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Agrilime and Effective Microorganisms as Growth and Yield Enhancer of Soybean *(Glycine max L.)*

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ABSTRACT

Soil health is a fundamental component of sustainable agriculture, directly influencing crop productivity, nutrient availability, and overall plant health. This study on soybean, using agrilime and effective microorganisms as growth and yield enhancers, was conducted at the experiment area of Quirino State University, Maddela, Quirino, from February 1, 2023, to June 2, 2023. Specifically, it evaluated the effects of different treatments on the growth and yield of soybeans and assessed which treatment combinations achieved the highest return on investment and enhanced the chemical properties of the soil. The study was laid out in a Randomized Complete Block Design (RCBD) with four replications and six treatment combinations. The application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} significantly affected the growth and yield of soybean, as well as the chemical properties of the soil in terms of soil pH, nitrogen, available phosphorus, and available potassium. These farm input combinations are potential nutrient management practices to obtain maximum yield in soybean production on acidic soil. This nutrient management practice may not only improve growth and yield but also enhance the chemical properties of the soil.

Keywords: *Agrilime, growth and yield enhancer, effective microorganisms, nutrient management practice, soybean*

Introduction

Soybean (*Glycine max L.*) is one of the most significant crops in many regions across the world. It is a source of food, protein, and oil (Pagano & Miransari, 2016). After wheat, maize, rice, and potatoes as the leading crops produced worldwide, soybeans appear as the top 5 (Sedaghati & Hokmabadi, 2014). Moreover, Brazil has been reported to be the world's top soybean producer, followed by the United States and Argentina, with a total global production of 395.4 million metric tons (Colussi & Schnitkey, 2021).

In the Philippines, it was noted that 78, 000 metric tons were produced in the year 2021. The country became the top importer of soybean meal globally from the year 2016 until 2021. In addition, 99 percent is imported and only 1 percent is locally produced. Soybean meal is the largest agricultural export of the United States to the Philippines, recording an 11 percent growth to 3.55 billion (Padilla *et. al.,* 2023). The promotion of soybean production and use for food and feed business enterprises have helped farmers in the Cagayan Valley, Region 02, become more aware of the crop's importance to upland conventional farming systems and its potential for crop diversification, increased income, soil fertility enhancement, organic farming, and food security (Aquino *et.al*, 2018).

Furthermore, this soybean as a legume crop can improve soil fertility through the symbiotic association with microorganisms, such as rhizobia, which fix the atmospheric nitrogen and make nitrogen available to the host and other crops by a process known as biological nitrogen fixation (BNF) (Kebede, 2021). In addition, microbial life is essential to soil fertility, plant health, and the availability and transmission of nutrients to plants (Duchene, 2017). As such, legume crops can be used in mitigation while improving soil health by biologically fixing nitrogen and enriching beneficial microbes in the soil. These microbes can solubilize unavailable phosphate by exuding organic acids from the roots of legume crops. Additionally, legumes facilitate the rebuilding of soil organic matter and restrict pests and pathogens (Jena *et al*., 2022).

Moreover, nowadays, conventional farming systems are commonly practiced in lowlands and upland areas, thus, soil is a renewable resource, and its health has been an issue for years and is crucial to feed the world. It turned lifeless and in a critical situation (Chauhan & Mittu, 2015; Notaris *et al.*, 2021). The regular use of inorganic fertilizers alone results in the deterioration of soil organic matter, acidification of the soil, and environmental contamination (Bhatt *et al.,* 2019) but these acidic soils can be productive with the use of lime for the yield and growth characteristics of soybean as a legume crop (Ameyu & Asfaw, 2020). With this regard, the specific soil conditions of the study area are characterized by acidity due to previous cassava cultivation and the long-term usage of inorganic fertilizer. Therefore, it is high time to adopt organic fertilizers because they have great advantages over chemical fertilizers.

Thus, effective microorganisms as biofertilizers are mixed cultures of advantageous naturally occurring microorganisms that can be used as inoculants to boost the microbial diversity of soil ecosystems. They mostly comprise lactic acid bacteria, yeasts, actinomycetes, photosynthesizing bacteria, and fermenting fungi (Joshinb *et al*., 2019). This EM and agricultural lime can enhance the biological, biochemical, and microbial community structure of the soil (Ilahi *et al*., 2021), while improving the growth and yield of soybeans. Specifically, this study aimed to determine the effects of the different combinations of effective microorganisms and agrilime on the growth and yield of soybean and on the chemical properties of the soil, and to evaluate the return on investment of the different treatments.

