Effect of Silica Fertilizer to Growth and Yield of Rice (*Oryza sativa* L.) in Jajar Legowo Method

ABSTRACT

Aims: The research aimed to study the interaction between Jajar Legowo method and silica fertilizer doses to growth and yield of rice.

Study design: Factorial design in Completely randomized design

Place and Duration of Study: The research was conducted in farmer's rice field in Linggo Sari Baganti, Pesisir Selatan, West Sumatera, Indonesia from July to Oktober 2020.

Methodology: Factorial design with 2 factors in completely randomized design was used in the research. The first factor was Jajar Legowo method that consisted of 3 degrees (2:1, 3:1 dan 4:1) and the second factor was silica fertilizer doses that consisted of 4 degrees (0 ml/L, 5 ml/L, 10 ml/L and 15 ml/L). The data was analysed using F test 5% and continued by Duncan's New Multiple Range Test (DNMRT) 5%

Results: Generally, the interaction between Jajar legowo method and silica fertilizer did not affect the production of rice plant. But, for single factor both jajar legowo method and silica application affected the growth of rice plant

Conclusion: The production per hectare of rice plant was lower than description so that this method should be improved to obtain the better result.

Keywords: Jajar legowo, rice, silica

1. INTRODUCTION

Rice is main staple food for Indonesia people. The demand for rice in the country always increased follows the increasing of population growth (2% per year) and the change of consumption pattern from non-rice to rice as main staple food [1]. If this condition is allowed, it will lead to food crisis. One of effort to avoid the food crisis is to increase the production by increasing the rice productivity.

Indonesia rice production in 2019 was 54.60 million ton and it decreased 4.60 million ton or 7.76 than 2018 [2]. In addition, in 2020, the global covid-19 production during 2020 caused the prediction of consumed rice increased. This condition indicates the government should find the solution to support national food security.

Many technologies have been introduced and applied by government and Indonesian research institute to increase rice production in Indonesia. One of them was Jajar Legowo method. Jajar Legowo was a method that used the planting space to increase rice production [3]. The system manipulated the layout of plants so that most cluster of plant became edge plants. Edge rice plants obtained more solar radiation and it could produce more grains of better quality. This system had more number of clump per unit area than conventional method that usually used by farmers. As comparison, if rice plants were planted by using conventional method, it produced 160,000 clumps per hectare and jajar legowo could produced 213,333 clumps per hectare [4]. The orientation of jajar legowo, even though in same population, it had a chance to produce more grains due to the occurrence of photosynthesis. This condition was caused by the ability of the plants to effectively absorb solar radiation and the easiness of carbon dioxide diffusion [5].

The good technology should be supported by sufficient nutrients to support the well growth and development of plant. One of nutrient that was reported and rare to use as fertilizer was silica [6]. Even though Si is not essential element for plant, but Si could increase plant production. This condition was caused by silica as it could improve plant physical characteristic and affect P solubility in soil. There was no other non-essential elements that was present consistently in plant as silica. In rice plant, Silica content was higher than macro elements (N, P, K, Ca, Mg and S)[7]. Deficiency of Si in plant caused plant leaves, ineffectiveness to absorb sunlight. These conditions caused low productivity or not optimal productivity. The other effect of Si deficiency is that the plant is susceptible to biotic and abiotic stress [8].

Ineffectiveness of silica was the separate problem so that the application of this element should be considered carefully. In Indonesia, the use of silica as fertilizer was not used widely so that the information of the element was still few. The research aimed to study the effect of silica fertilizer to growth and yield of rice in jajar legowo method.

2. MATERIAL AND METHODS

2.1 Experimental site

The research was conducted in farmer's rice field in Linggo Sari Baganti, Pesisir Selatan, West Sumatera, Indonesia from July to October 2020. The used materials were IR42 rice variety, liquid silica fertilizer, manure, urea, SP-36 and KCl fertilize, hoe, hand tractor, seedbag, sprayer and stationery.

