Economic feasibility of soybean cultivation using bio-pesticide technology

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Abstract. Pests and diseases are one of the obstacles to increase soybean productivity in Indonesia. Pests control by chemical pesticides requires high production cost resulted in a low profit of soybean farming; therefore, it is less favorable to farmers. The study aims to evaluate the economic feasibility of soybean farming using bio-pesticide in rainfed rice fields. The research was conducted in Banyuwangi Regency, East Java, during the second dry season of 2018. The survey involved forty respondents. Three improved soybean varieties (Anjasmoro, Argomulyo, and Devon) and one local variety (Martoloyo) were evaluated on two cultivation technologies, namely bio-pesticide and existing. The results showed that the yield of existing technology was 2.18 t ha⁻¹ or 5.8% higher than the bio-pesticide (2.06 t ha⁻¹). Anjasmoro obtained the highest seed yield, i.e. 2.31 and 2.38 t ha⁻¹, while the lowest was Argomulyo, i.e. 1.85 and 1.96 t ha⁻¹, respectively for both bio-pesticide and existing technologies. The application of soybean cultivation using bio-pesticide technology and improved varieties provided a profit of IDR 8,785,300. The profit was 125.88% higher than the existing. Bio-pesticide and existing technologies (both for improved and local varieties) showed the R/C ratio >1, suggested that both technologies were feasible to be developed.

1. Introduction

The realization target of the Indonesian Ministry of Agriculture's program on soybean self-sufficiency finds many challenges. Some of them are the decrease of soybean planting area and the low interest of farmers in soybean cultivation due to the price's inability to compete with other food crops, mainly with maize. The government has made various efforts to achieve the national soybean self-sufficiency program by expanding soybean planting area, particularly on sub-optimal lands. The expansion of soybean planting area coupled with the use of improved varieties, has been able to result in high soybean productivity. Crop productivity is determined by internal factors such as crop genetic and external factors, including biotic and abiotic stress. One of the biotic factors directly impacting the decrease of soybean production is pests and diseases [1, 2].

Indonesia's non-irrigated rice fields or rainfed rice fields were around 3.71 million ha or 45.7% of total rice fields [3]. According to data [4], 33.4% of rainfed rice fields can be planted twice or more every year. Therefore, the potential of rainfed rice fields is quite immense. Apart from being planted with rice, rainfed rice fields can also be planted with maize or soybean at the second or the third growing season. Some researches indicated that soybean productivity in rainfed rice fields in Java could reach 1.8-3.2 t ha⁻¹ depending on the variety used and the input provided [5, 6, 7]. Meanwhile, the potential yield of several improved soybean varieties released by the Indonesian Agency for Agricultural Research and Development (IAARD) has reached more than 3.0 t ha⁻¹ [7].
Farmers usually carried out pest control on soybean crops using chemical pesticides because they were easy to obtain and react quickly to eradicate pests [1, 2, 8]. However, farmers did not realize that the application of chemical pesticides has negative impacts, including the residual exposure in crop yields, killing non-target organisms, polluting water sources and the environment, poisoning human, and affecting health in the form of triggering some issues such as cancer, cleft lip or stroke [9, 10, 11].

In Indonesia, the price of pesticides was relatively high. The average cost of chemical pesticide components contributed to 25-40 percent of the total agricultural production costs [12]. The high production cost can reduce farmers' income. Therefore, to increase the added value of soybean farming, it is necessary to improve the cultivation technology so that the yield obtained has a high price and benefits farmers. The chemical pesticide-free soybean cultivation technology introduces the package of cultivation technology relying on the efficacy of various types of bio-pesticides; therefore, the soybean yield is categorized as an organic product because there is no residual exposure [13].

ILETRI has produced various types of formulated bio-pesticides to control various pests in soybean. Up to 2016, various bio-pesticide products of ILETRI tested for their efficacy included Trichol-8, SBM, BACTAG, CEKA, Bio-Lec, and Be-Bas and Virgra. The efficacy test resulted in that besides being effective in eradicating target pests, bio-pesticides were also environmentally friendly because they did not interfere with the survival of useful insects, particularly predators and parasitoids [14], biodegradable, leaving no residue or environmental pollution [15, 16, 17].

