The response of soybean (*Glycine max* (L) Merrill) growth to nanosilica fertilizer and rice husk ash treatment

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ABSTRACT

This study aimed to analyze the growth of soybean (*Glycine max* (L) Merrill) treated by nanosilica fertilizer and husk ash. The experiment was conducted at Palawija Seed Development Centre (PSDC) Plumbon, Cirebon, West Java from October 2017 to March 2018. The treatments consisted of two factors arranged in factorial randomized complete block design. The first factor was four levels of nanosilica fertilizer concentration (0, 1.25, 2.5, and 3.75 ml.l^{-1}) and the second factor was four levels of rice husk ash dose (0, 1, 2, and 3 ton.ha^{-1}). There were three replications within each treatment combination. The results showed that nanosilica concentration significantly affected LAI at 43 days after planting, while rice husk ash doses affected net assimilation rate (NAR) at 15-29 days after planting. There was interaction effect of nanosilica concentration and rice husk ash doses on the plants dry weight at 29 days after planting and RGR at 29–43 days after planting. The application of 2.50 ml.l^{-1} nanosilica resulted in the highest leaf area and LAI. The combination of 2.5-3.75 ml.l^{-1} nanosilica and 2–3 ton.ha^{-1} rice husk ash produced the highest biomass dry weight, while the combination of 1.25–2.50 ml.l^{-1} nanosilica and 3 tons.ha^{-1} rice husk ash resulted in the highest relative growth rate.

Keywords : nanosilica; rice husk ash; soybean growth

1 INTRODUCTION

The role of soybean (*Glycine max* (L.) Merr.) as the third source of food after rice and corn is highly needed to fulfill the need of vegetable protein. Soybean has potential as the source of vitamin, fat, mineral, and fiber among other legumes and as functional food since it contains secondary metabolites that are very beneficial to human health such as isoflavones and saponins. The increasing of soybeans for domestic needs has caused a gap between soybean production and consumption so that it strongly depends on imports. The soybean consumption projection shows that the total demand continues to increase from 2.71 million tons in 2015 to 3.35 million tons in 2025.

The addition of Si to the plants influences cell type and it also increases cell resilience and strength [1,2]. Silicon helps the leaves be more upright under the influence of high nitrogen fertilization conditions, so it can increase the photosynthetic levels and it is efficient to capture sunlight up to 10% [3,4,5,6]. Silicon also plays a role in reducing the rate of pest and disease through two mechanisms: it becomes a mechanical barrier and a physiological mechanism to increase resistance to the pests and diseases [7].

Growth analysis is a way to follow the dynamics of photosynthesis which is measured by dry matter production. The accumulation of dry matter is selected as a measurement of growth. The accumulation of dry matter reflects the ability of plants to receive sunlight energy through photosynthesis and its interaction with other environmental factors [8]. Therefore, the purpose of this study was to analyze the growth of soybean (Glycine max (L.) Merril), which was treated by nanosilica fertilizer and rice husk ash.

2 MATERIALS AND METHOD

This research was conducted from October 2017 to March 2018 at the Palawija Seed Development Center (PSDC) which is located at the altitude of 17 m above sea level. This study was a factorial research with two factors arranged in randomized complete block design. The first factor was nanosilica concentration consisting of 0, 1.25, 2.5, and 3.75 ml.l^{-1}, and the second factor was the dose of rice husk ash comprising 0, 1, 2 and 3 tons.ha^{-1}. The combination of each treatment was replicated three times. So there were treatment plots with a 3 m x 3 m plot size. The variables observed were plant height, stem diameter, number of leaves, leaf area, Leaf Area Index (LAI), Biomass Dry Weight

(BDW), Relative Growth Rate (RGR) and Nett Assimilation Rate (NAR). The data were analyzed by ANOVA then tested with DMRT at 5%.