Factorial design in completely randomized design was used in the research. The first factor was Jajar Legowo method that consisted of 3 degrees (2:1, 3:1 and 4:1). The second factor was silica fertilizer doses that consisted of 4 degrees (0 ml/L, 5 ml/L, 10 ml/L and 15 ml/L). Each experimental unit consisted of three replicates. The data was analyzed by F test in 5% and continued by Duncan's New Multiple Range Test (DNMRT) in 5%.

2.1 Procedure

The research was started by land preparation. The plowing was conducted two times. The first one was conducted using tractor by reversing the ground layer and then the land was flooded during the cultivation. The second one was conducted a week after the first one. In the second plowing, the sludging was conducted.

The nursery was conducted in experimental land sized 2 m x 1 m. The used variety was IR42. The nursery was conducted as follows: 1) Seeds selection by entering the seed into the bucket that contained water, 2) the float seeds was thrown out and submerged seeds were soaked for 48 hours and then dried for 12 hours until germinating, 3) The germinated seeds was sown for 21 days.

The used seedlings was 21 days after nursery (dan). The planting was conducted together with 2 seedlings per hole. The silica application was conducted by spraying. The spraying was conducted in 10, 20, 30 and 40 days after planting (dap). Fertilization was conducted by sowing. The fertilization was conducted by using urea according the recommendation, 250 kg/ha. It was conducted two weeks and five weeks after planting and 100 kg/ha of KCl was applied five weeks after planting.

The harvesting was conducted when the rice plants became yellowing 90% in one clump, the leaves were drying and grains were yellowing. The observations were Leaf area index (LAI), net assimilation rate, plant height, number of productive tiller, production per hectare and silica absorption. All data were tested by F test in 5% and continued by Duncan's New Multiple Range Test in 5%.

3.RESULTS AND DISCUSSION

3.1 Leaf area index (LAI)

The interaction between Jajar Legowo method and Silica affected the leaf are index (LAI). The result showed that Jajar Legowo 2:1 and 5 mL/L of silica was the best combination for this parameter (Table 1).

Table 1. Leaf area index of rice plant in 7-8 weeks after planting in Jajar Legowo method and silica fertilizer application (cm^2)

Jajar Legowo	Silica (ml/L)			
	0	5	10	15
2:1	2.90 b AB	4.34 a A	3.94 a A	3.60 ab B
3:1	2.52 b B	2.84 b B	3.35 a A	3.81 a A
4:1	3.00 b A	3.01 b B	2.87 b B	3.50 a B
CoD	6.63%			

Note: similar letters indicate significantly different according Duncan's New Multiple Range Test 5%; CoD : Coefficient of diversity

According the result, higher jajar legowo pattern that followed higher dose of silica, the LAI became higher. This condition was caused by 4:1 jajar legowo pattern was the best condition to absorb the silica. The LAI increasing was closely related to the ability of plant to absorb the sun energy. Higher LAI indicated the sun energy for photosynthesis was better until the certain range [8]. LAI was the indicator of plant growth than could show the photosynthesis relative component and the photosynthesis ratio of green leaves area for photosynthesis and soil area of plant [9]. LAI was also the indicator of plant potency to perform the photosynthesis and productive potency of plant in the field [10].

The plant could adapt to environmental change from optimum level and could complete the growth stages if the environmental condition was not higher that physiological limit so that the different silica application affected the leaves area index [11].

3.2 Net assimilation rate (NAR)

Net assimilation rate (NAR) was not affected by the interaction between jajar legowo pattern and silica application. For single factor, the jajar legowo method did not affect the NAR. Otherwise, the NAR was affected by silica application (Table 2). It was caused by the sunlight spread in canopy to perform photosynthesis, transpiration and repaired plasma membrane [12]. NAR was significantly caused by sunlight spread in canopy. Under shadow area decreased NAR [13].

