The effectiveness of technology packages of 15 biofertilizer formulas to increase soybean productivity on acidic soils

Harsono A¹, D Sucahyono¹, E Pratiwi², A Sarjia³, H Pratiwi³, D Andreas⁴, and T Simarmata⁵

¹Indonesian Legumes and Tuber Crops Research Institute
²Indonesian Soil Research Institute
³Indonesian Institute of Science
⁴Bogor Agricultural University
⁵Faculty of Agricultural, University of Padjajaran

E-mail: rifharsono@yahoo.co.id

Abstract. The potency of acidic soils for soybean development in Indonesia is quite large. However, low soil fertility and microorganisms population become contrains for achieving high productivity of soybean. The aim of this research is to determine the effectiveness of technology packages for 15 biofertilizers formula to increase soybean productivity in acidic soils. The research was conducted during the end of rainy season in South Kalimantan. The soil use in the study had pH 5.2 and soil Al-saturation 34.2%. The reasearch was arranged in a randomized block design, three replications consisted of 20 treatmens, namely: 1) 0 NPK, 2) 50% NPK, 3) 50% NPK +2 t/ha organic fertilizer 4) 70% NPK, 5) 100% NPK (100 kg urea + 100 kg SP36 + 100 kg KCl/ha), 6) Iletrisoy+ Biovam+Startmix, 7) Iletrisoy Plus, 8) Beyonic, 9 Biotricho, 10) Probio New, 11) RhizoBIOST, 12) Bio-SRF, 13) Biopim, 14) BioMIGE, 15) Biocoat, 16) FajarSOYA, 17) Rhizobion, 18) Agrizone, 19) Rhizophus, and 20) BISRF. For each biological fertilizer, 50-75% of recommended NPK fertilizers were given at 15 days after planting. The results indicated that combination of Biovam + Iletrisoy + Startmix biofertilizers, Iletrisoy plus, Biotricho, Probio New, Bio Mige, and Fajar SOYA were effective for increasing soybean productivity on acidic soils. These biological fertilizers + 50% recommended NPK + 1.5 t/ha organic fertilizer increases pods number, and soybean productivity more than 10% compared to the recommended NPK fertilizer dosage which was 1.81 t/ha. Several of these biological fertilizers have good prospects to be developed as bio-fertilizers for soybeans in acidic soils.

1. Introduction
In Indonesia, soybean is the third strategic commodity after rice and maize. However, soybean production in Indonesia only meet domestic demand for 25-30%, so the government continues to increase soybean production to achieve self-sufficiency.

The increased production of food crops including soybeans, according to the 2015-2045 Master Strategy for Agricultural Development, will be carried out by increasing the harvested area on sub-optimal land, including in acidic soils. Mulyani et al. [1] reported that in Indonesia there is an available of acid land which
is suitable for food crops development reached of 3.8 million ha. However these lands are considered the least favorable for soybean production due to lower fertility, potential toxicity from soluble forms of elements such as Al, Mn and Fe, unfavorable physical properties and acidic nature [2,3,4]. Therefore, to obtain high soybean productivity in this soils, it depends on the use of ameliorants and high doses of inorganic fertilizers. Several researchers reported that a number of microorganisms are considered as challenging agents for used as biofertilizer to improve soils vertility and plant growth [5,6,7]. Biofertilizers play an important role in increasing yield through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances, improving soil texture, pH, and other properties of soil [8, 9]. Macronutrients such as nitrogen, phosphorus, and potassium play a crucial role in plant growth and yield. Soybean nitrogen requirements are met in a complex manner, as this crop is capable of utilizing both soil N (mostly in the form of nitrate) and atmospheric N (through symbiotic nitrogen fixation).

Purba [10] reported that on acidic soils (pH 5.5) in Banten-Indonesia, the use of 200 g/ha of Agrimeth biofertilizer could substitute 50% of recommended inorganic fertilizer. The response of growth and yield of soybean using Agrimeth and Glicompost as biofertilizer separately these land were higher than those applying the recommended anorganic fertilizer. On acidic soils in Lampung, rhizobium biofertilizer (Iletrisoj) tolerant to acidic soil + 1.5 t/ha organic fertilizer which is enriched with P and Ca, can replace the role of 100% urea, 50% of SP36 and KCl, increasing yields more than 50% compared to control, and gave higher seed yield compared to using of recommended NPK dosage [11]. Triadiati et al. [12] reported that in acidic soils (pH 4.7), application of the acid tolerant B. japonicum BJ 11 (wt), compost, and nitrogen fertilizer (10 g m⁻²) increased the soybean plant height, dry weight of shoots and roots, nodule number, dry weight of nodules, nitrogenase activity, number of pod and seed, seed weight, and nitrogen content of seeds.

