Improvement of soybean yields using organic fertilizer enriched with microbes under dry land condition of Banten Province

S Yuniarti, T Mulyaqin, M C Hadicatri and R Purba*

Banten Assessment Institute for Agricultural Technology (AIAT)
Jl. Ciptayasa Km.01 Ciruas, Serang, Banten 42182.

E-mail: *resmayeti63@yahoo.com

Abstract. The objective of the present study was to determine the yield and growth of soybeans using organic fertilizers enriched with microbes under dryland conditions. The research was carried out in the Pandeglang Regency of Banten Province. A randomized block design was used using 4 treatments, and 6 replications. The treatments were fertilization, namely without fertilizer (control/P1); 3 ton/ha of chicken manure (P2); 3 ton/ha of chicken manure, and recommended inorganic fertilizer (P3); 1 ton/ha of organic fertilizer enriched with microbes, and recommended inorganic fertilizer (P4). The soybean variety used was the Anjasmoro variety. The parameters observed were the length of root, the height of plant, the nodules number, root weight at age 65 days after planting (DAP), the filled pods' number, and the soybean yield. The research results showed that the treatment of organic fertilizer enriched with microbes (P4) gave a higher growth response based on the value of the height of the plant, the length of root, the number of nodules, and the number of filled pods, compared to other treatments. It increased soybean yield from 1.58 ton/ha up to 2.61 ton/ha.

1. Introduction

Soybean (Glycine max L.) is an important source of vegetable protein for Indonesian people. In general, the problems faced by soybean farmers in Pandeglang Regency, Banten are almost the same as in other areas in Indonesia, including the use of low production of soybean varieties, unbalanced fertilization, low-nutrient of land cultivation [1,2]. Currently, soybean productivity in farmers' land varies from 0.50-1.5 ton/ha, while the potential productivity of superior soybean varieties in the last decade is greater than 2.5 ton/ha. One of the problems in soybean cultivation under dryland conditions is the lack of organic matter. This situation causes the soil structure unable to support root development in the absorption of nutrients. Because of that, nutrients are not available for soybean plants. As the result, fertilization becomes inefficient since the plant cannot absorb nutrients from fertilizer.

One way to increase the soybean yields on dry land is by using organic and inorganic fertilizers as well as biological fertilizers together. Optimal soybean yields can be achieved if inorganic fertilizers (Urea, SP-36, and KCl) are combined with the organic manure application, enriched with microbes, and biological fertilizers. Moreover, the use of bio-fertilizer as a seed treatment for soybean seeds planted on dry land is beneficial for improving soil quality and increasing the organic matter content [1,3,4]. Furthermore, the application of bio-fertilizer as a seed treatment 200 grams/ha combined with "Urea 25 kg/ha + SP 50-100 kg/ha and KCl 50-75 kg/ha + manure 1,000-1,500 kg/ha" on acid soils provide
soybean production 1.35 - 1.75 tons/ha, while without it was only 0.8-1.35 tons/ha [5]. It happened because the bio-fertilizer contains 3 isolates of *Bracythiozobium japonicum* bacteria which are effective and tolerant of acid soils up to pH 4.0. It was also able to replace the need for urea fertilizer of more than 50%-75% in soybean plants and stimulate the growth of root nodules and the number of filled pods per plant.

Cattle and chicken manure are organic fertilizers sources that can be produced by farmers. However, to obtain adequate growth and soybean yields, manure is needed in large quantities, approximately up to 3-5 tons/ha. Hence, its application faces problems in procurement, transportation, and application due to high labour and costs. In this matter, the application of an organic fertilizer that contains higher nutrients than cattle and chicken manure is a solution to reduce the quantities.

The application of "high nutrient" organic fertilizer as much as 1.5 tons/ha combined with biological fertilizer reached 1.43 tons/ha soybean production. It was higher than the application of 2.5 tons/ha of chicken manure (1.33 tons/ha) or 3.5 tons/ha cow manure (1.16 tons/ha). Furthermore, it improved plant growth and increased soybean yield from 0.89 tons/ha to 1.80 tons/ha. Moreover, the biological fertilizer combined with a high nutrient organic fertilizer in soybean plants with a base fertilizer of "Urea 50 kg/ha + SP36 50 kg/ha + KCl 50 kg/ha" effectively stimulated the formation of nodules and increased yields of 1.70 tons/ha to 2.23 tons/ha compared with the application of "Urea 100 kg/ha + SP36 100 kg/ha + KCl 100 kg/ha" [5].