Table 2. Net assimilation rate of rice plant in Jajar Legowo method and silica application

Jajar Legowo	Silica (ml/L)				Average
	0	5	10	15	
	cm^2				
2:1	7.07	8.26	8.87	10.33	8.63
3:1	8.53	10.97	9.52	11.14	10.04
4:1	7.67	10.30	9.48	9.60	9.26
Average	7.75 B	9.84 A	9.29 A	10.36 A	
CoD	8.73%				

Note: similar letters indicate significantly different according Duncan's New Multiple Range Test 5%; CoD : Coefficient of diversity

Canopy structure was caused by NAR. The canopy structure affected the number of light that absorbed by leaves due to the photosynthesis capacity did not relied to the factor that affected photosynthesis in leaves, but also affected by sunlight distribution in leaves [14]. Gardner (1991) [9] stated that the NAR was the description of dry weight accumulation of plant per time unit and size of leaves photosynthesis efficiency. Silica played role for plant in drought condition to increase the photosynthesis and root activity.

Plant growth relied on water availability in soil. The water was required to maintain protoplasm hydration, carried up the food and mineral materials and affected the nutrients absorption by plant root. Water availability in soil was significantly affected by temperature. High temperature caused the water availability decreased due to evaporation [15] .

3.3 Plant height

The plant height of rice was not affected by the interaction of jajar legowo method and silica application. As well as for jajar legowo as single factor, it did not affect the plant height of rice. But otherwise result showed that the silica application affected the plant height of rice (Table 3). The result showed that 10 ml/L and 15 ml/L were better than the other doses. This result was caused by silica could increase the photosynthesis so that the plant growth. Silica indirectly could increase photosynthesis efficiency through plant height growth and straightness of tiller corner. The plant height growth and straightness of tiller corner was caused by distribution and mobilization of silica in plant leaves tissue [16][17].

Table 3. Plant height of rice in Legowo method and silica application

Jajar Legowo	Silica (ml/L)				Average
	0	5	10	15	
	Cm				
2:1	120.62	122.28	130.42	131.78	126.28
3:1	119.82	123.58	126.45	128.62	124.62
4:1	119.20	122.27	129.40	129.77	125.16
Average	119.88 B	122.71 B	128.76 A	130.06 A	
CoD	3.29 %				

Note: similar letters indicate significantly different according Duncan's New Multiple Range Test 5%; CoD : Coefficient of diversity

The plant height was closely related to the role of silica affected the straightness of tiller corner so that it increased photosynthesis activity. The increasing of photosynthesis result will increase the cell formation so that the plant height increased [18]. The plant height was the result of cell division increasing due to assimilate increasing [19]. The silica effectiveness increase the plant height significantly due to leaves and stem grew straight. The plant stem was the sink part and cell elongation activity. The increasing of silica by using spraying method due to the apoplast of leaves could absorb silica. The leaves cells absorb the silica from apoplast [20].

3.4 Number of productive tiller

The result showed that the interaction of jajar legowo and silica application method did not affect the number of productive tiller. Otherwise, the different result was shown by jajar legowo method and silica application as single factor. For jajar legowo method, the 4:1 pattern was the best treatment for number of productive tiller. For silica application, the 15 ml/L silica was the best dose for number of productive tiller (Table 4). Number of productive tiller was the tiller that produced panicle. The planting space affected the ability of plant to grow and develop. Wide planting space increased the solar radiation absorption by plant canopy so that the number of productive tiller increased. In 4:1 pattern, the space was wider so that it reduce the competition to obtain nutrients, sunlight to photosynthesis process and it affected the number of productive tiller [3]. The rice plant quickly formed productive tiller if the nutrient and water were available. The other factor that affected the number of tiller was genetic factor and supported by the suitable environment for plant growth [19].

Table 4. Number of productive tiller of rice in Legowo method and silica application

Jajar Legowo	Silica (ml/L)				Average
	0	5	10	15	
2:1	24.44	29.04	22.04	28.91	26.11 b
3:1	22.32	27.12	27.98	28.65	26.52 b
4:1	28.00	24.00	32.06	31.33	28.85 a
Average	24.92 B	26.72 AB	27.36 AB	29.63 A	
CoD	12.27				

Note: similar letters indicate significantly different according Duncan's New Multiple Range Test 5%; CoD : Coefficient of diversity

Number of productive tiller was higher than control. It indicated that the silica affected the number of tiller and increased the photosynthesis in production stage of rice plant. The rice in drought condition if applied by silica, the plants showed the photosynthesis rate was higher that unfertilized by silica [17]. The number of productive tiller was closely related to the number of panicle. The panicle is shown in Figure 1.