Previous research results indicated that the use of biofertilizers could be reduced the need for inorganic fertilizers, and increase soybean productivity on acidic soils. Related to these results, the aim of this research was to determine the effectiveness of technology packages for 15 biofertilizers formula to increase soybean productivity in acidic soils.

2. Materials and Methods
The research was conducted during the end of rainy season 2013/2014 on dry land of acidic soil in Pelaihari sub-district, Tanah Laut district, South Kalimantan Province, Indonesia. The experimental design used was a randomized block with three replications. The research consisted of 20 treatments, including 5 doses of NPK fertilizer, and 15 packages of biological fertilizer technology as presented in table 1

Before planting, the soil was properly cultivated, with an experimental plot size of 4 m x 5 m. Between treatments a drainage channel was made about 25 cm wide and about 30 cm deep. The high of soil Al-saturation was reduced by dolomite application to about 20% (Tolerance Limit for soybean plants) with the following formula [13]:

\[ BD = \left\{ \text{Al-exch. saturation} - 0.20 \right\} \times \text{CEC Effective} \times Y \]

where BD : Amount of dolomite that must be given (t/ha);
Al-exch : Saturation level of Al-exchange in the percent, for example 40% is written 0.40;
0.20 : desired level of Al-exchange saturation.
CEC-Effective : CEC value at the original soil pH is obtained by summing the base cation (Ca, Mg, K, Na), H, and Al which are absorbed on the soils surface complex, or that can be exchanged.
Y : Correction factor, the value is 1.51 if it uses dolomite.
Table 1. The technological packages of biofertilizer which is tested for increasing soybean productivity in acidic soils of South Kalimantan

| No | Treatment                              | Dose of Biofertilizer | NPK dosage* (% | Organic Fertilizer (t/ha) |
|----|----------------------------------------|-----------------------|----------------|--------------------------|
| 1  | 0 NPK (Control)                        | 0                     | 0              | 0                        |
| 2  | Recomended NPK                         | 0                     | 100            | 0                        |
| 3  | ½ NPK                                 | 0                     | 50             | 0                        |
| 4  | ½ NPK+Organic Fertilizer               | 0                     | 50             | 2                        |
| 5  | 0.7 NPK                               | 0                     | 70             | 0                        |
| 6  | Iletrisoy+Biovam+StarTmik               | 0.3 kg Iletri+5 kg Biovam/ha+20ml/l water sprayed at 20, 40, 60 days after planting | 50 | 1.5 |
| 7  | Iletri Plus                            | 0.3 kg/50 kg seeds/ha | 50             | 1.5                      |
| 8  | Beyonic                               | 5 kg BioVam/50 kg seeds/ha | 50 | 2                        |
| 9  | Biotricho                             | 2 kg/50 kg seeds (seed treatment) | 50 | 2                        |
| 10 | PROBIO-New                             | 15 l/ha               | 50             | 1.5                      |
| 11 | Rhizo-BIOST                           | 200 g/50 kg seeds/ha (seed treatment) | 50 | 0                        |
| 12 | Bio-SRF                               | 100 kg/ha             | 50             | 0                        |
| 13 | Biopim                                | 6 kg/50 kg seeds/ha   | 70             | 0                        |
| 14 | BioMIGE                               | 2.4 kg/50 kg seeds/ha | 50 | 2                        |
| 15 | Biocat                                | 30 kg/50 kg seeds/ha (seed coating) | 50 | 0                        |
| 16 | Padjar-Soya                           | 10 g/kg seeds (seed treatment) | 75 | 0                        |
| 17 | Rhizobion-UP                          | 50 kg/ha              | 50             | 0                        |
| 18 | Agrizone                              | 200 g/50 kg seeds/ha (seed coating) | 50 | 0                        |
| 19 | Rhizoplus                             | 300 g/50 kg seeds/ha  | 50             | 0                        |
| 20 | Bio-SRF3*                              | 100 kg/ha             | 50             | 0                        |

Note: Recommendation of NPK fertilizer = 100 kg Urea+100 kg SP36+100 kg KCl/ha. *Bio SRF3: This treatment was planted 10 days later than other treatments due to material delay.