The development of soybean cultivation using bio-pesticide technology can reduce resistance and resurgence, as well as increase environmental health because there is no exposure to synthetic pesticide residues [9, 17, 18]. Moreover, it is expected that farmers will be able to independently prepare bio-pesticides because the material has been available in nature and easily obtained; therefore, farmers are no longer depend on chemical pesticides [19]. The government can also save foreign exchange due to the reduced annual budget to subsidize chemical pesticides.

Financial feasibility analysis is an essential aspect of assessing product development. New cultivation technology must be agronomic technically and socio-economically feasible [20, 21]. It is expected to directly impact the acceleration of technology adoption, increase farmers' production and income. Adaptive and appropriate technology has four characteristics, namely: technically usable, economically beneficial, socially acceptable and environmentally friendly [22]. Additionally, characteristics of innovation will be adopted by farmers included relative benefits, suitability, complexity, ease of trial, and can be distinguished from the older innovation [23].

Some research showed the feasibility of bio-pesticides applications. Research of [24] showed the application of bio-pesticides made from clove oil and lemongrass to control the main pests of pepper plants was economically feasible even though the analysis results of B/C ratio, Net Present Value and Internal Rate of Return were lower than the use of only synthetic pesticides. The use of bio-pesticides, a mixture of galangal, neem leaves, lemon grass and betel leaf, applied to white ginger farming was financially feasible and relatively insensitive to decreasing productivity and price [25]. Furthermore, researches on neem seed powder, entomopathogenic virus (Virgra), antagonistic fungi (Trichoderma sp.) and the entomopathogenic fungus Beauveria bassiana showed no negative impacts on the environment. The products using bio-pesticides can be categorized as organic products; therefore, it is more expensive and more profitable for farmers [26, 27]. This research aims to determine the economic feasibility of soybean cultivation using bio-pesticide technology in rainfed rice fields.

2. Materials and Methods
The research was conducted in Kedungsari Village, Tegaldlimo Sub-District, Banyuwangi Regency, East Java Province, during the second dry season of 2018 in 15 ha of rainfed rice field. The study consisted of two soybean cultivation technologies, namely 1) chemical pesticide-free (bio-pesticide) in an area of 10 ha; and 2) existing (recommended integrated pest management technology through monitoring which farmers have applied) in an area of 5 ha (Table 1).
### Table 1. Component of soybean cultivation technologies in Banyuwangi, East Java Province, 2018.

| Component of technology     | Soybean cultivation technologies |
|-----------------------------|----------------------------------|
|                             | Existing (5 ha)                  | Bio-pesticide (10 ha)            |
| **Land preparation**        | Weeding (Herbicide, non-tillage or minimum tillage) | Weeding (Herbicide, non-tillage or minimum tillage) |
| **Drainage channel**        | Every 3 - 4 m (20 cm width, 25 cm depth) | Every 3 - 4 m (20 cm width, 25 cm depth) |
| **Seeds Preparation**       | Quality seeds, growing ability >80% | Quality seeds, growing ability >80% |
| **Soybean varieties**       | Argomulyo Devon, Anjasmoro, Martoloyo | Argomulyo Devon, Anjasmoro, Martoloyo |
| **Seed treatment**          | Benomyl, Cypermethrin            | Trichol-8 (50 g/10 seeds)        |
| **Planting method**         | Using dibbling tool or adjusting the plow lane (3 seeds/hole) | Using dibbling tool or adjusting the plow lane (3 seeds/hole) |
| **Plant spacing**           | 40 cm x 15 cm                    | 40 cm x 15 cm                    |
| **NPK fertilizer**          | 200 kg Phonska ha⁻¹ + 100 kg SP36 ha⁻¹ + 1.0 l KCl Boron. | 200 kg Phonska ha⁻¹ + 100 kg SP36 ha⁻¹ + 1.0 l KCl Boron. |
| **Liquid fertilizer**       | 5 ml l⁻¹ (at 20, 40, and 60 DAP⁸) | 5 ml l⁻¹ (at 20, 40, and 60 DAP⁸) |
| **Weeding**                 | I (herbicide at 15-20 DAP⁸)       | I (herbicide at 15-20 DAP⁸)       |
|                             | II (herbicide at 28-30 DAP⁸)      | II (herbicide at 28-30 DAP⁸)      |
| **Pest controlling**        | Chemical insecticide (monitoring) | Preventive (SBM², Virgra³) |
| **Harvesting**              | Manually; brown pods              | Manually; brown pods              |
| **Seed threshing**          | Thresher                         | Thresher                         |

