Application of nano-silicon foliar fertilizer to double dry season soybean productivity of Central Lombok rainfed lowland

L Hadiawati and A Suriadi

Assessment Institute for Agricultural Technology (AIAT) of West Nusa Tenggara Province. Jalan Raya Peninjauan Narmada, Lombok Barat. NTB. Indonesia. 83711

Corresponding author: lia.hadiawati@gmail.com

Abstract: Soybean (Glycine max (L.) Merr) is the rotation crop that dominantly grown after rice during dry season in most lowland paddy field of Eastern Indonesia. This on-farm experiment aimed to improve dry season soybean production by spraying liquid fertilizer containing silicon. Burangrang soybean variety grown from August to October 2018 at Tenandon of Penujak Village, Praya Barat sub-district of Central Lombok, West Nusa Tenggara Province. Five treatments were arranged on randomized block design with five replications on 100 m² plot size. The treatments were application of silicon-based liquid fertilizer named T1 (O**n or ON), T2 (Bio**x or BX), T3 (BioS****a or BS), T4 (BioU**n or BU) that compare to T0 (control) which was without any foliar spray. Land preparation, planting, irrigation, and harvest were guided using integrated soybean management handbook. Yield and yield component data was collected at harvest. The result showed that application of liquid fertilizer was significantly increase total dry matter weight, including percentage dry matter accumulation on leaf, pods weight, and percentage of filled pods. Soybean productivity was improved about 102.06% (T3), 95.88% (T4), 61.86% (T1), dan 47.42% (T2) when compared to T0 at 0.9 t/ha.

1. Introduction

Soybean (Glycine max (L.) Merr) is one of the main sources of protein for smallholder farmers in eastern Indonesia, including in West Nusa Tenggara (NTB) Province. Soybean could substitute protein from some other sources such as milk, meat, and fish [1]. Most of the soybeans (88%) are consumed in the form of tempeh (fermented soybean), tofu, soy sauce or bean sprouts [2]. Besides containing 40% protein and amino acids such as glycine, tryptophane, and lysine, soybeans also contain 23% carbohydrates, 20% fat and a number of minerals, vitamins, fiber, high antioxidants, Omega-3 fatty acids and various other useful compounds such as phytosterols, lecithin and phenolic acids [3].

Indonesian soybean production is only able to meet 30% of national demand [4]. Key factors for low soybean production are reduced harvest area and low plant productivity. In case of NTB area, decreasing harvest area of soybean is due to low economic value that less competitive to other dry season crops such as maize, tobacco, watermelon, or shallots. Apart from reduced harvest area, soybean productivity in Indonesia is only half of its potential. The average soybean productivity ranges from 1.0 t/ha to 1.5 t/ha, while its potential reaches 2.0 t/ha to 2.5 t/ha [5]. Soybean is native sub-tropic plant that tends to flower earlier with shorter seed dormancy, and level of Rhizobium
symbiosis is lower when grown in tropical areas [6]. These might contribute to lowering soybean productivity although some adaptive varieties have been released [7].

NTB is one of national soybean production centre outside Java Island that covers 68.896 ha harvest area in 2014 with total production was 97.171 tones [8]. In NTB, soybean is the rotation crops that mostly cultivated during dry season or after harvest of rice. Sudaryanto and Swastika [2] reported that more than 60% of soybean is second crop that grown after rice in lowland paddy field, while the remaining 40% is grown in rainfed area. The main obstacle to dry season soybean in NTB is low water availability and high soil acidity. Soybean requires neutral soil pH between 5.5 and 7.0. This soil reaction is closely related to soil moisture content in determining available nutrients for plants. Soybean need nitrogen (N), phosphorus (P), and potassium (K) in large quantities at about 205 kg of N, 55 kg of P, and 135 kg of K to produce 3 t/ha [9].