The soybean variety used in this study was Anjasmoro, with a plants spacing of 40 cm x 15 cm, two plants per hole. Chemical fertilizers (NPK) were given at 10 days after planting by an array of 10-15 cm from the plants. For biological fertilizers, the dosage and method of application were adjusted according to inventor recommendation.

The data collected includes: soil chemical properties, rain fall, components of growth and crop yield such as plant high, number of root nodules, leaf chlorophyll indexes, leaf NPK content, pods number/plant, seeds weight/plant, and seed yield/ha.

3. Results and Discussion

The chemical properties of the soil used in the research were classified as acidic with a pH of 5.20. Low of organic matter, very low of N, K, Na, Ca, and Mg, low CEC, high Mn, and Al saturation above the tolerance limit of soybean plants (20%), namely 34.24% (Table 2). The low of pH and high Al saturation soils are the most soil chemical properties influencing soybean growth. This can cause decrease nitrogen fixation and nutrients uptake, especially P which is important for cell growth and photosynthesis. The excessive accumulation of Fe has been linked to oxidative-damage to proteins, lipids, and losses in chlorophyll
content, so that the photosynthetic process that is important for growth and crop yields is not optimal [14,15]. According to Nikodem et. al. [3], acidic soils (Podzolic) are considered least favorable for agricultural crop production owing to lower fertility, potential toxicity from soluble forms of elements such as Al, Mn and Fe, unfavorable physical properties and acidic nature.

During the research, rainfall received by soybean plants reached 283 mm, with the distribution of rainfall presented in Figure 1. This rainfall was considered insufficient to support optimum soybean growth. To produce maximum yield, during the growing season soybean was need amount water varied from 385 to 617 mm depending on climatic conditions and variety [16,17]. While Zhang [18] reported that the require of irrigation for soybean to achieve the maximum yield ranged beginning from 110 to 405 mm. In this research, distribution of rainfall during plant growth was good enough so the plants did not suffer from drought stress. Total rainfall during vegetative soybean growth period (the first 30 days) was classified as sufficient, reaching 149 mm. However during flowering period until pod formation (the second 30 days) the rainfall was relatively low, reaching only 16 mm so that the plants suffered from a little drought stress.

Table 2. Soil chemical properties of biological fertilizer research location in Pelaihari, South Kalimantan

| Elements       | Value | Criteria |
|----------------|-------|----------|
| pH H₂O         | 5.20  | Acidic   |
| CO (%)         | 1.66  | Low      |
| N (%)          | 1.12  | Low      |
| P₂O₅ (ppm)     | 33.30 | Very high|
| SO₄ (ppm)      | 48.70 | Low      |
| K (me/100 g)   | 0.07  | Very low |
| Na (me/100 g)  | 0.06  | Very low |
| Ca (me/100 g)  | 1.38  | Very low |
| Mg (me/100 g)  | 0.49  | Very low |
| Al Exch (me/100 g) | 1.26 | Low     |
| H- Exch (me/100 g) | 0.42 | -       |
| Al Saturation (%) | 34.24 | High   |
| CEC (me/100 g) | 10.50 | Low      |
| Zn (ppm)       | 0.74  | Low      |
| Mn (ppm)       | 12.67 | Very high|

Note : Al Exch = Al-exchangable, H Exch = H exchangable, CEC = Cation exchange capacity
The soybean plant growth in this study was optimal. Plant height at harvest ranged from 56 to 72 cm, and there was no difference in plant height between treatment of NPK, biological fertilizers and control (Figure 2). This was due to uptake of N nutrients which was importance for support the plant growth in the all treatments were in the optimal range, except for control plants and half of NPK fertilizer dose (Table 4). In line with leaf nitrogen content, the content of leaf chlorophyll which was important for photosynthesis also was not differ from among treatments (Tabel 3). This is indicated that at the level of soil fertility, such as in the research location, fertilization did not affected on plant height, although it affected on yield components and seed yields.
Figure 2. Effect of NPK fertilizer dosages and biofertilizers in soybean plant height at harvest on acidic soils.

