The effect of nano-silica fertilizer concentration and rice hull ash doses on soybean (Glycine max (L.) Merrill) growth and yield

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Abstract. Agriculture is facing a number of challenges included limited water supply, low nutrient use efficiency, etc affected by climate change. Nano-silica is a product of nanotechnology, the frontier technologies to enhance crop productivity under climate change threats. The purpose of the research was to investigate the effects of nano silica concentration and rice hull ash on growth and yield of soybean. The experiment was conducted at Gagasari village, Cirebon, West Java from March until June 2017. The treatments were arranged by using factorial completely randomized block design with two factors. The first factor was a concentration of nano silica fertilizer consisted of four levels i.e., 0, 1.75, 2.5, and 3.75 ml.l⁻¹. The second factor was doses of rice hull ash consisted of four levels i.e., 0, 1, 2, and 3 ton.ha⁻¹. Each treatment combinations was repeated three times. The result showed that concentration of nano silica individually affected the number of leaves and number of branches, NAR and RGR, productive branches at 21, 30-45, and 35 days, respectively. It also affected the seed dry weight plant⁻¹ and plot⁻¹. Meanwhile, doses of rice hull ash affected LAI, NAR, and RGR, 15-30, and 30-45 day, respectively. Dry seed weight plot⁻¹ was also affected by doses of rice hull ash. There was an interaction effect between nano-silica concentration and doses of rice hull ash on number pods plant⁻¹. Combinations of 2.5 ml.l⁻¹ nano-silica and 3 ton.ha⁻¹ of rice hull ash gave the highest number pods plant⁻¹.

1. Introduction
Climate change is a serious threat to the agricultural sector and potentially make a new problem for food production sustainability and agricultural production systems in general. Climate change affects agricultural sectors such as natural resource, agricultural infrastructure, agricultural production systems, food security, and farmers welfare, and society [1].

Climate change scales down agricultural production especially food crops (rice, maize, and soybean). Soybean (Glycine max (L.) Merrill) is an essential food crop after rice and maize in Indonesia, due to it contains healthy substances. Soybean acts as a source of vegetable protein which is very important, in order to build up the society nutrition, it is also relatively cheap compared to the animal protein source [2].
According to Kastono [3], new domestic soybean production is able to meet the needs of about 30% and at least 70% must be imported. Numerous efforts to strengthen the soybean production should be noted that the plant is able to produce high potency. Additional elements such as Si can be applied as a support plant growth since several studies explain that Si in the soil can boost the phosphorus availability. Si generates plant stronger and not easy to fall. The collapse causes a plant production declining, thus fertilizing Si is considered to multiply crop production [4].

The Si application greatly affects the rice plant growth, impacts on the plants stems strengthening, plant protection from pests, root reinforcement, and others [5]. The super-small sized fertilizer employment has several advantages, such as, more reactive, directly reach the target, and only needed in small amounts [6]. With these advantages, the nano fertilizer is expected to be a breakthrough technology to intensify agricultural production that is continuous and environmentally friendly [7].

The potassium responsibility in the body hull ash is to strengthen the plant leaves and flowers do not fall and stimulate the root hairs formation [8]. It purposes that can enhance soil physical and chemical properties. In addition, it serves to loosen the soil, thus can simplify roots nutrients absorption [9].

According to Fitiyani dan Haryanti [10] research stated that different rates of concentration nano silica fertilization treatment gave an effect on plant height, leaf number, and root length. Nano silica fertilizer 75% of concentration or by dissolving 3.75 ml nano-silica in 1.5 liters of water gave the highest growth of tomato (Solanum lycopersicum) var. Round. According to Melati et al [11], a combination of 5 ton of manure with 2 ton ha\(^{-1}\) of rice hull ash can provide the soybeans highest yield. It also donates the same effect with 150 kg ha\(^{-1}\) of KCl. The purpose of this study was to analyze the effect of nano silica fertilizer concentration and dosage of rice hull ash on soybean (Glycine max L. Merrill) growth and yield.