The application of liquid organic fertilizer (POC) is one of the strategies for more effective nutrient supply and more efficient water use that environmentally friendlier than chemical fertilizer for dry season soybean. Some recent studies show fertilizers containing silicon (Si) is not only provide nutrients to improve plant growth but also increase plant resistance to drought. Si is one of the prevalent macro nutrients that important for plants in responding to abiotic stresses such as limited water availability, increasing amount of available P, and turn it also increasing crop yields [10]. Si is also able to improve plant drought tolerance and nutrient use efficiency [11]. Actually 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]. Although the amount of Si is large in the soil, most of it is in a form that is not available to plants because it is tightly bonded with other elements to form silica or silica oxide. This study aims to determine the productivity of dry season soybeans grown in rainfed lowland with the application of several types of POC containing Si.

2. Materials and methods

2.1. Experiment site and design

A field experiment was carried out in Tenandon of Penujak village at Central Lombok district, NTB province, Indonesia. The geographic location is S -8°45’35” x E 116°14’20” located at 93.9 meter above sea level. Soybean grown during dry season from August to October 2018 in lowland paddy field within a week after rice harvested. There were some rainy days during experiment which was 3 mm in August, 25 mm in September, and 2 mm in October.

The experimental design used was a Randomized Block Design that consisted of five treatments of four liquid fertilizers namely orin (T1), biomax (T2), biosilika (T3), and biourine (T4) in addition to control (T0). Each treatment was replicate in five plots (10 m × 10 m) within 3,000 m² total area.

Based on the information in the packaging, the T1 is made of volcanic rock containing Si and other essential nutrients. Meanwhile, the T2 is nano liquid fertilizer that contains 10.90% SiO₂, 189 ppm Mo, and 0.35 ppm Co. Furthermore, T3 is organic fertilizer product made of rice husks with minimum SiO₂ content of 10% by weight, and it also contains other natural mineral nutrients. Unlike other, T4 is liquid organic fertilizer produced from fermented cattle urine which is enriched with microbes. Generally, recommendation dosage for each fertilizer was 3 lt/ha where 30 ml fertilizer was diluted in a liter of water.

Soybean plants (Glycine max (L.) Merr) cv. Burangrang was obtained from Unit Produksi Benih Sumber (UPBS)/Seed production Unit of Balai Pengkajian Teknologi Pertanian (BPTP)/Assessment Institute of Agricultural Technology of NTB 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. The liquid fertilizer treatment was first sprayed at 3 weeks after planting and repeated in 2 weeks interval until flowering period. During the growing period, water pumped from nearby river to irrigate the plant.
2.2. Data collection and analysis

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, branches number, root weight, stem weight, leaf weight, pod weight, dry biomass weight, filled pods, empty pods and number of seeds per 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

3.1. Productivity of soybean

Productivity of soybean with application of foliar spray was significantly higher when compare to control (T0) as shown in Figure 1. The highest yield was obtained at T3 (1.96 t/ha) and closely followed by T4 (1.90 t/ha), T1 (1.57 t/ha), and T2 (1.43 t/ha). The potential yield of Burangrang variety is about 1.6 to 2.5 t/ha [7] which was close to the yield in this experiment. However, without any liquid fertilizer treatment such as in control (T0), yield of Burangrang variety was much lower at average 0.97 t/ha. By comparing yield in T0 to other treatments, there were significant increases in yield at about 47.42% (T2) to 102.06% by spraying liquid fertilizer. Similar finding reported by Santi et al [11,19] that bean production of soybean cv. Detam-1 improved up to 36.7%.