Several biofertilizer products were able to stimulate the formation of root nodules compared to those of control, including Agrizone, a combination of Iletrisy + Biovam + Startmik, Iletrisy Plus, Rhizoplus and Bio SRF 2 (Table 3). This is possibility due to the rhizobium bacteria that make up some of these biological fertilizers are more tolerant on the acidic soil compared to the raw material of biological fertilizers which do not increase the number of soybean root nodules. Indrasumunar et al. [19] reported that in acidic soils with pH 4.36, inoculation of acid-resistant rhizobium strains on soybeans was able to form more nodules than strains sensitive to acid soils. Almost all tested biological fertilizers were able to increase leaf chlorophyll content during pod filling period (60 days after planting), except for Bio SRF3 because this treatment was planted 10 days later than other treatments so that the plants received less rainfall and growth was not optimal. Vollmann et al. [20] reported that root nodules of soybean plants has a positive correlation with size and content chlorophyll leaves, which in turn will affect the rate of photosynthesis and fixation nitrogen, plant height, number of pods per plants, weight of 100 seeds, protein content, and oil content of the seeds.
Table 3. The effect of biological fertilizers packages on the number of root nodules and chlorophyll index in soybean plant grown on acidic soil, South Kalimantan

| No | Treatment                              | Fertilizer       | Number of root nodules at 45 DAP | Leaf chlorophyll index at 45 DAP | Leaf chlorophyll index at 60 DAP |
|----|----------------------------------------|------------------|----------------------------------|---------------------------------|---------------------------------|
| 1  | 0 NPK (Control)                        | NPK (0%)        | 0                                | 26.7 ef                         | 40.6 bc                         | 43.53 c                         |
| 2  | Recomended NPK                         | NPK (100%)      | 100                              | 25.5 f                          | 43.1 abc                        | 47.40 a                         |
| 3  | ½ NPK                                  | NPK (50%)       | 50                               | 31.3 bcdf                       | 42.4 abc                        | 45.77 abc                       |
| 4  | ½ NPK + Organic Fertilizer             | NPK (50%)       | 50                               | 31.7 bcdf                       | 42.6 abc                        | 45.80 abc                       |
| 5  | 0,7 NPK                                | NPK (70%)       | 70                               | 30.5 bcdf                       | 43.6 ab                         | 46.17 ab                         |
| 6  | Iletrisoy + Biovam + StarTmix          | NPK (50%)       | 50                               | 39.2 ab                         | 44.0 a                          | 46.70 ab                         |
| 7  | Iletrisoy Plus                         | NPK (50%)       | 50                               | 35.9 abcd                       | 42.6 abc                        | 44.33 bc                         |
| 8  | Beyonic                                | NPK (50%)       | 50                               | 32.8 abcd                       | 44.1 ab                         | 45.07 abc                        |
| 9  | Biotricho                              | NPK (50%)       | 50                               | 28.4 cdef                       | 41.4 abc                        | 45.87 abc                        |
| 10 | PROBIO-New                             | NPK (50%)       | 50                               | 27.2 defc                       | 42.9 abc                        | 45.90 abc                        |
| 11 | Rhizo-BIOST                            | NPK (50%)       | 50                               | 30.3 bcdcf                      | 42.3 abc                        | 45.13 abc                        |
| 12 | Bio-SRF                                | NPK (50%)       | 50                               | 31.3 bcdf                       | 42.7 abc                        | 45.53 abc                        |
| 13 | Bio SRF                                | NPK (50%)       | 50                               | 28.3 cdef                       | 41.8 abc                        | 44.83 abc                        |
| 14 | Bio MIGE                                | NPK (50%)       | 50                               | 30.8 bcdf                       | 40.9 abc                        | 45.10 abc                        |
| 15 | Biocoat                                | NPK (50%)       | 50                               | 31.1 bcdf                       | 42.2 abc                        | 46.10 abc                        |
| 16 | Padjar-Soya                            | NPK (75%)       | 75                               | 30.6 bcdf                       | 42.5 abc                        | 46.00 abc                        |
| 17 | Rhizobion-UP                           | NPK (50%)       | 50                               | 26.1 ef                         | 43.3 ab                         | 45.27 abc                        |
| 18 | Agrizone                               | NPK (50%)       | 50                               | 40.3 a                         | 39.8 c                         | 45.23 abc                        |
| 19 | Rhizoplus                              | NPK (50%)       | 50                               | 36.5 abc                        | 41.3 abc                        | 45.57 abc                        |
| 20 | Bio SRF*                               | NPK (50%)       | 50                               | 34.5 abcd                       | 35.8 d                         | 40.60 d                         |