2. Methodology
The experiment was conducted in the Gagasari village, Gebang, Cirebon. with ± 2 meters of altitude above sea level on March until June 2017. Soybean varieties which exploited in this experiment were Grobogan. The experiment was arranged by utilizing two factors RCBD. The first factor was nano silica concentration that consisted of four levels i.e., 0, 1.25, 2.50, and 3.75 ml l\(^{-1}\). The second factor was rice hull ash dose that existed of four levels i.e., 0, 1, 2, and 3 ton ha\(^{-1}\). Each treatment combination repeated three times so there were 48 plots. The variable observation includes plant growth and yield.

3. Results and discussion
3.1. Growth components.
3.1.1 Plant height, number of leaves, and stem diameter. Based on the analysis, it showed that the effect of nano-silica fertilizer concentration employment and rice hull ash on soybean crop did not affect plant height and stem diameter at 14, 21, and 28 daps, however, it significantly affected the trifoliate leaf number at age 14 and 21 daps.

  According to Indradewa et al [12], the plant metabolism ability was associated with the plant age. At the age of 14-21 dap was still in the plant growth phase was slow, whereas at 28 dap due to nutrients absorption from fertilizers nano-silica and rice hull ash content provided together, thus providing the same effect on plant height and stem diameter.

  There was no interaction between of nano-silica fertilizer concentration and doses of rice hull ash on the number of leaves trifoliate, but at age 21 dap its treatment gave individually affected on the leaves trifoliate number at 21 and 28 dap, it is in line with the opinion Yukamgo and Yuwono [13], that Si is quite profitable biochemical and chemical-poss process for plant growth and Makarim et al [14] assert that Si in the plant causes the plant roots stronger so the nutrient absorption was more intensive.

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Table 1. Effect of nano-silica fertilizer concentration and doses of rice hull ash on plant height, number of trifoliate leaves and stem diameter at 14, 21, 28 daps on soybean plants.

| Treatment | Plant height (cm) | Number of trifoliate leaves | Stem diameter |
|-----------|-------------------|----------------------------|--------------|
|           | 14 dap  | 21 dap | 28 dap | 14 dap | 21 dap | 28 dap | 14 dap | 21 dap | 28 dap |
| 0         | 10.72a  | 15.86a | 26.46a | 1.77a  | 4.46a  | 12.84a | 2.43a  | 3.33a  | 5.16a  |
| 1.25      | 10.31a  | 15.75a | 23.58a | 1.77a  | 5.05bc | 13.68a | 2.40a  | 3.40a  | 5.10a  |
| 2.50      | 10.68a  | 15.83a | 25.43a | 1.73a  | 4.89b  | 13.62a | 2.32a  | 3.36a  | 4.89a  |
| 3.75      | 10.38a  | 15.49a | 24.87a | 1.75a  | 5.40c  | 13.77a | 2.33a  | 3.29a  | 4.99a  |

| Treatment | concentration nano-silica Fertilizer (mlL⁻¹) | doses of rice hull ash (ton.ha⁻¹) |
|-----------|---------------------------------------------|----------------------------------|
| 0         | 10.72a  | 15.86a  | 26.46a  | 0.0775a | 0.3399a |
| 1         | 10.31a  | 15.75a  | 23.58a  | 0.4068a | 0.4248a |
| 2         | 10.68a  | 15.83a  | 25.43a  | 0.4188a | 0.4164a |
| 3         | 10.38a  | 15.49a  | 24.87a  | 0.4164a | 0.3826a |

Table 1 shows the effect of nano-silica fertilizer concentration and doses of rice hull ash on plant height, number of trifoliate leaves and stem diameter at 14, 21, 28 daps on soybean plants. The average number followed by the same letter in the same column is not significantly different according to Duncan's Multiple Range Test at 5% level.

3.1.2 Number of branches and LAI. The analysis result variations portrayed that there was no interaction between nano-silica fertilizer concentration and rice hull ash dose on the number of branches and LAI. It presented an independent effect on the number of branches by 21 and 28 dap and LAI at 28 daps.