One of the fertilization technologies from the Indonesian Agency for Agricultural Research and Development, the Ministry of Agriculture is an organic fertilizer enriched with microbes *Azospirillum Sp.*, *Azotobacter Sp.*, and *Aeromonas Sp*. The microbes function to anchor N from the air to becomes a form that can be used by plants, to solidify soil aggregates, and to dissolve P so can be used by plants. The microbes also produce organic acids, enzymes, and hormones that can stimulate plant growth (growth-promoting substances). The use of an organic fertilizer enriched with microbes *Azospirillum Sp.*, *Azotobacter Sp.*, and *Aeromonas Sp*. resulted in higher soybean yields.

The research objective of the present study was to determine the growth and yield of soybeans fed with an organic fertilizer enriched with microbes *Azospirillum Sp.*, *Azotobacter Sp.*, and *Aeromonas Sp.* under dryland condition.

2. Materials and methods

2.1. Research site and materials

The research was conducted on dry land in Kadumadang Village, Cimanuk District, Pandeglang Regency, Banten Province, from October 2018 to February 2019. The materials used were soybean seed (Anjasmoro variety), organic fertilizer, inorganic fertilizer, a bio-fertilizer which contains 3 isolates of *Bracythiozobium japonicum* as a seed treatment, an organic fertilizer enriched with microbes *Azospirillum Sp.*, *Azotobacter Sp.*, and *Aeromonas Sp.*, etc.

2.2. Design experiment and management of the crop

A randomized block design was used in the experiment, four treatments with 6 replications. The treatments were fertilization, namely P1: without fertilizer (control), P2: chicken manure 3 tons/ha, P3: chicken manure 3 tons/ha + a recommended dosage of inorganic fertilizers (Urea 75 kg/ha + 100 kg/ha SP-36 + 100 kg/ha KCl), P4: organic fertilizer enriched with microbes *Azospirillum Sp.*, *Azotobacter Sp.*, and *Aeromonas Sp.*. 1 ton/ha + a recommended dosage of inorganic fertilizers (Urea 75 kg/ha + 100 kg/ha SP-36 + 100 kg/ha KCl).

We applied perfect tillage as a land preparation. The channel between the treatments was made 20-30 cm wide and deep, forming a plot with a size of 5 m x 10 m. Planting spacing was 40 cm x10 cm. Manure was applied during soil processing as basic fertilizer. A bio-fertilizer which contains 3 isolates of *Bracythiozobium japonicum* was used as seed treatment with a dose of 200 gram per 40 kg of soybean seed. The soybean seeds were sprinkled with water, then stirred until the bio-fertilizer attached to the seeds. The mixed seeds were planted immediately, the remaining bio-fertilizer which did not attach to
the seeds was immersed in the planting hole. Each planting hole consisted of 2 grains of soybean seed. An organic fertilizer enriched with microbes *Azospirillum Sp.*, *Azotobacter Sp.*, and *Aeromonas Sp.* was given during soil cultivation and also was given as a cover for the hole after the soybean seeds were planted. Inorganic fertilizers according to the treatment were given simultaneously at the age of 10 days after planting (DAP) plants and applied at a distance of ± 5 cm from the planting hole as deep as 7 cm. Maintenance of plants, control of weeds and pests and diseases were carried out optimally according to the development of existing plant pests. The harvesting was done after the plants were physiologically ripe with dropping leaves approximately 90% and pods were brown or brownish-black.

The parameters observed consisted of growth components (plant height, root length, the number of nodules at the age of 65 days after seedling (DAS), root weight), and yield components (the number of filled pods per plant and the yield of soybean seeds).

2.3. Data analysis
Data were analysed for variance (Analysis of Variance/Anova) and continued with the Duncan Multiple Range Test (DMRT).