Values in the same column that followed by the same letter are not significantly different according to Duncan Multiple 5%.

Note: Recomendation of NPK fertilizers = 100 kg Urea + 100 kg SP36 + 100 kg KCl/ha. *Bio SRF3: This treatment was planted 10 days later than other treatments due to material delay.

In line with the effect of biological fertilizers on the root nodules and leaf chlorophyll indexes, all studied biological fertilizers were able to increase leaf N uptake. Especially on the combination of the biological fertilizer Iletrisoy + Biovam + Starmix, Iletrisoy Plus, and Fajar Soya was able to increase the leaf N content (Table 4). The higher N content of leaves and leaf chlorophyll due to the use of biological fertilizers, its can increase the effectiveness of leaf assimilation activities so that they can produce more assimilates. Biofertilizers of Bio SRF2, Biopim, Bio MIGE, Biocoat, Padjar SOYA and Rhizobion were able to significantly increase the P nutrient content. As for K levels, almost all treatments did not show any significant differences, except for Iletrisoy plus and Bio MIGE (Table 4).
Table 4. Effect of biological fertilizer packages on the NPK content of soybean leaves in acidic soils of South Kalimantan

| No | Treatment                          | Fertilizer | Leaves NPK content (%) at 60 DAP |
|----|------------------------------------|------------|----------------------------------|
| 1  | 0 NPK (Control)                    | 0 NPK (%)  | 3.90 0.26 1.80                   |
| 2  | Recomended NPK                     | 50 NPK     | 4.29 0.21 1.60                   |
| 3  | ½ NPK                             | 50 NPK     | 3.43 0.20 1.80                   |
| 4  | ½ NPK+Organic Fertilizer          | 50 NPK     | 4.07 0.20 2.05                   |
| 5  | 0,7 NPK                           | 70 NPK     | 4.96 0.21 1.87                   |
| 6  | Iletrisoy+Biovam+StarTmix         | 50 NPK     | 5.29 0.24 1.82                   |
| 7  | Iletri Plus                       | 50 NPK     | 5.31 0.26 2.00                   |
| 8  | Beyonic                           | 50 NPK     | 4.89 0.27 1.73                   |
| 9  | Biotricho                         | 50 NPK     | 4.77 0.28 1.80                   |
| 10 | PROBIO-New                         | 50 NPK     | 4.50 0.28 1.85                   |
| 11 | Rhizo-BIOST                       | 50 NPK     | 4.75 0.29 1.74                   |
| 12 | Bio-SRF                           | 50 NPK     | 4.35 0.32 1.62                   |
| 13 | Biopim                            | 70 NPK     | 4.74 0.33 1.92                   |
| 14 | BioMIGE                           | 50 NPK     | 4.68 0.35 2.00                   |
| 15 | Biocat                            | 50 NPK     | 4.99 0.35 1.70                   |
| 16 | Padjar-Soya                       | 75 NPK     | 5.30 0.31 1.92                   |
| 17 | Rhizobion-UP                      | 50 NPK     | 4.79 0.31 1.71                   |
| 18 | Agrizone*                         | 50 NPK     | - - -                            |
| 19 | Rhizoplus*                        | 50 NPK     | - - -                            |
| 20 | Bio SRF*                          | 50 NPK     | - - -                            |

Adequate: 4.25-5.0 0.37-0.55 2.0-2.5

Note: *Leaves NPK content for agrozone, rhizopus and Bio SRF treatments that were planted late due to technical reasons could not be analyzed.