Table 2. Effect of nano-silica fertilizer concentration and doses of rice hull ash to total branch at 21 and 28 dap and LAI at 14, 21 and 28 daps on soybean plants.

| Treatment | Number of branches | LAI |
|-----------|--------------------|-----|
|           | 21 dap  | 28 dap | 15 dap | 30 dap | 45 dap |
| concentration nano-silica fertilizer (mlL⁻¹) | | | | | |
| 0         | 1.49a  | 3.91ab | 0.0839a | 0.3826a | 1.5099a |
| 1.25      | 2.28b  | 4.29b  | 0.0888a | 0.4164a | 1.6389ab |
| 2.50      | 1.93b  | 3.66a  | 0.0866a | 0.4188a | 1.7687ab |
| 3.75      | 1.95b  | 4.07ab | 0.0652a | 0.3404a | 2.1019b |
| doses of rice hull ash (ton.ha⁻¹) | | | | | |
| 0         | 2.03a  | 3.93a  | 0.0701a | 0.3826a | 1.5632a |
| 1         | 1.98a  | 4.04a  | 0.1000b | 0.4248a | 1.6288a |
| 2         | 1.88a  | 3.98a  | 0.0770ab| 0.4068a | 1.4839a |
| 3         | 1.76a  | 3.97a  | 0.0775ab| 0.3399a | 2.3436b |

Table 2 shows the effect of nano-silica fertilizer concentration demonstrated a significant effect on the of branches number 21 dap compared with controls, whereas at 28 dap treatment of nano-silica fertilizer concentration 0 mlL⁻¹, 1.25 mlL⁻¹, and 3.75 mlL⁻¹ were not significantly different yet it opposite performed with the treatment of 2.50 mlL⁻¹. This was due to the treatment of S, has the most reasonably optimal dose, so it can be used and the maximum available as a nutrients stimulator by plants, beneficial Si nutrients to support plant growth [14].

A large number of soybean crop branches were affected by the leaves number because the soybeans branch is grown over the books petiole, but the branches number will be less than the leaves number. This was due to the growth of the books leaves will be followed by the branches and flowers development, or one of its branches or flowers [15].
Table 2 displays that there was no interaction between the treatment of nano-silica fertilizer concentration and doses rice hull ash to the LAI. It had a significant effect on LAI at 45 daps, the higher of its value was followed by the LAI's. This is in line with the results Sumida [16], which states that the supply of Si is quite capable for providing a good crop, because it helps more upright stems and leaves, thus increasing the photosynthesis rate. Similarly, the doses of rice hull ash 3 ton.ha\(^{-1}\) were independently significantly different from the other dosage of rice hull ash. Rice hull ash 3 ton.ha\(^{-1}\) provided sufficient Si into the soil, so it can be used for plant growth.

LAI was illustrative of the leaf surface ratio of the land area which was occupied by the plant. Leaf area escalated with increasing age of the plant, therefore, the leaves number into lots [6], the leaf area increment was expected of the nutrients absorption effects larger than mutual shade effect inflation between leaf.

3.1.3 NAR, RGR, and total productive branch. Results analysis variation showed that the treatment of nano-silica fertilizer concentration and doses of rice hull ash did not provide interaction against the NAR, RGR at age 15-30 dap and 30-45 dap and the productive branches number at 35 daps. It had an independently significant effect.