![Figure 1. Effect of some fertilizer foliar spray on productivity of soybean cv. Burangrang grown on lowland rainfed of Central Lombok during dry season 2018](image)

The results of this field experiment showed the importance of additional nutrients in from of liquid fertilizer for soybean, mainly that grown during dry season. The data indicating that liquid fertilizer in smaller or nano particles was able to produce a better yield, for example, T3 that made of nanosized silica from rice husk charcoal was yield higher than others [14]. The advantages of nanosized fertilizers are reactive and directly available to plants even thought applied in small amounts [15]. Moreover, nano-sized fertilizers are expected to be a breakthrough environmentally friendly technology for more sustainable crop production [16]. Another potential source of foliar spray is fertilizer made organic material such as fermented cattle urine (T4) acts for both fertilizer and plant growth regulator.
3.2. Yield component of soybean

Statistical anova analysis of yield component shown in Table 1 where there was no significant difference on weight of 100 seed and total seed per plant between treatments, but there was significant effect on treatment on plot yield, plot biomass, and productivity. There was tendency that seed production with foliar spray fertilizer was higher than control. For example, seed production in T3 was the highest at 13.29 g/plant, and in turn it might contribute to a higher plot yield (1.18 kg/ 6 m$^2$) and higher productivity (1.96 t/ha). On the other hand, seed of soybean without foliar spray was consistently has the lowest values.

**Table 1.** Effect of some fertilizer foliar spray on weight of seed, weight of 100 seed, weight of plot yield, weight of plot yields dry biomass, and productivity of soybean cv. Burangrang grown on lowland rainfed of Central Lombok during dry season 2018

| Treatments | Weight of seed (g/plant) | Weight of 100 seed (g) | Weight of plot yield (kg/6 m$^2$) | Weight of dry biomass (kg/6m$^2$) | Productivity (t ha$^{-1}$) |
|------------|--------------------------|------------------------|-----------------------------------|-----------------------------------|-----------------------------|
| T0         | 6.17                     | 14.62                  | 0.58$^b$                          | 0.69$^b$                          | 0.97$^b$                    |
| T1         | 10.56                    | 15.25                  | 0.94$^a$                          | 1.45$^a$                          | 1.57$^a$                    |
| T2         | 9.44                     | 16.41                  | 0.86$^b$                          | 1.46$^b$                          | 1.43$^a$                    |
| T3         | 13.29                    | 14.98                  | 1.18$^a$                          | 1.57$^a$                          | 1.96$^a$                    |
| T4         | 12.43                    | 17.05                  | 1.14$^a$                          | 1.64$^a$                          | 1.90$^a$                    |
| CV (%)     | 31.21                    | 8.49                   | 32.68                             | 23.92*                            | 32.47                       |

$^a$ $^b$ Number followed by the same letter in the same column is indicating no significant difference. *: Least significant difference at P≤0.05, **: Least significant different at P≤0.01

Moreover, weight of plot dry biomass (Table 1) was significantly the lowest at T0. This data indicating that growth of soybean was less optimal without additional foliar spray fertilizer. There was positive correlation ($R^2 = 0.7359$) between biomass and seed production of soybean as shown in Figure 2. In line to this result, Krisnawati and Adie [17] reported that agronomic character such as plant height is contributing to increase plant biomass and positively correlated ($r = 0.315**$) to seed production of soybean. Next, application of nano-sized silicon fertilizer was affecting seed production per plant and plot yield [18].

Based on soybean variety description book [7], soybean cv. Burangrang has potential of 100 seed weight at 17 g which is close to seed in T4 (17.05 g), while the lowest was in T0 (14.62 g). Although there was no significant difference on weight of 100 seed between treatments, low value in T0 may cause by less available supplemented nutrient, in turn seed development was less optimal compared to plant with foliar spray treatment.
In Table 2, there was no significant effect of treatment on most of yield component parameter (pods weight, pods number, and seed number) except percentage of filled pods. Interesting significant high percentage of filled pods (88.13%) data in T0 was followed by high number of pods (76.20 pods) and high weight of pods (67.48 g), but it has the lowest seed number (40.58 seed/plant). These data indicating that T0 has smaller pods size with lower seed number at about 1-2 seed/pods. In contrast, seed number was higher in plants with foliar spray fertilizer such as in T3 (88.82 seed/plant) even though number and weight of pods were lower. According to Zulputra [19], fertilizer that contain Si could trigger P nutrient intake which is important to support plant metabolism. In this study, pods and seed development were better with application of foliar spray fertilizer, in results, seed number increase between 29% (T2) to 54% (T3) compared to T0.