3 Results and Discussion

3.1 Plant Height and Diameter

The results of the analysis of variance showed that there was no interaction between the application of nanosilica fertilizer and rice husk ash on the plant height and stem diameter at 15, 29 and 43 days after planting (dap) as presented in Table 1. The influence of the application of nanosilica fertilizer could be observed clearly at 29 and 43 dap, while the influence of it at 15 dap was unclear. The application of rice husk ash could not be observed clearly on the plant height and stem diameter in all obeservation period.

TABLE 1
PLANT HEIGHT AND STEM DIAMETER OF SOYBEAN
AT VARIOUS CONCENTRATIONS OF NANOSILICA FERTILIZER AND DOSES OF RICE HUSK ASH

Treatment	Plant height (cm)			Stem diameter (mm)		
	15 dap	29 dap	43 dap	15 dap	29 dap	43 dap
s0 (0 ml.l^{-1})	10.81	27.75^{a}	32.81	2.31	3.35^{a}	4.16^{a}
s1 (1.25 ml.l^{-1})	10.68	30.79^{b}	33.77	2.23	3.73^{b}	4.92^{b}
s2 (2.50 ml.l^{-1})	10.65	32.77^{b}	34.25	2.23	3.56^{b}	4.85^{b}
s3 (3.75 ml.l^{-1})	11.3	27.81^{a}	30.79	2.17	3.20^{a}	4.19^{a}
p0 (0 ton.ha^{-1})	10.86	29.33	34.33	2.21	3.43	4.42
p1 (1 ton.ha^{-1})	11.15	28.99	33.99	2.2	3.46	4.46
p2 (2 tons.ha^{-1})	10.77	29.43	34.43	2.24	3.69	4.53
P3 (3 tons.ha^{-1})	10.65	28.88	33.88	2.29	3.64	4.51

Remarks: Means associated with the same lowercase letter in the same column are not significantly different according to DMRT at 5%.

The average of the plant height increased by 169% which was from 10.86 cm at 15 dap to 29.16 cm at 29 dap. The growth of stem diameter also increased by 155% which was from 2.21 mm at 15 dap to 3.43 mm at 29 dap. This was because at 15 dap to 29 dap, the soybean plants were in a period of rapid growth. This result was in line with the opinion of [9] mentioning that the plant height grew actively in the beginning of growth, or at the formation of vegetative organs and it stopped after entering the generative phase starting from the appearance of the first flower to ripening of the fruit or seeds. Meanwhile, the plant height and stem diameter from 29 dap to 43 dap increased by 18% and 25%. It was lower compared to the increase from 15 dap - 29 dap. This was because the soybean plants were in the generative phase from flowering to pod formation at 29 - 43 dap.

The aplication of nanosilica fertilizer concentration up to the level of 1.25 - 2.50 ml.l^{-1} could increase the plant height and stem diameter. Meanwhile, the increased concentration of nanosilica fertilizer to 3.75 ml.l^{-1} decreased the plant height and stem diameter. The increase of the plant height and stem diameter from 29 dap to 43 dap was around 10 to 13 %. It was in line with [10] stating that Si nutrient was beneficial to support the plant growth. On the other side, [11] showed that the number of rice increased with the increasing of P uptake due to the application of silica in which P is needed by plants in the process of cell division and as energy in every metabolic process of [12]. Si deficiency can cause both organs (leaves and stems) of plants to be less sturdy since they are not protected by a strong silica layer.

3.2 Number of Leaves, Leaf Area, and Aeaf Area Index (LAI)

The results of the analysis of variance showed that there was no interaction between the application of nanosilic fertilizer and rice husk ash on the number of trifoliate leaves, leaf area and leaf area index at 15, 29 and 43 dap. The influence of the application of nanosilic fertilizer could be observed clearly at 43 dap, while the influence of it at 15 dap and 43 was unclear. The effect of rice husk ash application on the leaf area and leaf area index was unclear in all observation periods.

