Optimum dosage of rice husk-based silicon foliar spray to improve yield of soybean grown on irrigated lowland

N Herawati1*, L Hadiawati1, F Zulhaedar1

1 Assessment Institute for Agricultural Technology (AIAT) of West Nusa Tenggara Province. Jalan Raya Peninjauan Narmada, Lombok Barat, NTB. Indonesia. 83371.

*Corresponding author: nani.subhan@yahoo.com

Abstract. Silicon (Si) is highly abundant in soil and plays important role in growth and development of plant. However, number of available Si is limited depend on soil type and condition, thus supplementary Si from fertilizer is needed. Rice husk is one of potential source of Si fertilizer. This study aimed to determine the optimum dosage of rice husk-based bio-silicon foliar spray (SiF) improve yield of soybean. The experiment was laid out in a randomized block design at Narmada Research Station of AIAT (Assessment Institute for Agricultural Technology) of West Nusa Tenggara Province from May to June 2018. There were four treatments of SiF concentration with four replications viz. SiF1 = 3 ml/lt, SiF2 = 6 ml/lt, SiF3 = 9 ml/lt, and SiF0 = 0 ml/lt (control). The results showed that plant growth and yield attribute i.e., weight of biomass, number of pods, fresh pod weight, yield were improved on all SiF treatments when compared to the control. Total ground above biomass m$^{-2}$ was also significantly improved, while the highest yield produced at SiF3. Current study suggests that optimum dosage of rice husk-based bio-silica foliar spray for lowland irrigated soybean was 6 ml/lt, and further on-farm experiment is needed to test the dosage at wider scale. (Key words: biosilicon, concentration, foliar spray, soybean).

1. Introduction

Estimation on soybean deficit in Indonesia is increased by 4.55% per year during 2005 to 2020 [1] which is closely related to reduction on national soybean harvest area. In 2017/2018, soybean harvest area in Indonesia was about 680.000 ha with total production about 985.00 tons [2]. In the same period, import was reached 2.5 million tons [3]. Even though soybean productivity is improved at about 1.01% per year during 1990-2004, innovation on cropping technology should be addressed to increase production per unit harvest area [4]. One of strategy to improve soybean yield is application of an effective and efficient fertilizer for specific environment.

Despite concern on sustainable and environmentally friendly agricultural practices, popularity of organic-based fertilizer is increasing following the increase of potential agricultural waste, especially massive waste produced from rice production. Rice is the staple food in Indonesia with total production at 79 million tonnes in 2016 [5], and there will be a similar amount of wasted biomass in form rice straw and rice husk. While fermented rice straw is potential to feed cattle or decomposed into compost, rice husk is potential to produce biochar through pyrolysis process. And the biochar can be further extracted to get nanosized silica that can be formulated into nano biosilica liquid fertilizer. According to Rahman [6] nanosilica gel could contain up to 93.46% silica.

Silicon (Si) is one of the prevalent macro nutrients that important for plants in responding to abiotic stresses. Foliar application of silicon could strengthen stem under low light stress [7], and improving plant drought tolerance and nutrient use efficiency [8]. Although the amount of Si is large in the soil, most of it is in a form that is not available to plants. Si is tightly bonded with other elements to form silica (SiO$_2$), silicic acid (H$_4$SiO$_4$), and silicate [9]. Soil contains 50 to 400 g Si per kg depending on soil type, and Si is available to plants in the form of silicic acid [Si(OH)$_4$]. Supplementary liquid fertilization through foliar spray is not only practical but also effective to increase yield. In most reports, soybean responds positively to silicon fertilizer. Field experiment [19] showed that Si
application to the soil and leaves of soybean was increasing number and size of nodule, including diameter and average root link diameter, and improved net photosynthesis, transpiration rate and stomatal conductance in soybean. Sapre and Vakhara [19] reported that silicone help plant to form oxidative enzyme that support the growth and development under water stress condition. Application of silicon could reduce availability of Na⁺ ions while increasing K⁺ exchange [20]. There was improvement on yield of soybean grown on saline soil [21].