The biological fertilizers of Iletrisoy + Biovam + StarTmix, Probio New, Rhizo BIOST, Bio SRF, Biocat, Padjar soya, Rhizobion UP, and Rhizoplus were able to produce a greater number of filled pods than that of control and no different compared to recommended NPK fertilization, and ½ NPK + 2 t of organic fertilizers (Table 5). Meanwhile, Biotricho and Bio MIGE biological fertilizers, although able to increase the number of filled pods/plant, were still lower than the recommended NPK treatment and ½ NPK + 2 t/ha of organic fertilizer. It is indicates that the biological fertilizer Iletrisoy + Biovam + StarTmix, Iletri Plus, Probio New, RhizoBIOST, Bio SRF, Biocat, Padjar soya, Rhizobion UP, and Rhizoplus have the opportunity to be further developed. Table 5 also shows that all biological fertilizers have no potential to increase the number of empty pods per plant.

The use of the Illetrisoy Plus biofertilizer package, the combination of Iletrisoy + Biovam + StarTmix, Probio New, Bio MIGE, Biotricho, and Padjar Soya was able to produce higher soybean seeds, namely 24%, 17%, 12%, 12%, 11% and 10% respectively compared to soybeans fertilized with NPK recommendations (Table 5). This is because with the application of biological fertilizers, the plants can absorb more nitrogen and phosphor nutrients (Table 4). This shows that the bio-fertilizers Iletrisoy + Biovam + StarTmix, Iletrisoy plus, Biotricho, Probio New, Bio MIGE, Padjar soya, Biopim and Biocat have the opportunity to be further developed for soybean cultivation on acidic soils. The Biofertilizer of Beyonic, RhizoBIOST, Bio SRF, Rhizobion, Agrizone, and Rhizoplus have not been able to increase soybean yields.
in acidic soils with the chemical properties as described above (Table 2). This was due to these biological fertilizers have not been functioning optimally in providing the nutrients needed by plants in this soil. To improve growth and increase soybean yields on acidic soils, those formula technology package for biological fertilizers still needs to be improved.

**Table 5.** Effect of biofertilizers to number of filled pods and empty pods, seed weight per plant, and seed yield in acidic soils of South Kalimantan

| No | Treatment                  | Fertilizer NPK (%) | Organic (t/ha) | Number of filled pods/plant | Number of empty pods/plant | Seeds weight/plant (g) | Seed yield (t/ha) | Yield rate compared to recommended NPK (%) |
|----|----------------------------|--------------------|----------------|-----------------------------|---------------------------|------------------------|------------------|------------------------------------------|
| 1  | 0 NPK (Control)           | 0                  | 0             | 29.73 g                     | 1.53 a                    | 7.37 cd                | 1.5 fghi         | 86                                       |
| 2  | Recommended NPK           | 100                | 0             | 44.53 abc                   | 2.53 a                    | 9.80 abc               | 1.8 cd           | 100                                      |
| 3  | ½ NPK                     | 50                 | 0             | 37.20 def                   | 1.63 a                    | 8.79 bcd               | 1.6 defg         | 90                                       |
| 4  | ½ NPK + Organic Fertilizer | 50 2              |               | 44.30 abc                   | 1.83 a                    | 8.93 bcd               | 2.1 ab           | 117                                      |
| 5  | 0.7 NPK                   | 70                 | -             | 36.03 defg                  | 1.30 a                    | 9.06 bcd               | 1.9 bc           | 107                                      |
| 6  | Iletrisoy + Biovam + StarTmik | 50 1.5        |               | 41.50 abcd                  | 1.10 a                    | 10.2 ab                | 2.1 ab           | 117                                      |
| 7  | Iletri Plus               | 50 1.5             |               | 35.90 defg                  | 1.03 a                    | 8.51 bcd               | 2.2 a            | 124                                      |
| 8  | Beyonic                   | 50 2               |               | 32.00 efg                   | 1.27 a                    | 7.51 cd                | 1.5 efg h        | 87                                       |
| 9  | Biotricho                 | 50 2               |               | 37.60 de                    | 1.13 a                    | 9.33 abcd              | 2.0 abc          | 111                                      |
| 10 | PROBIO-New                | 50 1.5             |               | 42.33 abcd                  | 1.63 a                    | 10.8 ab                | 2.0 abc          | 112                                      |
| 11 | Rhizobi-BIOST             | 50 0               |               | 39.00 bcd                   | 2.97 a                    | 7.36 cd                | 1.6 defg         | 89                                       |
| 12 | Bio-SRF                   | 50 0               |               | 38.20 cde                   | 1.90 a                    | 9.30 abcd              | 1.6 def          | 93                                       |
| 13 | Biopim                    | 70 0               |               | 35.93 defg                  | 1.40 a                    | 8.88 bcd               | 1.8 cde          | 100                                      |
| 14 | BioMIGE                   | 50 2               |               | 36.43 def                   | 1.10 a                    | 9.09 abcd              | 2.0 abc          | 112                                      |
| 15 | Bioclate                  | 50 0               |               | 46.63 a                     | 2.10 a                    | 11.5 a                 | 1.8 cd           | 102                                      |
| 16 | Padjar-Soya               | 75 0               |               | 39.87 bcd                   | 1.73 a                    | 8.92 bcd               | 1.9 abc          | 110                                      |
| 17 | Rhizobion-UP              | 50 0               |               | 41.00 abcd                  | 1.70 a                    | 10.0 ab                | 1.6 defg         | 92                                       |
| 18 | Agrizone                  | 50 0               |               | 30.90 fg                    | 0.73 a                    | 7.20 d                 | 1.3 hi           | 76                                       |