3. Results and discussion

3.1. Soil analysis
Soil samples from the research location were analysed physically, chemically, and biologically before planting soybeans. The results of soil analysis can be seen in Table 1a, 1b, and Table 2. The condition of the research soil was sand (4%), dust (53%) and clay (43%), pH acid, high CEC with low Al saturation, low N, and C content. The results of the soil analysis showed that the land needed N and K fertilization and organic matter to increase C content. Furthermore, the results of the analysis of the biological properties of the soil showed positive N-fixing activity and P solvent, which meant that the nutrients in the fertilizer could be dissolved into the soil properly and gave an impact on the growth of soybean plants.

| No. | Parameters                        | Results |
|-----|-----------------------------------|---------|
| 1.  | Soil Texture                      |         |
|     | Sand (%)                          | 4       |
|     | Dust (%)                          | 53      |
|     | Clay (%)                          | 43      |
| 2.  | pH                                |         |
|     | KCl                               | 4.5     |
|     | H2O                               | 5.5     |
| 3.  | Organic Matter                    |         |
|     | C (%)                             | 1.63    |
|     | N (%)                             | 0.18    |
|     | C/N                               | 9       |
| 4.  | HCl extract 25%                   |         |
|     | K2O (HCl 25%) mg/100g             | 16      |
|     | P2O5 (HCl 25%) mg/100g            | 146     |
|     | Morgan K2O ppm                    | 149     |
|     | Olsen P2O5 ppm                    | 65      |
|     | Bray P2O5 ppm                     | 139     |
**Table 1b.** Physical and chemical analysis of soil sample in the research location (continue).

| No. | Parameters                      | Results |
|-----|--------------------------------|---------|
| 5.  | Cation exchange rate            |         |
|     | Na Cmol/kg                      | 0.26    |
|     | Ca Cmol/kg                      | 7.00    |
|     | K Cmol/kg                       | 0.28    |
|     | Mg Cmol/kg                      | 2.35    |
|     | Total                            | 9.53    |
| 6.  | CEC Cmol/kg                     | 14.43   |
| 7.  | BS %                            | 69      |
| 8.  | Al3++ Cmol/kg                   | 0.00    |
| 9.  | H+ Cmol/kg                      | 0.20    |

**Table 2.** Biological analysis of the soil sample in the research location.

| No | Parameters                      | Unit       | Results    |
|----|--------------------------------|------------|------------|
| 1  | Total of Heterotrophic bacteria | CFU/g      | 1.57 x 10^7|
| 2  | Total of Fungi                  | Propagul/g | 8.10 x 10^4|
| 3  | Actinomycetes Sp.               | CFU/g      | Not detected|
| 4  | The N-fixing bacteria           | CFU/g      | 1.73 x 10^6|
| 5  | Solvent-bacteria                | CFU/g      | 1.90 x 10^6|
| 6  | Dehydrogenase activity          | Ug TPF/g/soil/day | 128,052 |
| 7  | Respiration                     | Mg C-CO3/day/kg/soil | 6,738     |
| 8  | The N fixing activity           | -          | Positive   |
| 9  | P solvent activity              | -          | Positive   |

3.2. The growth of soybean

The results of growth parameters measurement and statistical analysis can be seen in Table 3. In this experiment, fertilizer treatment had a significant effect on all growth components.

**Table 3.** The results of the soybean growth component.

| Treatments | Plant height (cm) | Root length (cm) | Number of root nodules (unit) | Root Weight (g) |
|------------|-------------------|------------------|-------------------------------|-----------------|
| P1         | 50.44^a           | 20.37^a          | 50.12^a                       | 0.2^a           |
| P2         | 55.15^b           | 21.34^a          | 52.61^a                       | 0.4^c           |
| P3         | 58.23^c           | 22.34^a          | 57.92^b                       | 0.7^b           |
| P4         | 62.34^d           | 25.24^b          | 62.80^c                       | 0.9^b           |

Note: ^abc,d^ Numbers in the same column followed by the same letters show no significant difference (P<0.05) based on the DMRT