**Table 3.** Effect of concentration nano-silica fertilizer and doses of rice hull ash to NAR, RGR of ages 15-30 dap and 30-45 dap and total productive branch on soybean plants.

| Treatment | NAR (x10\(^{-4}\) gcm\(^{-2}\)day\(^{-1}\)) | RGR (x10\(^{-4}\) gday\(^{-1}\)) | Number of productive branches |
|-----------|-----------------------------------------------|-----------------------------------|-------------------------------|
|           | 15-30 dap | 30-45 dap | 15-30 dap | 30-45 dap | 35 dap |
| concentration nano-silica fertilizer (mll\(^{-1}\)) | | | | | |
| 0         | 1,152.58a | 1,664.77ab | 1,201.23a | 1,228.73a | 4.02b |
| 1.25      | 1,139.50a | 1,447.80a  | 1,243.92a | 1,185.94a | 4.33c |
| 2.50      | 1,089.33a | 1,5884.45a | 1,329.45a | 1,230.47a | 3.68a |
| 3.75      | 1,256.50a | 2,380.53b  | 1,385.43a | 1,518.29b | 3.88ab |

| doses of rice hull ash (ton.ha\(^{-1}\)) | | | | | |
| 0         | 1,591.41b | 1,664.77a | 1,431.16a | 1,096.29a | 3.80ab |
| 1         | 869.41a   | 1,725.51a | 1,174.22a | 1,295.57ab | 3.94a |
| 2         | 1,072.03a | 1,884.55a | 1,296.20a | 1,327.56ab | 4.08a |
| 3         | 1,105.08ab| 1,947.45a | 1,258.44a | 1,444.02b | 4.09a |

Description: The average number followed by the same letter in the same column showed no significant according to Duncan's Multiple Range Test at 5% level.

From Table 3 above portrays that treatment of nano-silica fertilizer concentration 3.75 ml.l\(^{-1}\) were significantly different from other treatments both to the net assimilation rate (NAR) is 2,380.53x10\(^{6}\) g.cm2.day\(^{-1}\) and relative growth rate (RGR) of 1,518.29x10\(^{4}\) g.day\(^{-1}\) at the age of 30-45 dap, the same as is shown by its treatment of 3.75 ml.l\(^{-1}\) of the LAI with the highest LAI values 2.1019 (Table 2). LAI is the net assimilation unity leaf area and time result. It can be concluded that it can enhance the LAI, NAR, and RGR. This is in accordance with the opinion of Gardner et al [17], that the plant growth rate is affected by the NAR and LAI. High NAR and optimum LAI will boost its rate. It is the independently significant effect on the productive branches number, nano-silica fertilizer treatments concentration 1.25 ml.l\(^{-1}\) to provide the best effect on the productive branches number at age 35 dap is 4.33. It is suspected that Si accumulated in the leaves which make it moves upright and stretching well into the leaf surface consequently get more sunlight, so a more optimal photosynthesis. More photosynthesize result, it will be distributed and stored in the plant's vegetative organ of such as roots, stems, and leaves as a food reserve for plant growth [18].
The dose of rice hull ash independently significant effect on the NAR aged 13-30 dap, while at the age of 30-45 dap were not significant. Its 3 ton.ha⁻¹ provides the best effect against the RGR to amounted RGR to 1,444.02x10⁻⁴ g.day⁻¹, but the dose of rice hull ash did not significantly affect the number of productive branches.

3.2 Yield component

3.2.1 The number of pods per plant. Results of analysis of variance showed interaction effect between concentration nano-silica fertilizer and dose rice hull ash to the number of pods per plant.

**Table 4.** Effect of nano-silica fertilizer concentration and doses rice hull ash on contents number of pods per plant.

| Dose of rice hull ash (ton.ha⁻¹) | Concentrations of nano-silica fertilizer (ml.l⁻¹) |
|----------------------------------|--------------------------------------------------|
|                                  | (0)     | (1.25) | (2.50) | (3.75) |
| 0                                | 59.23a  | 63.07a  | 65.17a  | 75.50a |
|                                  | A       | A       | A       | B      |
| 1                                | 55.20a  | 60.60a  | 61.17a  | 77.40a |
|                                  | A       | A       | A       | B      |
| 2                                | 53.20a  | 70.57b  | 67.07a  | 77.60a |
|                                  | A       | B       | B       | C      |
| 3                                | 74.17b  | 72.63c  | 79.37b  | 69.70a |
|                                  | A       | A       | B       | A      |

Description: Lowercase for columns, capitals of the line. The average number followed by the same letter in the same row and column shows no significant according to Duncan’s Multiple Range Test at 5% level.