Although a foliar application of Si has been reported widely, comparative studies on investigating the effect of different kind of Si foliar spray made of rice husk charcoal have not been reported for specific tropical soybean cultivation at Eastern Indonesia condition. This study aimed to find out optimum dosage of rice husk-based nano biosilicon foliar spray on growth and yield of lowland irrigated soybean of West Lombok.

2. Materials and methods
Field experiment was conducted on inceptisol irrigated lowland of Narmada Research Station (8°35’51” x E 116°13’8” on 154 m above sea level) of Assessment Institute for Agricultural Technology (AIAT) of West Nusa Tenggara (WNT) Province, Indonesia during dry seasons of 2018. The experimental site is in C3 type of climate region based on Schmidt-Ferguson [10]. The statistical design of the experiment was complete randomized blocks with four concentration of nanosized biosilicon at 0 ml/l (P0 for control), 3 ml/l (P1), 6 ml/l (P2), and 9 ml/l (P3) that replicate in five plots (5 m x 5 m) for each treatment. Nanosized biosilicon foliar fertilizer produced by Balai Besar Pasca Panen Badan litbang Pertanian with brand Bioshinta® that made of rice husks with minimum SiO₂ content of 10% of its weight, and it also contains other natural mineral nutrients [14].

Soybean plants (Glycine max (L.) Merr) Dega variety [11] obtained from Unit Produksi Benih Sumber (UPBS)/Seed production Unit of AIAT WNT Province. Land preparation, planting, spacing, irrigation, and harvest were guided using integrated soybean management handbook [12]. Planting was done using direct seeded system with two seeds per hole in 40 cm spacing between row and 15 cm within row. The recommended NPK fertilizers were applied according to the recommendations of Ministry of Agriculture using 50 kg/ha of Urea, 250 kg/ha of SP-36, and 100 kg/ha of KCL [12]. The nano biosilicon treatment was first sprayed at 20 days after planting and repeated in a week interval until flowering period, while watering was done in two weeks interval using furrow irrigation system.

Measurement of growth parameters and yield components were collected from 15 plants (3 plants from each replication plot) that selected randomly at harvest. Data for plant height, weight of biomass, pod, and seed for both in plot and plant were recorded after dried at 70°C. Calculation for productivity data were based on plot yield of 6 m² size. All collected data were subject to statistical analysis of variance using the Statistical Tools for Agricultural Research (STAR) program version 2.0.1, and statistically significant differences between means were tested using Duncan at p<0.05 [13].

3. Results and discussion
Effect of nanosized biosilicon foliar spray on yield of soybean was significantly different in plant height and weight of plot dry biomass, however moisture content and plot yield were similar between treatment. Plant height was significantly higher in control (43.33 cm) than the rest in threaten plants with supplementary Si nutrient. In this experiment, average height of Dega variety soybean was lower than its potential at 53 cm [11]. According to Hussain et al. [7], silicon foliar application could strengthen stem of soybean and reduce shading stress. Further they concluded that plant cell walls component was affecting by application of Si, mostly by altering linkage of non-cellulosic polymers and lignin.

Although no significant difference in plant height between all plant with foliar spray at some concentration, plant height at dosage of 6 ml/l was the lowest at 37.40 cm. In contrast, weight of plot dry biomass was the highest at the same dosage. Silicon foliar spray was reported increase the net photosynthesis rate of soybean by conducting stomatal conductance, chlorophyll content, and fresh
That response was not only shown in soybean, but also in different crops such as tomatoes [9], rice [15], wheat [16], and tobacco [17].

Better photosynthesis rate might be contributed to high moisture content, and in turn it produced the highest plot yield (Table 1). Increase of yield was about 39.06% when yield in 6 ml/lt dosage (1.92 kg/6 m²) compare to control plant (1.17 kg/6 m²). This result is similar to yield of Detam-l soybean variety with application of 6 l/ha bio-nano silica in which the yield was increased to 32% that reported by Santi et al [8]. According to Suryanti and Umami [18], stomatal opening was in positive correlation to the yield of Anjasmoro soybean variety when nanosilica and PGPR applied.