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³ DAP = day(s) after planting.
² SBM = serbuk biji mimba (Indonesian) or neem seed powder; effective in controlling leaf pests (O. phaseoli, S. litura, Chrysodeixis chalcites (Esper), and L. indicata); a dose of 50 g l⁻¹ [14].
³ Virgra = entomopathogenic viruses contains S.litura nuclear polyhidrosis particles virus (SINPV); effective in killing armyworms and controlling leaf pests of L. indicate, C. chalcites and borer larvae of M. testulalis [14].

The data collected included primary and secondary data. The research approach to obtain primary data was field observation and survey. The field observation aimed to know the needs of production facilities and labor each technology. The survey was conducted by interviewing 40 cooperator farmers and key informants using guidance from an open questionnaire. Data collected included both cultivation technologies' financial aspects as the primary data, while technical aspects related to soybean cultivation (land preparation, planting, weeding, pest controlling, and harvesting) as supporting data. The financial analysis was economic feasibility involved soybean farming income [28], Break Event Point (BEP) [29], Revenue Cost Ratio (R/C ratio) [30], Benefit Cost Ratio (B/C ratio) [31], and Marginal Benefit Cost Ratio (MBCR) [32].

### 3. Results and Discussion

The cropping pattern carried out by farmers in their rice fields was generally rice-rice-soybean or rice-soybean-soybean with the local ‘Martoloyo’ soybean variety. The application of soybean cultivation using bio-pesticide technology with the use of improved soybean varieties will economically improve the existing technology as follows:

#### 3.1. Seed yield productivity

The average yield of existing cultivation technology was 2.18 t ha⁻¹. It was 5.8% higher than the bio-pesticide (2.06 t ha⁻¹). The highest yield was obtained by Anjasmoro, i.e., 2.31 and 2.38 t ha⁻¹, for bio-pesticide and existing technologies, respectively. The local variety of Martoloyo had a higher yield...
than two other improved varieties, i.e., 2.12 and 2.24 t ha$^{-1}$, while the lowest was Argomulyo, i.e., 1.85 and 1.96 t ha$^{-1}$, respectively for bio-pesticide and existing technologies (Figure 1).

![Figure 1. Soybean productivity in Banyuwangi, East Java Province, 2018.](image)

**Table 2.** Production inputs of soybean farming in Banyuwangi, East Java Province, 2018.

| Description                          | Soybean cultivation technologies |
|--------------------------------------|----------------------------------|
|                                      | Existing (IDR ha$^{-1}$)         | Bio-pesticide (IDR ha$^{-1}$) |
| A. Production facilities             |                                 |                                |
| Soybean seeds                        | 600,000                          | 600,000                        |
| Seed treatment                       | 122,000                          | 250,000                        |
| Bio-pesticides                       |                                 |                                |
| Virgra                               | 0                                | 500,000                        |
| SBM                                  | 0                                | 1,200,000                      |
| Chemical pesticides                  | 1,172,000                        | 0                              |
| Herbicides                           | 260,000                          | 260,000                        |
| Fertilizers                          | 1,195,000                        | 1,195,000                      |
| Total (A)                            | 3,349,000                        | 4,005,000                      |
| B. Labor activities:                 |                                 |                                |
| Seed treatment                       | 35,000                           | 35,000                         |
| Rice straw cutting                   | 300,000                          | 300,000                        |
| Planting                             | 1,400,000                        | 1,400,000                      |
| Fertilizing                          | 210,000                          | 210,000                        |
| Weeding                              | 1,470,000                        | 1,470,000                      |
| Pest controlling                     | 420,000                          | 420,000                        |
| Irrigating                           | 200,000                          | 200,000                        |
| Harvesting                           | 735,000                          | 780,500                        |
| Threshing                            | 1,056,600                        | 934,200                        |
| Total (B)                            | 5,826,600                        | 5,749,700                      |
| Total cost (A+B)                     | 9,175,600                        | 9,754,700                      |
The average yield of existing technology was generally higher than the bio-pesticide, even though the difference was not significant. The phenomenon occurred due to the application of chemical pesticides was able to eradicate all the pests resulted in the minimal damage of the crops particularly the pods. This finding is in contrast to the way of bio-pesticides work. Bio-pesticides use active ingredients and microorganisms both from the groups of viruses and entomopathogenic fungi. Bio-pesticides work as insect repellent or kill the pests within a particular time. Thus the existing pests still have a big chance to destroy the crops even though it causes no major damage.