Methods

This chapter contains the materials used in the study such as soybean seeds, inorganic fertilizers, vermicompost, agricultural lime (CaCO3:100%, CaO: 55.04%, and MgO: 0.28%), farm tools and materials, treatment placards, bamboo sticks, and tarpaulin.

Procurement of Soybean Seeds

The soybean seeds (CL Soy1 variety) were secured from the Department of Agriculture- Cagayan Valley Research Center.

Procurement of Agricultural Lime

Agricultural lime is a soil amendment made from pulverized limestone or chalk. Its primary component is calcium carbonate, which works to neutralize soil acidity, thereby improving the pH balance of the soil. It was purchased at Santiago City public market.

Preparation of Effective Microorganism (EM)

The process began by fermenting rice wash in a container, after a week, add fresh milk. After another one week of fermentation, strain the liquid and dissolve the molasses. The vessel was sealed to create an anaerobic environment and left to ferment for one to two weeks in a warm, dark place, with occasional stirring. Successful fermentation was indicated by a slightly acidic pH and a sweet, tangy smell. Once ready, the EM solution was diluted with water and applied to the soybean plants.

Soil Sampling

Soil samples were collected before land preparation using sufficient sub-samples in a zigzag pattern. Soil samples were collected in a zigzag pattern across the field to ensure a representative sample. Multiple sub-samples were taken from different points in the field to form a composite sample. This method helped capture the variability in soil properties throughout the area.

In terms of preparation of soil samples, the following steps were executed:

- *Air Drying:* The collected soil samples were air-dried to remove moisture, which can affect the weight and concentration of nutrients during analysis.
- *Pulverization:* The dried soil samples were pulverized to break down clumps, ensuring uniformity and easier handling during testing.
- *Removal of Foreign Matter:* Non-soil materials such as stones, roots, and debris were removed to prevent contamination and ensure the accuracy of the analysis.
- *Composite Sample Creation:* A composite soil sample, weighing one kilogram, was prepared by mixing the sub-samples. This composite sample is a representative of the overall field condition than individual samples.

Laboratory Analysis

The one kilogram of composite soil samples was brought to the Integrated Laboratory – Cagayan Valley Research Center for analysis. The analysis determined the amount of nitrogen, phosphorus, potassium, and pH of the soil. By following this thorough sampling and analysis process, accurate fertilizer recommendations can be made to optimize soybean growth and yield, ensuring that the plants receive the appropriate nutrients based on the actual soil conditions.

Land Preparation

The experiment area was cleared of any existing vegetation, rocks, and debris, and applied with herbicide before plowing. The area was prepared with a tractor using a rotary tiller to break up compacted soil layers, improve soil aeration, and incorporate organic matter or crop residues into the soil to a depth of 15-20 cm, depending on the soil structure and compaction level. It was left idle for two weeks for the weeds to decay and final plowing, harrowing, and application of agricultural lime were done before the preparation of plots measuring 7 meters by 5 meters.

Experimental Layout and Design

After land preparation, an area of 1, 046.25 square meters was divided into four blocks, each block measuring 7 meters by 35 meters with an alleyway of one meter between blocks. Each block was divided into six plots, each plot measuring 7 meters by 5 meters with an alleyway of 75 centimeters between plots. The treatments were arranged according to the Randomized Complete Block Design (RCBD) procedure because the research study was conducted in the field. This design helped control variability within the blocks, providing more precise estimates of treatment effects, especially since environmental weather conditions are not controllable.

Experimental Treatments

The treatments for the study were the following:

Treatment 1- 4 bags 16-20-0 ha^{-1}
Treatment 2- 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1}
Treatment 3- 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1}
Treatment 4- 1 bag 16-20-0 ha^{-1} + 3,750 ml EM ha^{-1} + 500 kg Agrilime ha^{-1}
Treatment 5- 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1}
Treatment 6- 15,000 ml EM ha^{-1}

Construction of Plots and Furrows

The soil was plowed and harrowed twice, or until it was loose and friable. Plots were constructed measuring 5 meters by 7 meters. Furrows were constructed 75 centimeters apart between plots.

Planting

Soybean seeds were sowed using the hill method, wherein two seeds were dropped per hill with a planting distance of 30 centimeters between hills and 50 centimeters along furrows.