In Table 2, it can be seen that the treatment of nanosilica fertilizer at 3.75 ml.l^{-1} decreased the number of trifoliate leaves, leaf area, and leaf area index (LAI) in each observation period compared to the treatment of nanosilica fertilizer at 1.25-2.50 ml.l^{-1}. It showed that the application of nanosilica fertilizer with a maximum concentration would decrease the number of trifoliate leaves, leaf area and leaf area index in soybean plants. The more the number of leaves, the greater the leaf area and leaf area index. The high number of leaves will enhance photosynthesis thus the photosynthesis rate will also increase. According to [13], the application of Si fertilizer had an effect on decreasing the level of leaf transpiration. Besides, Si also strengthens the epidermal cell wall thus it can suppress transpiration activity and reduce water stress. Sakamoto and Shaw [14] stated that the effective LAI in soybean plants was defined as the center of LAI 90, which is in a 90% full radiation interception condition. Beuerlein and Pandleton [15] proved that soybean leaves carrying out the maximum clean photosynthesis

need saturated light between 0.27-2.17 cal.cm^{-2}. minute^{-1} with photosynthetic speed 8 - 65 mg CO2.dm^{-2}.hour^{-1}.

TABLE 2
NUMBER OF LEAVES, LEAF AREA, AND LEAF AREA INDEX OF SOYBEAN
AT VARIOUS CONCENTRATIONS OF NANOSILICA FERTILIZER AND DOSES OF RICE HUSK ASH

	Number of leaves			Leaf area (cm^2)			Leaf area index		
Treatment	15 dap	29 dap	43 dap	15 dap	29 dap	43 dap	15 dap	29 dap	43 dap
s_0 (0 ml/l)	2.7^b	7.5^a	13.8^a	32.76	991.88	1,160.42^a	0.15	1.65	1.92^a
s_1 (1,25 ml/l)	2.6^b	8.5^b	15.6^{bc}	33.9	1,013.72	2,232.58^{bc}	0.16	1.71	3.72^c
s_2 (2,50 ml/l)	2.9^b	8.3^b	15.3^c	42.72	1,062.80	2,364.22^c	0.17	1.77	3.94^c
s_3 (3,75 ml/l)	2.4^b	7.4^b	14.6^{ab}	32.76	961.82	1,392.32^{ab}	0.15	1.61	2.32^b
a_0 (0 ton.ha^{-1})	2.7	7.7	15	41.46	963.86	1,554.56	0.17	1.61	1.76
a_1 (1 ton.ha^{-1})	2.6	7.9	14.5	37.68	1,015.80	1,633.76	0.16	1.69	1.89
a_2 (2 ton.ha^{-1})	2.7	8.1	14.9	29.76	1,029.74	1,471.16	0.15	1.71	1.62
a_3 (3 ton.ha^{-1})	2.7	8	15	33.24	1,030.76	1,490.06	0.16	1.72	1.65

Remarks: Means associated with the same lowercase letter in the same column are not significantly different according to DMRT at 5%.

3.3 Biomass Dry Weight (gram)

The result of the analysis of variance showed that there was interaction between the application of nanosilica and rice husk ash on the dry weight of plants at 29 dap, while there was no interaction at15 dap and 43 dap as presented in Table 3.

The dry weight of the plants is determined by the values of other growth components such as the plant height, stem diameter, the number of leaves, and leaf area. According to the result of the analysis of variance, there was interaction between the application of nanosilica and rice husk ash on the dry weight of the plants at 29 dap. The treatment combination of nanosilica fertilizer at 2.50 ml.l^{-1} and rice husk ash at 2 tons.ha^{-1} and the treatment combination of nanosilica fertilizer at 3.75 ml.l^{-1} and rice husk ash at 3 ton.ha-1 gave the best effect on the dry weight of the plants at 29 dap showing the value of 2.21 g and 2.54 g, respectively. It is supposed that soybean plants get rapid vegetative growth at 29 dap so that they need many nutrients.