Table 2. Effect of some fertilizer foliar spray on pods weight, pods number, percentage of filled pods, and seed number of soybean cv. Burangrang grown on lowland rainfed of Central Lombok during dry season 2018

| Treatments | Weight of pods (g/plant) | Pods number per plant | Percentage of filled pods | Seed number per plant |
|------------|--------------------------|------------------------|---------------------------|-----------------------|
| T0         | 67.48                    | 76.20                  | 88.13^a                   | 40.58                 |
| T1         | 57.10                    | 76.80                  | 78.50^b                   | 72.77                 |
| T2         | 57.78                    | 70.20                  | 81.18^b                   | 57.17                 |
| T3         | 55.44                    | 64.67                  | 76.88^b                   | 88.82                 |
| T4         | 58.80                    | 65.00                  | 78.66^b                   | 73.63                 |
| CV (%)     | 29.77                    | 35.75                  | 10.40**                   | 31.88                 |

^a Number followed by the same letter in the same column is indicating no significant difference. *: Least significant difference at P≤0.05, **: Least significant different at P≤0.01

3.3. Growth of soybean

Statistical anova analysis of some growth parameter were shown in Table 3. There was no significant effect of treatment on plant height, branch number dry biomass weight. In this study, soybean cv. Burangrang grown during dry season was about 54.62 cm height, with average number of branches was 4.49 and dry biomass weight was 40.96 g. All values in T0 were consistently lower that these averages. Growth of soybean cv. Burangrang grown in optimal environment condition is 60-70 cm in height with 1-2 branches [7].

Table 3. Effect of some fertilizer foliar spray on plant height, branch number, dry biomass, percentage stem, root, leaf, and pods dry weight accumulation of soybean cv. Burangrang grown on lowland rainfed of Central Lombok during dry season 2018

| Treatment | Plant height (cm) | Branch number | Dry biomass weight (g/plant) | Percentage of dry biomass accumulation (%) |
|-----------|-------------------|---------------|------------------------------|--------------------------------------------|
|           |                   |               |                              | Stem | Root | Leaf | Pods |
| T0        | 52.33             | 4.47          | 38.49                        | 13.20 | 2.16^a | 1.15^b | 83.49^a |
| T1        | 55.90             | 5.13          | 44.41                        | 12.17 | 1.70^b | 12.66^a | 73.47^b |
| T2        | 54.30             | 4.27          | 35.70                        | 17.58 | 1.59^b | 11.04^a | 69.80^b |
| T3        | 54.53             | 4.60          | 41.95                        | 12.92 | 1.49^b | 9.84^a | 75.75^b |
| T4        | 56.33             | 4.00          | 44.26                        | 13.20 | 1.36^b | 10.72^a | 74.49^b |
| CV (%)    | 13.77             | 37.39         | 38.88                        | 54.22 | 40.18* | 46.94** | 11.27** |

^a Number followed by the same letter in the same column is indicating no significant difference. *: Least significant difference at P≤0.05, **: Least significant different at P≤0.01