Treatment Application

In the agricultural process described, the preparation of the land involved the application of agricultural lime, which was carried out over a period of at least one month prior to planting. Upon sowing, a fertilizer 16-20-0 was applied, approximately two inches below and to the side of the seeds to provide essential nutrients for initial growth. As the crops entered their vegetative stage, effective microorganisms (EM) were introduced, starting ten days after emergence and continuing until the pod-formation stage, which typically occurs around 80 days after emergence. This application of EM was done at five-day intervals to ensure consistent microbial support throughout the crucial growth phases of the plants.

Care and Management

Cultivation and Weed management. The agricultural practices involved hilling-up methods, which were implemented approximately 25 days after planting (DAP) to facilitate the growth of the plants. This technique likely involved the formation of ridges or mounds of soil around the base of the plants, aiding in root development and providing stability. Weed management was addressed through cultural methods, indicating that manual or mechanical techniques were employed to remove weeds, rather than relying solely on chemical herbicides.

Irrigation. Watering was done as need arose, suggesting a responsive approach to maintaining optimal soil moisture levels for plant growth. This method likely involved monitoring soil moisture levels and plant requirements to determine when irrigation was necessary, ensuring efficient water usage while meeting the plants' needs.

Pest and Disease Management. Fungicides and insecticides were utilized as required, indicating a reactive approach to combating pests and diseases. These chemical treatments were likely applied when pest or disease pressure reached a threshold level that posed a threat to crop health and yield. By employing this approach, the use of pesticides and fungicides could be minimized while still effectively managing potential threats to the crop.

Harvesting

The maturity of the soybean plant was determined by the yellowing and shredding of the leaves, and the change of color of the pod (from green to brown or dark brown) at about 109 days after planting. Harvesting was done by cutting the stalk at the base or uprooting during early morning hours or late in the afternoon to reduce shattering losses. The newly harvested soybean plants were exposed to direct sunlight or on a dry floor before threshing.

Threshing and Drying

Threshing was done using a manual method, with the use of the fingers, the dry pods were cracked and the seeds were removed from the pods. Sun-dry of soybean seeds was done by spreading evenly on a tarpaulin, and trays to attain the moisture level of 10-12 percent.

Data Gathered

1. Plant height at 30, 45, and 60 days after planting. Plant height is measured at specific intervals after planting (30, 45, and 60 days) to track how the plants are developing. Ten sample plants were randomly selected from each plot to ensure representative data. By measuring plant height in centimeters, it can assess the rate of growth and compare it across different treatments or conditions.
2. Number filled and unfilled pods at harvest. During harvest, the number of filled (containing mature seeds) and unfilled pods (empty or underdeveloped pods) on ten sample plants per plot was recorded. This data provides insights into the yield potential of the crop and can indicate factors affecting pod development, such as pollination success or environmental stressors.
3. Weight of marketable seeds. After harvest, the soybean seeds that meet market standards were identified and weighed using a digital scale. This measurement provides a direct assessment of seed yield and quality, which are essential factors for determining the economic value of the crop. The marketable seeds per treatment were weighed to compare the effectiveness of different agronomic practices or treatments in maximizing seed production and quality.
4. Yield per hectare. The yield of the different treatments was computed following the formula:

$$\text{Yield per hectare} = \frac{\text{Yield per Plot (kg)}}{\text{Plot Area (m}^2\text{)}} \times 10{,}000\ \text{m}^2$$

Cost and return analysis. The cost of production and gross income was determined based on the prevailing price in the market within the locality. The net income is equal to the gross income minus the cost of production and the return on investment was computed by dividing the net income by the cost of production multiplied by 100 percent.

Statistical Analysis

The data collected were analyzed using the Analysis of Variance for Randomized Complete Block Design (RCBD). The Statistical Tool for Agricultural Research (STAR) was used for data analysis. The treatments with significant results were compared using Tukey's Honestly Significant Difference (HSD) Test.

Ethical Considerations

Those who participated in the survey had to have a prior agreement with the department concerned and teachers. It was voluntary and the researcher asked for informed consent of the respondents. Moreover, the respondents were assured of confidentiality of information and other ethical guarantees.

Results and Discussion

Observations

Characteristics of the Soil. The samples were analyzed for pH, organic matter (%), available phosphorus (ppm), and available potassium (PPM). Based on the result of soil analysis, the soil pH is acidic at 4.56 pH.

Stand and Vigor of the Crop. It was observed that the plants in all the treatments had vigorous growth and had a good stand despite the occurrence of pests and the absence of rain throughout the duration of the study.