TABLE 3
BIOMASS DRY WEIGHT OF SOYBEAN
AT VARIOUS CONCENTRATIONS OF NANOSILICA FERTILIZER AND DOSES OF RICE HUSK ASH

	The average of biomass dry weight (gram)			
The treatment	s_0 (0 ml.l^{-1})	s_1 (1.25 ml.l^{-1})	s_2 (2.50 ml.l^{-1})	s_3 (3.75 ml.l^{-1})
a_0(0 ton.ha^{-1})	1.72^b C	1.26^b B	1.93^b D	0.65^a A
a_1(1 ton.ha^{-1})	1.72^b C	1.55^c B	2.07^c D	1.03^b A
a_2(2 ton.ha^{-1})	1.57^a A	2.03^d C	2.21^d **D**	1.89^c B
a_3(3 ton.ha^{-1})	1.91^c C	1.18^a A	1.34^a B	2.54^d **D**

Remarks: Means associated with the same lowercase letter in the same column or uppercase letter in the same row are not significantly different according to DMRT at 5%.

The accumulation of dry matter reflects the ability of plants to bind energy from sunlight through photosynthesis and their interaction with other environmental factors. The distribution of dry matter accumulation in plant organs such as roots, stems, leaves, and generative organs can reflect the productivity of the plants. Karamoy [16] states that dry matter production is influenced by the amount of light absorbed by the plant. Sumarsono [8] states that the weight of dry plants reflects the plant patterns to accumulate products from photosynthesis integrated with other environmental factors.

3.4 Relative Growth Rate ((g.g^{-1}.day^{-1})

The results of the analysis of variance showed that there was no interaction between the application of nanosilica and rice husk ash on the relative growth rate at 15 to 29 dap. The application of nanosilica fertilizer and rice husk ash did not significantly affect the relative growth rate. The average magnitude of the relative growth rate from 15 dap to 29 dap was 0.101 g.g^{-1}.day^{-1}. Meanwhile, there was interaction effect of nanosilica fertilizer and rice husk ash on the relative growth rate from 29 to 43 dap.

Table 4 shows that a high relative growth rate was obtained by applying nanosilica fertilizer at the level of 1.25 - 2.50 ml.l^{-1} which was accompanied by fertilizer from rice husk ash up to a dose of 3 ton.ha-1 i.e. 0.153 g.g-1.day-1 or by applying nanosilica fertilizer at 3.75 ml.l^{-1} without the addition of rice husk ash, i.e. 0.164 g.g^{-1}.day^{-1}. These RGR values are the range which is suggested by [17] stating that soybean RGR ranges from 0.011 - 0355 g.g^{-1}.day^{-1}. According to [18], the relative growth rate (RGR) shows an increase in dry weight in an interval time. Applying Si to plants in general can improve physiological function, strengthen tissue, and increase plant resistance to pests and diseases so it can increase the plants growth and production [19]. Silicon can also increase photosynthetic efficiency so that photosynthates can be produced more increasing the weight of the plants. Photosynthates will be distributed and stored in vegetative organs of plants such as roots, stems and leaves as food reserves. This storage of food reserves will affect the fresh weight and dry weight of the plants.

TABLE 4
RELATIVE GROWTH RATE OF SOYBEAN
AT VARIOUS CONCENTRATIONS OF NANOSILICA FERTILIZER AND DOSES OF RICE HUSK ASH

	Relative growth rate (RGR) (g.g^{-1}.day^{-1})			
The treatment	s_0 (0 ml.l^{-1})	s_1 (1.25 ml.l^{-1})	s_2 (2.50 ml.l^{-1})	s_3 (3.75 ml.l^{-1})
a_0(0 ton.ha^{-1})	0.125^{ab} A	0.124^{a} A	0.121^{b} A	0.164^{b} A
a_1(1 ton.ha^{-1})	0.133^{b} A	0.122^{a} A	0.112^{b} A	0.133^{ab} A
a_2(2 ton.ha^{-1})	0.085^{ab} AB	0.122^{a} B	0.035^{a} A	0.042^{a} A
a_3(3 ton.ha^{-1})	0.055^{a} A	0.153^{a} B	0.144^{b} B	0.052^{a} A

Remarks: Means associated with the same lowercase letter in the same column or uppercase letter in the same row are not significantly different according to DMRT at 5%.