The number of nodules, length, and root weight in P4 treatment was higher than treatment P3, P2 and the lowest was treatment P1. The root system in soybeans consists of a taproot formed from root candidates, several secondary roots arranged in four rows along with the taproot, secondary root branches, and adventitious roots that grow from the bottom of the hypocotyls [6]. Various factors, such as soil hardness, plant population, and variety, determine the length of the taproot. Ripe nodules were seen at the age of 60-65 DAS. The characteristic of ripe root nodules is pinkish colour caused by the presence of leghemoglobin, which is thought to be active in fixing nitrogen, whereas green nodules are thought to be inactive [7]. It is suspected that soil conditions in the P4 treatment were more fertile and...
loose, thus affecting the growth of soybean roots. Root nodules are an indicator of the addition of N by soybean plants. The root nodules correlate with the rhizobium population in the soil, the N nutrient of soybean requirements, and plant growth [8]. Furthermore, biological fertilizers influenced the number of soybean root nodules [2,6]. Furthermore, the bio-fertilizer which contains 3 isolates of Bradyrhizobium japonicum which was applied as a seed treatment can increase the uptake of N, P, and K [4]. In the soil, N, P, and K exist in 2 forms as "inorganic" and "organic" which are important as sources of nitrogen, phosphorus, and potassium and can spur the nodules growth and the number of filled pods per plant.

The high production of root nodules is a measure of the effectiveness of N reform and increase the availability of N, support the plant growth, and increased soybean yield. The impact of P4 treatment causes the condition of soybean plants to form the nodules well. In this case, until the age of 65 days, the plants were still green which indicated that it has a longer period in the filling process of pithy pods. This is in line with the research studies which stated that soybean plants which able to form nodules until the age of 65 days, the leaves of the plants were still green so that the filling process of pithy pods took longer and resulted in optimal soybean seed yields [4].

3.3. The soybean yield

The result of yield components can be seen in Table 4. From the result, P4 gave the highest number of pods and the number of filled pods and the yield of soybean seeds, compared with fertilized P3 and P2, while the lowest was P1. The use of an organic fertilizer enriched with microbes, inorganic fertilizers, and bio-fertilizers as a seed treatment was able to increase the number of filled pods. This was presumably due to microbial activities: Azospirillum Sp, Azotobacter Sp, and Aeromonas Sp. Furthermore, bio-fertilizer contains solvent microbes and Bacillus Sp as a solvent for nutrients in the soil. The content of phosphate elements in the soil could be more effective with the addition of organic fertilizers so that plants grew optimally and provided a greater number of filled pods [9].

| Treatment | Number of filled soybean pods (pod) | Weight of 100 dry seeds (gram) | Soybean yield (ton/ha) |
|-----------|----------------------------------|-------------------------------|------------------------|
| P1        | 40.14\textsuperscript a          | 11.58\textsuperscript b        | 0.92\textsuperscript a  |
| P2        | 42.34\textsuperscript b          | 12.10\textsuperscript b        | 1.25\textsuperscript b  |
| P3        | 45.16\textsuperscript c          | 12.24\textsuperscript b        | 1.58\textsuperscript c  |
| P4        | 70.23\textsuperscript d          | 14.70\textsuperscript c        | 2.61\textsuperscript d  |

Note: \textsuperscript a,b,c,d Numbers in the same column followed by the same letters show no significant difference (P<0.05) based on the DMRT test

From the results, the application of an organic fertilizer enriched with microbes combined with inorganic fertilizers and bio-fertilizer as a seed treatment of soybean seeds was able to provide higher soybean yields. As shown in Table 4, the number of seeds produced in the P4 treatment was more than 50 per plant and yielded in more than 2 tons/ha which is statistically higher than other treatments. This is in line with another study that mentioned whether the number of soybean seeds is 50 seeds per plant, then theoretically the soybean yield will be more than 1.75 tons/ha [2]. Furthermore, the weight of 100 seeds of P4 treatment is suitable with the description of the Anjasomo variety which weighs 100 seeds ranging from 14.8 to 15.3 grams [10].

Dryland has a low organic matter content so that soil fertility is low. Soil organic matter is a buffer for soil biology and can maintain a balanced supply of nutrients for plants. The supply of organic matter that has been enriched with microbes in the soil has functions such as forming and causing stable soil aggregate stability, increasing water holding capacity, increasing soil porosity, improving soil physical and chemical properties, and influencing soil permeability and infiltration rate. The application of an organic fertilizer enriched with microbes Azospirillum Sp, Azotobacter Sp, and Aeromonas Sp of 1.0 ton/ha combined with inorganic Urea 75 kg/ha + 100 kg/ha SP-36 + 100 kg/ha KCl resulted in soybean
yields of 2.61 ton/ha. It was higher compared to the use of 3 ton/ha of chicken manure + Urea 75 kg/ha + 100 kg/ha SP-36 + 100 kg/ha KCl of 1.58 ton/ha. This means that the addition of organic fertilizers enriched with microbes improves plant growth and increased soybean yields from 1.58 ton/ha to 2.61 ton/ha.