### Table 1. Effect of nanosized biosilicon foliar spray on plant height, moisture content, and weight of plot dry biomass and yield of Dega soybean variety grown on irrigated lowland of West Lombok during dry season 2018

| Dosage of BiSilicon Fertilizer (SiF) | Plant height (cm) | Plot dry biomass (kg/6 m²) | Moisture content (%) | Plot yield (kg/6 m²) |
|------------------------------------|-------------------|---------------------------|---------------------|---------------------|
| 0 ml/lt                            | 43.33a            | 6.86a¹                  | 58.69               | 1.17                |
| 3 ml/l                             | 39.43b            | 9.05ab                  | 53.14               | 1.13                |
| 6 ml/l                             | 37.40b            | 12.11c                 | 63.36               | 1.92                |
| 9 ml/l                             | 41.20b            | 10.16bc                | 57.53               | 1.07                |
| L.s.d                              | 3.64              | 225.70                  | 40.73               | 40.35               |

¹Number followed by same letter in the same column indicate no significant difference at P≤0.05. Lsd: Least significant difference

Application of nanosized biosilicon foliar spray was significantly affecting pod number, fresh pod weight, and 100 seed weight of soybean at different concentration. While pod moisture content and number of seed was similar between treatments as shown in Table 2 below.

### Table 2. Effect of nanosized biosilicon foliar spray on pod number, fresh pod weight, pod moisture content, seed number, and weight of 100 seed of Dega soybean variety grown on irrigated lowland of West Lombok during dry season 2018

| Dosage of BiSilicon Fertilizer (SiF) | Pod number plant⁻¹ | Fresh pod weight (g plant⁻¹) | Pod moisture content (%) | Seed number (plant⁻¹) | 100 seed weight (g plant⁻¹) |
|------------------------------------|---------------------|-----------------------------|------------------------|-----------------------|-----------------------------|
| 0 ml/lt                            | 39.9a               | 37.2a                      | 44.11                  | 60.7                  | 13.22a                      |
| 3 ml/l                             | 45.2ab              | 45.1b                     | 49.33                  | 60.7                  | 13.72a                      |
| 6 ml/l                             | 47.6b               | 43.6ab                   | 47.5                  | 63.7                  | 13.86a                      |
| 9 ml/l                             | 41.1ab              | 42.7ab                   | 54.07                 | 54.7                  | 9.65b                       |
| L.s.d                              | 7.5                 | 6.79                      | 3.279                  | 12.91                 | 2.14                        |

¹Number followed by same letter in the same column indicate no significant difference at P≤0.05. Lsd: Least significant difference

Pod number in dosage of 6 ml/l was significantly the highest at 47.6 pod/plant compare to control plants. Average pod number for Dega soybean variety is 29 pod/plant [11] in which the value was close to control plant (39.9 pod/plant). Data in Table 2 indicating that silicon foliar spray increases pod number by 2.9% (9 ml/lt) to 16.2% (6 ml/lt). Furthermore, weight of fresh pod number was also significantly higher in 6 ml/lt dosage when compare to control plant. While pod number tends to increase, weight of 100 seed was much lower than its potential. Soybean cv. Dega has potential of 100 seed weight at 22.98 g [11]. Lower seed weight might be caused by increasing number of pods, so seed development was contributed to many pods.

4. Conclusion

Application of nanosized biosilicon foliar spray at optimum concentration was significantly increase plant biomass, pod number and pod weight of soybean grown at lowland irrigated soil. Current study suggests that optimum dosage of rice husk-based biosilicon foliar spray for the better growth and
higher yield is 6 ml/lt which increases yield at about 39.06% compared to plant without supplementary nutrient.

Acknowledgment
This experiment was part of dissemination activity entitled “Developing cropping system in West Nusa Tenggara (NTB) province” at Assessment Institute of Agriculture Technology (BPTP) NTB in 2018.