Figure 1. The panicle of rice in jajar legowo method

3.5 Production per hectare

The interaction of jajar legowo and silica application did not affect the production per hectare of rice. The similar result was shown by single factor both jajar legowo method and silica application (Table 5).

Table 5. Production per hectare of rice in Legowo method and silica application

Jajar Legowo	Silica (ml/L)				Average
	0	5	10	15	
		ton			
2:1	5.90	6.48	6.97	5.46	6.20
3:1	5.32	7.50	6.73	6.60	6.55
4:1	6.10	6.97	6.65	7.02	6.68
Average	5.78	6.99	6.78	6.37	
CoD	18.50				

One of silica role was to increase the photosynthesis efficiency so that the rice production could increase. The other factor was the phosphorus absorption was not optimal, even though indirectly the organic silica application could increase the phosphorus availability in soil. Phosphorus was the important element for grain formation and early stage of maturity in cereal plants [19][21].

The production per hectare of the research was lower than the description of IR42 variety (7.0 ton/ hectare) [22]. Hopefulness, the use of jajar legowo method, the production of rice per hectare could be increased because this method was proven to increase the production per hectare. This result was caused by environmental factor. The environmental factor caused the most of photosynthesis result could not be distributed to panicle, but it was used for tiller formation. The generative development was supported by vegetative growth [13].

3.6 Silica absorption of rice plant

The interaction of jajar legowo method and silica application did not affect the silica absorption of rice plant. But, for single factor both of jajar legowo method and silica application affected the silica absorption. According the result for jajar legowo method, 4;1 pattern was the best treatment and 15 ml/L silica was the best treatment for silica absorption (Table 6).

Table 6. Silica absorption of rice in Legowo method and silica application

Jajar Legowo	Silica (ml/L)				Average
	0	5	10	15	
		g/plant			
2:1	4.62	3.33	8.06	4.63	5.16 b
3:1	4.06	5.67	8.55	14.20	8.12 a
4:1	6.31	9.14	18.45	34.59	17.12 a
Average	5.00 B	6.05 B	11.69 AB	17.81 AB	
CoD					

Note: similar letters indicate significantly different according Duncan's New Multiple Range Test 5%; CoD : Coefficient of diversity

The result showed that for higher dose of silica, the silica content of rice plant was higher. This result indicated that higher silica application caused the absorbed silica to be higher. Liquid silica fertilizer could increase the silica availability in rice plant. Apoplast of leaves cells played a role to absorb the silica [20]. Silica could improve the soil structure, water absorption and increased the nutrients absorption by plant. The well plant growth increased the photosynthesis process and photosynthate was higher. Silica in soil could stimulate photosynthesis and carbon dioxide translocation (CO_2) [23]. Silica in plant leaves played role to maintain the leaves straight and this helped the sunlight absorption in photosynthesis process and CO_2 translocation to panicle so that P role was optimal. Silica also reduced the abiotic stress effect such as temperature, solar radiation, wind, water and drought and also increased the plant resistance to biotic stress such as pests and diseases [24].

4. CONCLUSION

The interaction of jajar legowo method and silica application did not affect the production or rice plant. But, for several result, single factor of jajar legowo method and silica application affected the growth of rice plant.

REFERENCES

1. Gurning IP, Yuprin AD, Taufik EN. Trend and estimation or rice production and rice consumption in Central Borneo Province. Journal Socio Economics Agricultural. 2019, 14(1): 48-61

2. Statistics Indonesia. Rice production of Indonesia. 2019 https://www.bps.go.id/

3. Ikhwani, Pratiwi GR, Paturrohman E, Makarim AK. The increasing of rice productivity by jajar legowo method. IPTEK Tanaman Pangan. 2013, 8(2): 72-79

4. Witjaksono J. The Assessment of Legowo Planting System for Increasing Paddy Productivity in Southeast Sulawesi. Jurnal Pangan. 2018, 7(1): 1-8