4. Conclusions
The application of organic fertilizers enriched with microbes combined with inorganic fertilizers and seed treatment gave higher soybean growth and yield. Soybean cultivation under dryland condition using organic fertilizer enriched with microbes 1 ton/ha and the recommended dosage of inorganic fertilizers combined with seed treatments increased the yield from 1.58 tons/ha to 2.61 tons/ha.

References
[1] Purba R 2016 Respon pertumbuhan dan produksi kedelai terhadap pemupukan hayati pada lahan kering di Pandeglang Banten [Response of growth and soybean production to biological fertilization on dry land in Pandeglang Banten] JPPTP 19(3) pp 253-61
[2] Pieter Y and Mejaya MJ 2018 Pengaruh pemupukan hayati terhadap pertumbuhan dan hasil kedelai di lahan sawah [The effect of biological fertilization soybean growth and yield in paddy fields] J. Penelitian Pertanian Tanaman Pangan 2(1) pp 51-58
[3] Saraswati R 2013 Potensi penggunaan pupuk mikroba secara terpadu pada kedelai [Kedelai: Teknik Produksi dan Pengembangan] [Potensial use of integrated microbial fertilizers on soybean Soybean: Production Technique and Development] [Bogor: Badan Penelitian dan Pengembangan Pertanian Pusat Penelitian dan Pengembangan Tanaman Pangan] ed Sumano, Suyamto, A widjono, Hermanto, and H Kasim p 73
[4] Purwani J and Pratiwi E 2015 Pengaruh pupuk hayati terhadap pertumbuhan dan hasil kedelai pada ultisols Kabupaten Serang di rumah kaca [The effect of biological fertilizers on soybean growth and yield in Serang Districts ultisols in greenhouses] Prosiding Seminar Nasional Hasil Penelitian Tanaman Aneka Kacang dan Umbi Tahun 2015 p 162
[5] Harsono A, Prihastuti, and Subandi 2011 Efektivitas multi isolate Rhizobium dalam pengembangan kedelai di lahan kering masam [The effectiveness of Rhizobium multi isolates in the development of soybeans on acid dry land] Jptek Tanaman Pangan 6 pp 57-75
[6] Adhie M and A Krisnawati 2013 Biologi Tanaman Kedelai Kedelai: Teknik Produksi dan Pengembangan Badan Penelitian dan Pengembangan Pertanian [Soybean biology Soybean: Production Technique and Development] [Bogor: Badan Penelitian dan Pengembangan Pertanian Pusat Penelitian dan Pengembangan Tanaman Pangan] ed Sumarno, Suyamto, A widjono, Hermanto, and H Kasim p 73
[7] Bachtiar T dan S H Waluyo 2013 Pengaruh pupuk hayati terhadap pertumbuhan dan serapan nitrogen tanaman kedelai variasit Mitani dan Anjasmoro [Effect of biological fertilizers on the growth and nitrogen uptake of Mitani and Anjasmoro soybean plants] Widyariset 16(3) pp 411-18
[8] Saragih S D Hasanah Y dan Bayu E S 2016 Respons pertumbuhan dan produksi kedelai terhadap aplikasi pupuk hayati [The response of growth and soybean production to the application of biological fertilizers] J. Agroekoteknologi 3(614) pp 2167-72
[9] Gani JSA, Bahua MI and Zakaria F 2013 Pertumbuhan dan Hasil Tanaman Kedelai Berdasarkan Dosis Pupuk Organik Padat [Soybean Growth and Yield Based on The Dose of Organic Solid Fertilizer] Undergraduate Thesis [Gorontalo: Universitas Negeri Gorontalo]
[10] Balai Penelitian Tanaman Aneka Kacang dan Umbi 2013 Deskripsi Varietas Unggul Kedelai [Description of Superior Soybean Varieties] (Malang: Balai Penelitian Tanaman Aneka Kacang dan Umbi) p 80

Acknowledgements
We would like to thank the Indonesian Agency for Agricultural Research and Development (IAARD), the Indonesian Ministry of Agriculture for providing the research funding.