Occurrence of Insect Pests and Diseases. Cutworms, beet armyworm, soybean looper, yellow striped armyworm, corn earworm, and bean leaf beetle were observed in plants and fruits in all treatments. Those were controlled by applying insecticide. Frog eye leaf spot, root, and stem rot were also observed during their fruiting stage. It was controlled by spraying fungicide in all treatments.

Number of Days to Maximum Flowering. The number of days to maximum flowering of the Soybean (Cl Soy1) was observed at 45 days after planting.

Number of Days to Fruit Setting. The number of days to fruit setting was observed at 55 days after planting.

Number of Days to Harvesting. The number of days to harvest the soybean (CLSoy1) was observed at 109 days after planting.

Climatic Data During the Conduct of the Study. The climatic data during the conduct of the study was gathered from ISU-PAGASA-DOST Agrometeorology Station, Echague, Isabela. The minimum temperature ranged from 19.9 to 24.19 degrees Celsius (ºC) while the maximum temperature ranged from 29.1 to 35.86 ºC. The relative humidity recorded throughout the study ranged from 78.35 to 89 percent at 8:00 AM, and 52 to 64 2:00 pm, and the rainfall received by the plants ranged from 0.5 to 2.2 millimeters (Figure 1).

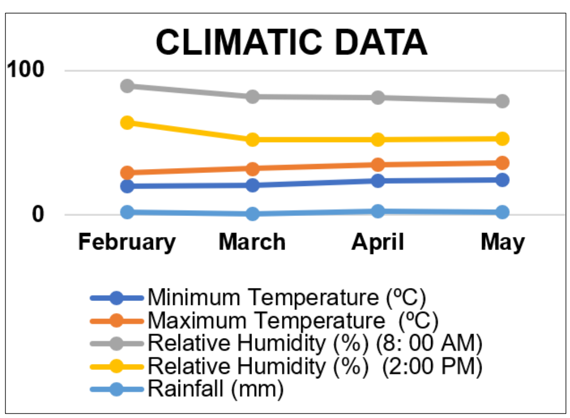

Figure 1. *Climatic Data During the Conduct of the Study*

(Source: ISU-PAGASA-DOST Agromeoteorology Station, Echague, Isabela)

Chemical Properties of the Soil Before the Conduct of the Study. The chemical properties of the soil in terms of pH and NPK after harvest are presented in Table 1. Soil samples were collected from the experimental area and brought to the Integrated Laboratory – Cagayan Valley Research Center for analysis. The result of the analysis in terms of pH is 4.56 and it shows an acidic soil, 2.8% for nitrogen, 2.65 ppm for phosphorus, and 132.91 ppm for potassium. The result of the analysis served as the basis for the treatments.

Table 1. Chemical Properties of the Soil Before the Conduct of the Study

pH	Nitrogen or OM (%)	Phosphorus (ppm)	Potassium (ppm)
4.56	2.8	2.65	132.91

Chemical Properties of the Soil After the Conduct of the Study. The chemical properties of the soil in terms of pH and NPK after harvest are presented in Table 2. In terms of soil pH, the result of pH before the conduct of the study was 4.56, and by the application of 15,000 ml ha^{-1} effective microorganism (EM) in Treatment 6, it increased to 4.71 pH. These findings conformed to the of Mtolera and Dongli (2018) who mentioned that effective microorganism regulates the soil pH and other properties of the soil.

It was followed by Treatment 3 by applying 2 bags 16-20-0 ha^{-1} + 7,500 ml EM/ ha^{-1} + 500 kg Agrilime ha^{-1} with 4.67 soil pH. It was observed that among all treatments, the application of 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} decreased the soil pH to 4.46. This result agreed with the findings of Ozlu and Kumar (2018) who highlighted that the application of inorganic fertilizers can decrease soil pH.

In terms of nitrogen content, all treatments decreased its nitrogen content. However, Treatment 3 has the highest N with 2.48 percent. For the available phosphorus in soil, it was observed that all treatments increased P content. Treatment 6 obtained 11.74 ppm and the highest P compared to the P content before the conduct of the study with 2.65 ppm.

Furthermore, for available potassium in the soil, Treatment 3 obtained the highest K content with 189.47 ppm. However, Treatment 1, Treatment 4, and Treatment 5 have decreased their K content to 124.32 ppm, 132.22 ppm, and 113.47 ppm.