5. Lin XQ, Zhu DF, Chen HZ, Zhang YP. Effects of plant density and nitrogen application rate on grain yield and nitrogen uptake of super hybrid rice. Rice Science. 2009, 16(2):138-142

6. Tubana BS, Babu T, Datnoff LE. A review of silicon in soils and plants and its role in US agriculture: History and future perspectives. Soil Science. 2016, 9/10: 1-19

7. Roesmarkam, Yuwono NW. Soil Fertility. Kanisius, Yogyakarta, Indonesia; 2002

8. Williams DE, Vlamis J. The effect of silicon on yield and manganese-54 uptake and distribution in the leaves of barley plants grown in culture solutions. Plant Physiol.1957, 32:404–409

9. Gardner FP, Pearce RB, Mitchell RL. Physiology of crop plants. University of Indonesia Press. 1991.

10. Aschonitis VG, Papamichail DM, Lithourgidis A, Fano EA. Estimation of leaf area index and foliage area index of rice using and indirect gravimetric method. Communication in soil science and soil analysis. 2014, 45:1726-1740

11. Dobermann A, Pampolino MF. Indirect leaf area index measurement as a tool for characterizing rice growth at the field scale. Communications in Soil Science and Plant Analysis.1995. 26 (9–10): 1507–1523.

12. Danmaigoro O, Ishaya DB, Shabayan JAY. Performance of upland rice (Oryza sativa L.) as affected by weed control treatments, poultry manure and stand density. Nigerian Journal of Agriculture, Food and Environment. 2015, 11(3): 1-6

13. Ko KMM, Hirai Y, Zamora OB, Guzman LED. Agronomic and Physiological Responses of Rice (*Oryza sativa* L.) under Different Water Management Systems, Fertilizer Types and Seedling Age. American Journal pf Plant Sciences. 2017, 8(17): 1-12

14. Mia MAB, Shamsuddin ZH. Physio-morphological appraisal of aromatic fine rice (Oryza sativa L.) in relation to yield potential. International Journal of Botany. 2011, 7(3): 223-229

15. Tanaka A. Physiological Aspects of Productivity in Field Crops: Potential Productivity of Field Crops Under Different Environments. IRRI, Los Banos, Philippines. 1983. pp 61-80.

16. Luyckx M, Hausman JF, Guerriero. Silicon and Plants: Current Knowledge and Technological Perspectives. Frontiers in Science. 2017, 8(411):1-8

17. Ma JF, Takahashi E. Soil, Fertilizer and Plant Silicon Reserach in Japan. Elsevier Science, Amsterdam, Netherland. Annals of Botany. 2002, 121(7):1265-1273.

18. Putri FM, Suedy SWA, Darmanti S. The effect of nanosilica fertilizer on number of stomata, chlorophyll content, and growth of black rice (*Oryza sativa* L. cv. Japonica). Bulletin Anatomi dan Fisiologi. 2017;2(1):72-79

19. Hall Jr RO, Baker MA, Rosi-Marshall EJ, Tank JL, Newbold JD. Solute-specific scaling in-organic nitrogen and phosphorus uptake in streams. Biogeoscience. 2013;10:7323-7331

20. Annunziata MG. Plant leaf apoplast: an easy method to estimate its hydration state and contents. Plant Physiology. 2019, 180: 688

21. Bahmanyar MA, Ranjbar GA. Response of rice cultivar to rates of nitrogen and potassium application in field and pot conditions. Pakistan Journal of Biological Sciences. 2007; 10(9):1430-1437

22. Ministry of Agriculture of Indonesia. Description of IR-42 variety. http://upbs.litbang.pertanian.go.id/index.php/varietas-detail/69/ir_42

23. Sahebi M, Hanafi MM, Akmar ASN, Rafii MY, Azizi P, Tengoua FF, Azwa JNM, Shabanimofrad M. Importance of silicon and mechanism of biosilica formation in plants. Biomed Research International. 2015, 396010: 1-16

24. Currie HA, Perry CC. Silica in plants: biological, biochemical and chemical studies. Annals of Botany. 2007,100 (7): 1383–1389

DEFINITIONS, ACRONYMS, ABBREVIATIONS

APPENDIX