3.5 Net Assimilation Rate (g.cm^{-2}.day^{-1})

The results of the analysis of variance showed that there was no interaction between the application of nanosilica and rice husk ash on the net assimilation rate (NAR) from 15 dap to 29 dap and from 29 dap to 43 dap. There was no effect from nanosilica fertilizer on net assimilation rate, either in the net assimilation rate from 15 dap to 29 dap or in the net assimilation rate from 29 dap to 43 dap. The application of rice husk ash gave the effect on the net assimilation rate from 15 dap to 29 dap, while the net assimilation rate from 29 dap to 43 dap didn't give significant effect.

TABLE 5
NET ASSIMILATION RATE OF SOYBEAN
AT VARIOUS CONCENTRATIONS OF NANOSILICA FERTILIZER AND DOSES OF RICE HUSK ASH

	Net Assimilation Rate (g.cm^{-2}.day^{-1})	
Treatment	15 dap to 29 dap	29 dap to 43 dap
s_0 (0 ml.l^{-1})	0.00074	0.0015
s_1 (1.25 ml.l^{-1})	0.00068	0.00139
s_2 (2.50 ml.l^{-1})	0.0007	0.001
s_3 (3.75 ml.l^{-1})	0.00076	0.00102
a_0 (0 ton.ha^{-1})	0.00058^{a}	0.00155
a_1 (1 ton.ha^{-1})	0.00066^{a}	0.00142
a_2 (2 ton.ha^{-1})	0.00092^{b}	0.00092
a_3 (3 ton.ha^{-1})	0.00072^{ab}	0.00101

Remarks: Means associated with the same lowercase letter in the same column are not significantly different according to DMRT at 5%.

From the result of the analysis, it was obtained that the net assimilation rate from 15 dap to 29 dap was 72 x 10-5g.cm^{-2}.day^{-1} and from 29 dap to 43 dap was 122 x 10-5 g.cm^{-2}.day^{-1}. It showed that the rate of net assimilation had increased with the increasing age of plants. As it is shown in Table 5, the net assimilation rate from 29 dap to 43 dap was higher than the net assimilation rate from 15 dap to 29 dap. This can be due to the formation of more leaves by the increasing age of the plants, in which the leaf is the site of the assimilation process in the plant. This is in line with the opinion of [20] stating that silicon plays a role for plants in drought conditions to increase photosynthesis and root activity, suppress the rate of transpiration, and improve plasma membranes. Thus, the interaction between nanosilica fertilizer and rice husk ash can increase the rate of photosynthesis, so that the photosynthate will be produced more and transfered to all parts of the plant (roots, stems, leaves, and pods). Gardner et al. [18] state that NAR is an illustraton of the rate of accumulation of dry weight of the plants per unit of time and it is also used as measurement of the efficiency of photosynthetic leaves.

4 CONCLUSION

The application of nanosilica fertilizer and rice husk ash had effects on the growth components of soybean plants (*Glycine max* (L.) Merril), i.e. 1) the application of nanosilica fertilizer up to 2.50 ml.l^{-1} gave the best effect on the plant height, stem diameter, number of leaves and leaf area; 2) the application of 2 ton.ha^{-1} rice husk ash produced the highest net assimilation rate at 15-29 dap which was 0.00092 g.cm^{-2}.day^{-1}; (3) there was an interaction between nanosilica fertilizer and rice husk ash on the plant dry weight and relative growth rate. The combination of nanosilica fertilizer at 2.50-3.75 ml.l^{-1} and rice husk ash at 2-3 ton.ha^{-1} gave the best effect on the plant dry weight showing the value of 2.21 g and 2.54 g. Meanwhile, the application of nanosilica fertilizer at 3.75 ml.l^{-1}without rice husk ash resulted in the highest relative growth rate.

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