|    |   |   |   |   |   |   |
|----|---|---|---|---|---|---|
|    |   |   |   |   |   |   |
| 19 | Rhizoplus | 50 | 0 | 45.20 | ab | 0.93 | a |
|    |     |    |   |      |    |     |  9 |
| 20 | Bio SRF* | 50 | 0 | 21.33 | h  | 0.83 | a |
|    |     |    |   |      |    |     |  4 |

Values in the same column that followed by the same letter are not significantly different according to Duncan Multiple 5%. *Bio SRF3 : This treatment was planted 10 days later than other treatments due to material delay.

4. Conclusion

Combinations of Biovam + Iletrisoy + Startmix biofertilizers. Iletrisoy plus. Biotricho. Probio New. Bio Mige. and Fajar SOYA were effective for increasing soybean productivity on acidic soils. These biological fertilizers + 50% recommended NPK + 1.5 t/ha organic fertilizer can increase pods number. and soybean productivity more than 10% compared to the recommended NPK (100 kg Urea+100 kg SP36+100 kg KCl/ha) fertilizer dosage whic was yielded 1.81 t/ha. The biological fertilizers combination of Biovam + Iletrisoy + Startmix biofertilizers. Iletrisoy plus. Biotricho. Probio New. Bio Mige. and Fajar SOYA have good prospects to be developed as bio-fertilizers for soybeans in acidic soils.

Acknowledgement

The author would like to thank for Suryantini. E Pratiwi. R Sutarya. A Sarjia. H Pratiwi. D Andreas. I Anas. T Simarmata. R Hidersah. B Sukmadi. Kusnandar. and Y Bakhtiar for their cooperation as inventors of biological fertilizer Illetri Plus. Agrizone. Biotrico. StarTmik. Biovam. Probio-New. Rhizo-Biost. Padjar-Soya. Rhizobion-U. Bio-SRF. Biopim. and Biocoat. so that this research can be carried out well. This research was funded by the IAARD. under coordination and supervision of the National Innovation Committee.