Table 2. Chemical Properties of the Soil after the Conduct of the Study

Treatment	pH	Nitrogen or OM (%)	Phosphorus (ppm)	Potassium (ppm)
T_1	4.60	2.43	8.73	124.32
T_2	4.46	2.46	5.95	146.04
T_3	4.67	2.48	7.61	189.47
T_4	4.62	1.62	8.92	132.22
T_5	4.61	1.75	10.10	113.47
T_6	4.71	2.32	11.74	149.00

Root Nodulation. It was observed from the 10 sample plants through destructive sampling during the flowering stage that there were no root nodules formed. This result agreed with the claim of Lin *et.al* (2012) that soil acidity causes the loss of nodulation in soybean.

Plant Height at 30, 45, and 60 Days After Planting (cm). The plant height of soybeans at 30, 45, and 60 days after planting is shown in Table 3. The height of soybeans at 30 days after planting showed no significant differences. At 45 days after planting, soybeans applied with 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 2) obtained the highest plant height with a mean of 53 centimeters. It was followed by the application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} with a mean of 52 centimeters, Treatment 1, Treatment 4 and Treatment 6 with mean values of 45 and 43 centimeters, and the plants applied with 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} in Treatment 5.

Moreover, at 60 days after planting, Treatment 3 with the application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} showed the highest plant height with a mean of 65 centimeters, followed by the application of 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 2) with a mean of 63 centimeters, Treatment 1, Treatment 6, and Treatment 4 with an average of 54, 53, and 52 centimeters, respectively. Treatment 5 obtained the shortest plant height with a mean of 51 centimeters. Significant differences were observed in the plant height at 45 and 60 days after planting. However, the application of 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 2) and 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 2) showed comparable results with each other. The effects of effective microorganisms with inorganic fertilizer and agrilime show effective results among other treatments and such differences in plant height were attributed to the combined effect of inorganic fertilizer, effective microorganisms, and agricultural lime. As cited by Naik *et al.,* (2020), EM application as foliar increased various morphological characteristics of legumes such as plant height. Hurtado *et al.* (2019) also cited that the effects of effective microorganisms showed significant results as they increased the plant height of legumes.

Table 3. Plant Height at 30, 45, and 60 days After Planting

Treatments	Height at 30 DAP	Height at 45 DAP	Height at 60 DAP
T_1	33	45^b	54^b
T_2	33	53^a	63^a
T_3	33	52^a	65^a
T_4	31	45^b	52^b
T_5	30	43^b	51^b
T_6	31	45^b	53^b
F- RESULTS	ns	**	**
C.V. (%)	7.12	4.58	4.22
HSD		6.26	6.89

Number Filled and Unfilled Pods. The number of filled and unfilled pods is presented in Table 4. The application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 3) significantly affected the number of filled pods of soybean with a mean of 176.98 pods, followed by the application of 4 bags 16-20-0 ha^{-1} + 15, 000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 2), with a comparable mean value of 173.98 pods, respectively. A mean of 153.93, 141.46, 126.50, and 116 pods were obtained at Treatment 1, Treatment 4, Treatment 5, and Treatment 6. The varied number of filled pods was due to the application of different rates of effective microorganisms that enhance soybean production as cited by Muslikah *et al.* (2016).

Furthermore, the application of inorganic and effective microorganism (EM) combinations has not significantly affected the number of unfilled pods among treatments. The application of 15,000 ml EM obtained the highest number of unfilled pods with a mean of 21.68 pods, followed by 21.35, 21.18, 20.23, and 19.70 pods from Treatment 2, Treatment 4, Treatment 5, Treatment 1, and Treatment 3, respectively. However, such variations in the number of unfilled pods show comparable results for all the treatments. The combination of 16-20-0, EM, and agricultural lime did not affect the number of unfilled pods with mean values ranging from 19.70 to 21.68.

Table 4. Number of Filled and Unfilled Pods

Treatments	Number of Filled Pods	Number of Unfilled Pods
T_1	150.93^b	19.70
T_2	173.98^a	21.35
T_3	176.98^a	19.70
T_4	141.46^{bc}	21.18
T_5	126.50^{cd}	20.23
T_6	116.00^d	21.68
F- RESULTS	**	ns
C.V. (%)	4.52	13.71
HSD	19.33	

Weight of Marketable Seeds. The weight of marketable seeds is shown in Table 5. The plants applied with 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} produced the heaviest seeds with a mean value of 339.45 grams but somehow comparable to the plants applied with 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} with a mean of 320.22 grams. However, the treatments produced the highest marketable weight were significantly different to the plants applied with pure inorganic fertilizer at the recommended rate of 4 bags 16-20-0 ha^{-1}, 1 bag 16-20-0 ha^{-1} + 3,750 ml EM ha^{-1} + 500 kg Agrilime ha^{-1}, and pure EM at the recommended rate of 15,000 ml EM ha^{-1} with mean values of 266.75 grams, 251.67 grams, 233.93 grams, and 228.95 grams. The latter mean values were significantly comparable. Such differences in the weight of marketable seeds were attributed to the combined effects of inorganic fertilizer with effective microorganisms through spraying as it conforms to the claim of Gaweda *et al.* (2018).

