha-1 (twice application)	14.3	17.0	16.0	15.8 a
2 L ha-1 (once application)	17.0	15.3	14.3	15.5 a
2 L ha-1 (twice application)	14.3	12.0	12.7	13.0 b
Average	15.2	14.8	14.3	
	Productive tiller number (tiller)			
1.33 L ha-1 (twice application)	12.3	14.3	13.7	13.4 a
2 L ha-1 (once application)	15.0	13.3	13.0	13.8 a
2 L ha-1 (twice application)	12.0	10.0	10.0	10.7 b
Average	13.1	12.5	12.2	
	Panicle length (cm)			
1.33 L ha-1 (twice application)	27.3	27.4	27.7	27.4
2 L ha-1 (once application)	24.9	27.1	27.9	26.7
2 L ha-1 (twice application)	26.9	28.1	27.7	27.6
Average	26.4	27.5	27.8	
	Grain number per panicle (seed)			
1.33 L ha-1 (twice application)	143.7 b	130.9 b	169.6 a	148.1 a
2 L ha-1 (once application)	110.2 c	131.5 b	144.3 b	128.7 b
2 L ha-1 (twice application)	126.0 c	133.7 b	130.0 b	129.9 b
Average	126.6 b	132.0 b	147.9 a	
	Filled grain number per panicle (seed)			
1.33 L ha-1 (twice application)	114.8 b	103.6 b	134.8 a	117.8 a
2 L ha-1 (once application)	80.5 c	99.6 b	107.6 b	95.9 b
2 L ha-1 (twice application)	95.1 c	103.1 b	107.1 b	101.8 b
Average	96.8 b	102.1 b	116.5 a	
	Filled grain weight per clump (g)			
1.33 L ha-1 (twice application)	23.9	33.0	33.6	30.2
2 L ha-1 (once application)	24.9	27.6	31.9	28.1
2 L ha-1 (twice application)	25.3	26.8	27.6	26.6
Average	24.7 b	29.1 a	31.0 a	
	1000 grain weight (g)			
1.33 L ha-1 (twice application)	29.02	29.16	29.34	29.17
2 L ha-1 (once application)	28.46	28.63	28.76	28.62
2 L ha-1 (twice application)	29.02	28.76	28.77	28.85
Average	28.83	28.85	28.96	

Values in the same column with the same letter are not significantly different at the $P < 0.05$ level using Duncan's test

Urea fertilization significant to characters plant height, grain number panicle-1, filled grain number panicle-1, and filled grain number per clumps-1, but did not significant to others characters (Table 1). The availability of nitrogen is a major factor in plant growth and productivity (Zhao *et al.*, 2003). Nitrogen elements are needed by plants as constituent components of amino acids, nucleic acids, nucleotides, and chlorophyll (Havlin *et al.*, 1999).

Interaction of both fertilization showed the significant effect to grain number panicle-1 and filled grain number panicle-1 (Table 1). The role of nitrogent to support the vegetative growth will provide the well generative performance, and resulted the good grain fiilling in generative process. Silica roles to increased the suculence of stem, and resilience to lodging.

Grain filling in generative process will determine the seed quality. High seed quality was indicated by the high germination percentage, maximum growth potential, vigour index, growth rate, and dry weight of normal seedling. The effect of silica and urea fertilization to seed quality were presented in Table 2. The result showed neither silica and urea did not signifcant effect to seed quality. The interaction of both showed significant effect to growth rate, nevertheless did not significant effect to other parameters. The high growth rate was obtained in interaction of 1.33L Si (twice application) and 2.5kg ha^{-1} Urea.

Table 2. The effect of silica and urea fertilization on seed quality of IPB 3S rice varieties in lowland swamp ecology.

Silica	Urea			Average
	2.5kg ha^{-1}	3.3kg ha^{-1}	5kg ha^{-1}	
	Seed germination percentage (%)			
1.33 L ha^{-1} (twice application)	86.0	81.5	89.0	85.5
2 L ha^{-1} (once application)	88.0	89.0	87.0	88.0
2 L ha^{-1} (twice application)	81.5	84.0	86.5	84.0
Average	85.2	84.8	87.5	
	Maximum growth potential (%)			
1.33 L ha^{-1} (twice application)	89.5	86.0	94.5	90.0
2 L ha^{-1} (once application)	92.0	94.5	87.5	91.3
2 L ha^{-1} (twice application)	88.0	87.0	89.0	88.0
Average	89.8	89.2	90.3	
	Vigour index (%)			
1.33 L ha^{-1} (twice application)	65.0	44.0	61.0	56.7
2 L ha^{-1} (once application)	57.5	56.0	62.0	58.5
2 L ha^{-1} (twice application)	50.5	54.0	46.5	50.3
Average	57.7	51.3	56.5	
	Growth rate (% etmal-1)			
1.33 L ha^{-1} (twice application)	21.0 a	18.4 b	18.3 a	19.2
2 L ha^{-1} (once application)	19.2 b	20.9 a	16.0 b	18.7
2 L ha^{-1} (twice application)	20.4 a	19.7 b	17.6 a	19.2
Average	20.2 a	19.6 ab	17.3 b	
	Dry weigth of normal seedling (g)			
1.33 L ha^{-1} (twice application)	0.0053	0.0058	0.0055	0.0055
2 L ha^{-1} (once application)	0.0058	0.0059	0.0057	0.0058
2 L ha^{-1} (twice application)	0.0058	0.0060	0.0057	0.0058
Average	0.0056	0.0059	0.0056	

Values in the same column with the same letter are not significantly different at the $P < 0.05$ level using Duncan's test

Oliveira *et al.* (2016) reported that treatment of rice seeds with silicon does not adversely affected the physiological quality of treated seeds, and it provides the production of rice seeds with greater vigor. Si fertilizer could improve rice nutritional quality by increasing concentrations of mineral elements, protein and some amino acids in brown and milled rice (Liu *et al.,* 2017). The application of nitrogen fertilizer with urea, at tillering and floral primordium at 34kg ha-1 of N increased the production of rice seeds, and it increased rice seeds yield and physiological quality (Santana *et al.,* 2017).

Conclusion

Silica fertilization affected the characters of tiller number, productive tiller number, grain number panicle^{-1}, and filled grain number panicle^{-1} on IPB 3S rice in lowland swamp ecology, and doses application of 1.33L (twice application) showed the high tiller number, productive tiller number, grain number panicle^{-1}, and filled grain number panicle^{-1}.

1. Urea fertilization affected the character of grain number panicle^{-1}, filled grain number panicle^{-1}, filled grain number clumps^{-1} on IPB 3S rice in lowland swamp ecology, and doses application of 5kg ha^{-1} showed the high grain number panicle^{-1}, filled grain number panicle^{-1}, and filled grain number clumps^{-1}.
2. The interaction of silica and urea fertilization affected characters of tiller number, productive tiller number, grain number panicle^{-1}, and filled grain number panicle^{-1} on IPB 3S rice in lowland swamp ecology, and the interaction of 1.33L (twice application) and 5kg ha^{-1} showed the highest those characters.
3. Neither silica and urea fertilization did not affect seed quality of IPB 3S rice in lowland swamp

ecology. The interaction of silica and urea fertilization, 1.33L (twice application) and 2.5kg ha^{-1} showed the highest growth rate.

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