In Table 3, percentage of dry biomass accumulation from stem, root, leaf, and pods weight was significantly different between treatments, except the stem weight. Percentage of root and pods weight in control (T0) was significantly higher than foliar spray treatments, but the leaf weight was the lowest (P≤0.01). Plant in T0 was likely spur root development to get sufficient water and nutrient to grow, and then it was dominantly mobilized for pods and seed development. During dry season, warm
climate and less available water stimulate early generative stage by shed leaves. That is why leaf weight in T0 was the lowest at harvest that causing percentage of pods was higher. Santi et al [11] reported that water consumption of soybean cv. Detam-1 was reduced by 65%, further, chemical fertilizer (N, P, and K) was 32% more efficient when nano-bio silica fertilizer applied. Although no significant differences after application of liquid fertilizer between treatments, respond of plant was specific for each foliar spray. Even at different concentration of silica fertilizer, respond of soybean was varies on leaf number, branch number, Net Assimilation Rate/NAR, Relative Growth Rate/RGR, productive branches at 21 days, 30-45 days, 35 days after planting [18]. In this experiment, plant was grown taller in T4 that made of fermented cattle urine, while T3 that made of nano-sized rice husk charcoal was likely stimulate branch formation, and biomass accumulation was much higher in T1 that made of volcanic rock-based materials. All in all, plant respond to fertilizer was varied due to different element and nutrient content in each fertilizer that most likely depend on ingredient and materials.

4. Conclusion
Foliar spray could increase productivity of soybean cv. Burangrang grown during dry season t about 47.42% (T2) to 102.06% (T3) higher than without it. Nano-sized silicon based liquid fertilizer that made from organic materials such as rice husk is recommended to improve biomass, seed weight and number, yield and productivity of soybean grown during dry season.

Acknowledgements
This experiment was part of dissemination activity entitled “Developing cropping system in West Nusa Tenggara (NTB) province” In 2018 by Assessment Institute of Agriculture Technology (AIAT) NTB

References
[1] Bhama S and Sadana B K 2004 J. Food Science and technology 41 459–461
[2] Sudaryanto T and Swastika D K S 2013 Ekonomi Kedelai di Indonesia (Malang: Pusat Penelitian dan Pengembangan Tanaman pangan) p 28–44
[3] Akubor P I 2005 J. Food Science and Technology 42 303–307
[4] Kastono D 2005 J. Agricultural Science 12 103–116
[5] Adisarwanto T, Subadni, Sudaryono 2013 Teknologi Produksi Kedelai. (Malang: Pusat Penelitian dan Pengembangan Tanaman Pangan) p 229–252
[6] Thoenes P 2004 The role of soybean in fighting world hunger (Rome: Food and Agricultural Organization of the United Nation)
[7] Balitkabi 2016 Deskripsi varietas unggul kedelai 2018-2016 (Malang: Balai Penelitian Tanaman Aneka Kacang dan Umbi)
[8] BPS 2014 Nusa Tenggara Barat dalam Angka tahun 2014 (Mataram: Badan Pusat Statistik Provinsi Nusa Tenggara Barat)
[9] Rubio A R I and Ciapara I H 2002 Soybean: Post-harvest Operation. (Rome: Food and Agricultural Organization of the United Nation)
[10] Rosmarkam A and Yuwono N W 2002 Soil Fertility Science (Yogyakarta: Kanisius)
[11] Santi L P, Goenadi D H, Barus J and Dariah A 2018 Jurnal Tanah dan Iklim 42 43–52
[12] Marwoto, Subandi, Adisarwato T, Sudaryunoo, Kasno A, Hardaningsih S, Setyorini D, Adie M M 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. (Los Banos: Internasional Rice Research Institute)
[14] Hoerudin 2017 Biosilika dari sekam padi: meraup rupiah dari gundukan limbah (Jakarta: Balai Penelitian dan Pengembangan Pertanian)
[15] Rochman N and Jumaranman 2008 J. Industrial Research 2 56–63
[16] Syahri R, Djaadi, Sumarni and Nugroho A 2016 *Jurnal Produksi Tanaman* 4 73–81
[17] Krisnawati A dan Adie M M 2016 *Buletin Palawija* 14 49–54
[18] Suciaty T, Purnomo D, Sakya A T and Supriyadi 2018 *IOP Conference series:Earth and Environmental Science* 129 012009
[19] Zulputra, Wawan dan Nelvia 2014 *Jurmal Agroteknologi* 4 1–10