At 0 ml⁻¹ and 3.75 ml⁻¹ of nano-silica concentration level combined with a level of dose husk ash began to 0-3 ton ha⁻¹ did not significantly affect the pods per plant number, while at 1.25 ml⁻¹ of nano-silica and 2.50 ml⁻¹ combined with rice hull ash dose level of 0-3 ton ha⁻¹ significantly influence the pods per plant number, its concentration extent 1.25 ml.l⁻¹ in combination with rice hull ash dose of 2 ton ha⁻¹ and 3 ton ha⁻¹ served the best effect on the pods number i.e., 70.57 and 72.63, respectively.

Combination treatment of nano-silica fertilizer concentration 2.50 ml.l⁻¹ and rice hull ash with the dose of 3 ton.ha⁻¹ indicated the highest (79.37) of pods number. According to Kusuma et al [9] rice hull ash presented the plant growth significant effect, especially the growth in the leaves number and pods number escalation, and described by several studies that Si can multiply the availability of P and reduce the toxic metals activity, one of the functions P is for helps the flowers and fruit composition.

3.2.2 Weight dry seeds per plant, the weight of 100 grains dry beans and dry seed weight per plot. The Results variation analysis, there was no interaction between the treatment of nano-silica fertilizer concentration and doses and rice hull ash to the dry seed weight per plant, the weight of 100 seed, dry weight of seeds and dry weight seeds per plot, but there was an independent effect of each variable observation.

From Table 5 it can be seen that the treatment of nano-silica fertilizer concentration did not significantly affect the weight of dry seeds per plant and weight of 100 of dry beans grains, while it was independently instant effect on the dry seeds weight per plot, treatment 2.50 ml.l⁻¹ provided the best effect with dry grain weight per plot was 950.17 g.plot⁻¹. It is assumed that Si fertilizing can boost the uptake of P and phosphorus needed by plants in cell division and as energy in every plant metabolic process [19].
Table 5. Effect of nano-silica fertilizer concentration and doses rice hull ash on weight dry seeds per plant, weight of 100 grains and weight dry seeds per plot

| Treatment | Dry seeds per plant (g) | Weight of 100 seeds (g) | Dry seed per plot (g) |
|-----------|-------------------------|-------------------------|----------------------|
| Concentration nano-silica fertilizer (ml l⁻¹) | | | |
| 0 | 26.93a | 21.41a | 870.83a |
| 1.25 | 24.99a | 21.24a | 867.83a |
| 2.50 | 30.89a | 21.75a | 950.17b |
| 3.75 | 27.03a | 21.82a | 857.08a |
| Doses of rice hull ash (ton ha⁻¹) | | | |
| 0 | 26.02a | 21.57a | 878.67a |
| 1 | 25.77a | 21.36a | 839.92a |
| 2 | 28.07ab | 21.43a | 880.50a |
| 3 | 29.98ab | 21.84a | 947.83b |

Description: The average number followed by the same letter in the same column showed no significant according to Duncan's Multiple Range Test at 5% level.

The treatment dose rice hull ash was significantly affected the dry seed weight per plant and per plot independently, while against the weight of 100 grains of dry beans were not significantly different. Rice hull ash dose of 3 ton ha⁻¹ served the best effect on the dry seed weight (29.98 g plant⁻¹) and seed weight per plot (947.83 g). It is suspected that the rice hull ash can replace or the potassium substitution content in soil under soybean cultivation. The rice hull ash provision can increase the content of K highly supportive crop production. The more the number or the dose is given to the soil, the better [20].

4. Conclusion
In the treatment of nano-silica fertilizer concentration of 2.5 ml l⁻¹ portrayed the best result in the dry seed weight per plot of 950.17 g, equivalent to 1.58 ton ha⁻¹ and doses of rice hull ash 3 ton ha⁻¹ provided the best results on a dry seed weight per plot of 947.83 g, equivalent to 1.57 ton ha⁻¹.

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