In addition, according to Muslikah et al. (2016), the application of rhizobium and effective microorganisms showed significant results on the growth and yield of soybeans. The interaction of bio-fertilizer, organic fertilizer, and inorganic fertilizer with lime is also effective on the nodulation, leaf area index, and yield of soybean, as claimed by Abeje et al. (2021).

Table 5. Weight of Marketable Seeds (Grams)

Treatments	Marketable Weight (g)
T_1	266.75^{bc}
T_2	320.22^{ab}
T_3	339.45^{a}
T_4	251.67^{c}
T_5	233.93^{c}
T_6	228.95^{c}
F- RESULTS	**
C.V. (%)	8.56
HSD	67.85

Projected Yield per Hectare. The yield of soybean as affected by the application of varied rates of Effective Microorganism (EM) is shown in Table 6. In descending order, the application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 3), had 1805.71 kilograms, followed by Treatment 2 with the application of 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} with 1714.29 kilograms, 1 bag 16-20-0 ha^{-1} + 3,750 ml EM ha^{-1} + 500 kg Agrilime/ a^{-1} (Treatment 4) had 1347.14 kilograms, 4 bags 16-20-0 ha^{-1} (Treatment 1) had 1050.00 kilograms, 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} (Treatment 5) had 1041.43 kilograms, and the lowest projected yield was recorded in the application of 15,000 ml EM ha^{-1} alone in Treatment 6 with 864.29 kilograms.

Table 6. Projected Yield of Soybean per Hectare

Treatments	Yield per Hectare	
	Kilograms	Tons
T_1	1050.00	1.05
T_2	1714.29	1.71
T_3	1805.71	1.81
T_4	1347.14	1.35
T_5	1041.43	1.04
T_6	864.29	0.86

Cost and Return Analysis. The cost and return analysis of one-hectare soybean production is presented in Table 8. The return on investment in every treatment is organized in descending order: Treatment 3 with the application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} with 90.65 percent, Treatment 2 with the application of 4 bags 16-20-0 ha^{-1} + 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} with 60.11 percent, Treatment 1 with the application of 4 bags 16-20-0/ ha^{-1} with 56.56 percent, Treatment 4 with the application of 1 bag 16-20-0 ha^{-1} + 3,750 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} with 52.16 percent, 36.03 percent for Treatment 6 with the application of 15,000 ml EM ha^{-1} alone, and 12.04 percent for Treatment 5 with the application of 15,000 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} , which bears the lowest return on investment among the treatments.

Table 7. Cost and Return Analysis of One-Hectare Soybean Production

Treatments	Cost of Production (PHP)	Gross Income (PHP)	Net Income (PHP)	ROI (%)
T_1	57,005.21	89,250.00	32,244.79	56.56
T_2	91,006.25	145,714.65	54,708.40	60.11
T_3	80,506.25	153,485.35	72,979.10	90.65
T_4	75,256.25	114,506.90	39,250.65	52.16
T_5	79,006.25	88,521.55	9,515.30	12.04
T_6	54,006.25	73,464.65	19,458.40	36.03

Conclusion and Future Works

Based on the results of the study, the application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} affected the growth and yield of soybean, and chemical properties of the soil. It is observed that it increases the pH, nitrogen, phosphorus, and potassium content of the soil, plant height, number of filled pods, weight of marketable seeds, projected yield, and return on investment. Therefore, the use of inorganic fertilizer, effective microorganism (EM), and agrilime combination (2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1}) is a potential nutrient management good practice for soybean production under the same condition.

The application of 2 bags 16-20-0 ha^{-1} + 7,500 ml EM ha^{-1} + 500 kg Agrilime ha^{-1} can be used to attain the tallest plants, highest marketable seeds, highest numbers of filled pods, highest projected yield, and highest return on investment based on the results. These farm input combinations are potential nutrient management practices to obtain maximum yield of soybean production in acidic soils. This nutrient management practice may not only improve the growth and yield but also enhance the chemical properties of the soil. Lastly, studies on the nodulation of soybeans may be further explored.

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