3.2. Production inputs of soybean farming

Production inputs included production facilities such as soybean seeds, fertilizers, pesticides (chemical and biological), labor, land, and other institutions become essential factors in soybean farming. Farmers need 50-60 kg ha⁻¹ of seed for the existing farming with an average price of IDR 9,500 kg⁻¹. The seed was obtained from other farmers in their village. For the research, the need for improved soybean varieties seed was 40 kg ha⁻¹ with the price of IDR 15,000 kg⁻¹ for the class of foundation seed (FS). The application of soybean farming using bio-pesticide increased the production cost for the bio-pesticides provision that is 31.06% higher than the cost expensed for chemical pesticides in the existing farming. However, it did not affect to labor cost for pest controlling (Table 2).

3.3. Soybean farming feasibility

The previous research [33] found that bio-pesticides that reduced chemical pesticides by 50-100% would not reduce the crop yields and lower production cost. Even though the application of bio-pesticides in this research had not yet brought more income for farmers through lower production cost, however, the higher selling price of the seed, up to 150% than the general seed selling price, could increase the revenue of soybean farming using bio-pesticide (Table 3). It was in accordance with the research of [34].

Table 3. Financial feasibility of soybean farming in Banyuwangi, East Java Province, 2018.

| Description               | Soybean cultivation technologies |
|---------------------------|----------------------------------|
|                           | Existing                          | Bio-pesticide                    |
| Total of production facilities cost (IDR ha⁻¹) | 3,349,000                         | 4,005,000                         |
| Total of labors cost (IDR ha⁻¹)       | 5,826,600                         | 5,749,700                         |
| Total of production cost (IDR ha⁻¹) | 9,175,600                         | 9,754,700                         |
| Average seed yield (kg ha⁻¹)           | 2,178                             | 2,060                             |
| Selling price (IDR kg⁻¹)              | 6,000                             | 9,000                             |
| Revenue (IDR ha⁻¹)                  | 13,065,000                        | 18,540,000                        |
| Profit (IDR ha⁻¹)                   | 3,889,400                         | 8,785,300                         |
| R/C ratio                          | 1.4                               | 1.9                               |
| B/C ratio                          | 0.4                               | 0.9                               |
| MBCR                                | -                                 | 9.45                              |
| BEP production (kg ha⁻¹)             | 1,529                             | 1,084                             |
| BEP price (IDR kg⁻¹)                | 4,214                             | 4,735                             |

In addition to the increase and profit of the farming revenue by applying bio-pesticide cultivation technology, respectively 41.91% and 125.88% higher than the existing technology, the R/C ratio of 1.9 and MBCR of 9.45 indicated that the bio-pesticide technology was profitable and more efficient than the existing. Moreover, the actual seed yield and selling price, which were higher than the break-
even point, implied that both technologies' application was profitable (Table 3). Research [35] reflected that the comprehensive impact of bio-pesticides was in terms of production efficiency and the environmental impact. The beneficial characteristics of bio-pesticides that are environmentally friendly include biodegradable, suppressing crop damage, having a broad spectrum in controlling the pests even though they have been resistant to synthetic pesticides, and low toxicity to humans or mammals [36].

4. Conclusion
The application of soybean cultivation technology in rainfed rice fields using bio-pesticides produced by ILETRI (Virgra and SBM) was financially more feasible than the existing with the increase of revenue and profit were 41.91% and 125.88%, respectively. The R/C ratio of 1.9 and MBCR of 9.45 of bio-pesticide technology implied that the technology was profitable and more efficient than the existing one. Therefore, it is recommended that farmers avoid chemical pesticides and switch to using bio-pesticides that are more profitable, efficient, and environmentally friendly.

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