References

[1] Mulyani A. D Nursyamsi. and D Harnowo 2017. Potency and challanges for the use of suboptimal land for development of legumes and tuber crop. Proceedings of the National Seminar on legumes and tuber crops. 2016. Indonesian Agricultural Agency Research and Development. pp 16-30.
[2] Ruckstuhl K E. E A Johnson. K Miyaniishi 2008. Introduction. The boreal forest and global change. Philos. Trans. Biol. Sci. 363 : 2245–2249.
[3] Nikodem A. R Kodešova. O Drabek. L Bubeničkova. L Borůvka. L Pavlů. V Tejnecky 2010. A numerical study of the impact of precipitation redistribution in a beech forest canopy on water and aluminum transport in a podzol. Vadose Zone J. 9 : 238–251.
[4] Harsono A. A Wijanarko. and S A D Lestaril 2020. Productivity of soybean under palm oil plantation on tidal swamps due to several packages of technology. IOP Conf. Series: Earth and Environmental Science 456 (2020) doi:1 0.1 088/1 7 55-13t5/456/t/012052.
[5] Singh J S 2015. Microbes: the chief ecological engineers in reinstating equilibrium in degraded ecosystems. Agric. Ecosyst. Environ. 203: 80-82.
[6] Kumar M S. G C Reddy. M Phogat. and S Korav 2018. Role of bio-fertilizers towards sustainable agricultural development : A review. J. Pharmacogn. Phytochem. 7: 1915–1921.
[7] Mącik M. A Gryta. M Frąc 2020. Biofertilizers in agriculture: An overview on concepts. strategies and effects on soil microorganisms. Advances in Agronomy. Volume 162. https://doi.org/10.1016/ bs.agron.2020.02.001.
[8] Tiwari P and J S Singh 2017. A plant growth promoting rhizospheric Pseudomonas aeruginosa strain inhibits seed germination in Triticum aestivum (L) and Zea mays (L). *Microbiol. Res.* 8: 1-7.

[9] Vimal S R, V K Patel. and J S Singh 2019. Plant growth promoting *Curtobacterium albidum* strain SRV4: An agriculturally important microbe to alleviate salinity stress in paddy plants. *Ecological Indicators* 105: 553-562.

[10] Purba R 2016. The Growth and Production of Soybean towards Organic Fertilization on Dryland in Pandeglang Banten. *Jurnal Pengkajian dan Pengembangan Teknologi Pertanian*. 19 (3): 253-261.

[11] Harsono A, D Sucahyono, D A A Elisabeth 2020. Soybean cultivation packages applied in young palm oil plantation on tidal land. *Buletin Palawija* 18 (2): 63-73.

[12] Triadiati. N R Mubarak. and Y Ramasita 2013. Growth Response of Soybean to Acid Tolerant *Bradyrhizobium japonicum* and Fertilizers Application in Acid Soil. *J. Agron. Indonesia* 41 (1): 24 – 31.

[13] Subandi, Marwoto, Adisarwanto T, Sudaryono, Kasno A, Hardaningsih S, 2007. *Panduan umum pengelolaan tanaman terpadu kedelai*. Malang: Balitkabi.

[14] Alves L A, V G Ambrosini, L G O Denardin, J P M Flores, A P Martins, D Filippi, C Bremm, P C F Carvalho, G D Farias, I A Ciampitti, and T Tiecher 2021. Biological N₂ fixation by soybeans grown with or without liming on acid soils in a no-till integrated crop-livestock system. Soil and Tillage research. Vol. 209 May 2021. 104923.

[15] Yu H N, P Liu, Z Y Wang, W R Chen and G D Xu 2011. The effect of aluminum treatments on the root growth and cell ultra structure of two soybean genotypes. *Crop Protection*. 30 (3): 323-328.

[16] Sincik M, B N Candoga, C Demirtas, H Büyükacangaz, SYazgan, and AT Göksoy 2008. Deficit irrigation of soybean [*Glycine max* (L.) Merr.] in a sub-humid climate. *J. Agron. Crop Sci.* 194: 200-205.

[17] Garcia G A, T Persso, LC Guerra, and G Hoogenboom 2010. Response of soybean genotypes to different irrigation regimes in a humid region of the southeastern USA. *Agric. Water Manage.* 97: 981–987.

[18] Zhang B, G Feng, L R Ahuja, X Kong, Y Ouyang, A Adeli, and J N Jenkins 2018. Soybean cropwater production functions in a humid region across years and soils determined with APEX model. *Agricultural Water Management* 204 :180–191. https://doi.org/10.1016/j.agwat.2018.03.024.

[19] Indrasumunar A, N W Menzies, and PJ Dart 2012. Calcium affects the competitiveness of acid-sensitive and acid-tolerant strains of *Bradyrhizobium japonicum* in nodulating and fixing nitrogen with two soybean cultivars in acid soil. *Soil Biology & Biochemistry*. 46 (2012) 115-122.

[20] Vollmann J, H Wakter, T Sato, P Schwelger 2011. Digital image and chlorophyll metering for phenotyping the effect of nodulation in soybean. *Computers and Electronics in Agriculture* 75(1): 190-195.