References
[1] Aldillah, Rizma. 2015. Projected Indonesian soybean production and consumption. Applicable Quantitative Economic Journal, Vol. 8 (1): pp 9-23.
[2] BPS, 2018. Indonesia dan Nusa Tenggara Barat dalam Angka 2018.
[3] Bisnis.com News. 2019. Impor Kedelai Diprediksi Capai 2.75 Juta Ton. Available at
[4] Sudaryanto, T and D.K.S. Swastika. 2013. Teknik Produksi dan Pengembangan Kedelai: Ekonomi Kedelai di Indonesia.
[5] BB Pascapanen, “Menambang Nano Biosilika dari Sekam Padi”
[6] Rahman, Arif. 2018. Pembuatan Nanosilika Gel Dari Abu Sekam Padi. UIN Alauddin Makassar : Makassar
[7] Hussain S, Shuxian L, Mumtaz M, Shafiq I, Iqbal N, Brestic M, Shoaib M, Sisi Q, Li W, Mei X, Bing C, Zirvak M, Rastogi A, Skalicky M, Hejnak V, Weiguo L, and Wenyu Y. 2020. Foliar application of silicon improves stem strength under low light stress by regulating lignin biosynthesis genes in soybean (Glycine max (L.) Merr.). Journal of Hazardous Materials. Vol. 401. 123256 (https://doi.org/10.1016/j.jhazmat.2020.123256)
[8] Santi L P, Goenadi D H, Barus J and Dariah A. 2018. Pengaruh Bio-nano silica terhadap hasil dan efisienesi penggunaan air kedelai hitam di lahan kering masam.
[9] Zhang X, Shang C, and Xiao S. 2012. Continuous method and production device for producing hydrolysis-resistant stable ionic tatanium. Journal of Integrative Agriculture. Vol 17 (10). 2151-2159
[10] Schmidt F H and Ferguson J H A. 1951. Rainfall types based on wet and dry periode ratios for Indonesia with Western New Guinea. Jakarta: Kementerian Perhubungan Metiorologi dan Geofisika
[11] Balitkabi, 2016. Deskripsi varietas unggul kedelai 2016-2018.
[12] Marwoto, Subandi, Adisarwato T Sudaryunoo, Kasno, A, Hardaningsih S, Setyorini D, Adie MM. 2015. Pedoman Umum Pengelolaan Tanaman Terpadu (PTT) Kedelai. Bogor: Pusat Penelitian dan Pengembangan Tanaman Pangan
[13] STAR, 2014. Stastical tool for agricultural Reserch (STAR) 2.0.1. International Rice Research Institute.
[14] BB Pascapanen, n.d. Balitbangtan kenalkan pupuk biosilika dari sekam di lahan pasang surut.
[15] Wang Y, Zhang B, Jiang D, and Chen G. 2019. Silicon improves photosynthesis performance by optimizing thylakoid membrane protein component in rice under drought stress. Eniron. Exp. Bot., 158. 117-124
[16] Pei Z F, Ming D F, Liu D, Wan G L, Geng X X, Gong H J, et al. 2010. Silicon improves the tolerance to water-deficit stress induced by polyethylene glycol in wheat (Triticum aestivum L.) seedling. J. Plant Growth Regul. 29. 106-115
[17] Lu Y, Ma J, Teng Y, He J, Christie P, Zhu L, et al. 2018. Effect of silicon on growth, physiology, and cadmium translocation of tobacco (Nicotiana tabacum L.) in cadmium-contaminated soil. Pedosphere (28). 680-689.
[18] Surywnai S and Umami A. 2020. Stomata and trichone of the Anjasmoro soybean cultivar during the application of nanosilica and plant growth promoting Rhizobacteria. Vegetalika. 9(1) 343-349
[19] Sapre S. S and D.N. Vakharian. 2016. Role of silicon under water deficit stress in wheat: Biochemical perspective. Agricultural Reviews. 37 (2): 109-116
[20] Khsanti A., B. Kurniasih and D. Indradewa. 2018. Pengaruh aplikasi silika terhadap pertumbuhan dan hasil tanaman padi (Oryza sativa) pada kondisi salin. J.Vegetalika, 7(4):1-11
[21] Taufiq F., B. A. Kristanto, and F. Kusmiyati. 2020. Pengaruh pupuk silika terhadap pertumbuhan dan produksi kedelai pada tanah salin.