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Adoption and advantages of eco-friendly technology application at the Shallot farming system in Indonesia

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Abstract. This study aimed to evaluate the benefits farmers obtained by adopting eco-friendly technologies on local shallot cultivation in Central Sulawesi, Indonesia. The technology applied includes; trap crops, biofertilizers (bokashi and mycorrhiza arbuscular) biopesticides (*Beauveria bassiana* and *Trichoderma* sp.) and plastic mulch. Ninety-nine shallot farmers were selected, consisting of 35 farmers who applied the technology (adopters) and 64 farmers who did not (non adopters). Characteristics, rates of adoption, and benefits of both groups of farmers were measured and analyzed. The results showed that the level of technology adopted by the farmers was high and supported by farmer characteristics, particularly their age and education. The application of technology increases the production of shallots and the total profits of farmers by 29.5% and 79.1% respectively. In addition, adopters can reduce the costs of chemical inputs by around 69.5%. Therefore, the technology introduced provides multiple benefits for farmers; economically and environmentally.

Key words: adoption, sustainable farming system, shallot cultivation, farmer's benefits.

INTRODUCTION

Shallot is one of the horticultural commodities that has a significant contribution to farmer's income in Indonesia. The farmers in Central Sulawesi Province of Indonesia have grown a local variety of shallot called 'Lembah Palu Shallot' or 'Palu Fried Shallot' as one of the leading commodities potentially to be registered as a geographical indication of this area (Nur et al., 2015). The productivity of this local shallot at the farmer's scale varies from 3 and 5 tons per hectare which are still below from its biotic potential of 11.10 tons per hectare (Christoporus et al., 2016).

The productivity of the shallot cultivation in Palu valley is limited by several factors such as low soil fertility, lack of water availability as well as an infestation of pests and plant diseases (Lasmini et al., 2015; Saleh et al., 2018). In addition to the low productivity, the local shallot is also faced with food safety and environmental problems.

Recent studies reported that the presence of chlorpyrifos residues on local shallot tubers has exceeded the maximum limit the plant can tolerate according to ISO 7313: 2008 (Jamaluddin et al., 2015). This chemicals compound is very hazardous for human health (Saunders et al., 2012).

To overcome environmental problems due to the high application of pesticides by the farmers, FAO recommends the integrated pest management system that prioritizes the use of bio-pesticides and bio-control (FAO, 2017). This is in line with the principles of sustainable agriculture which emphasizes the management of agroecosystems and optimizes ecosystem services of the biological control agents to manage the pests (Sullivan, 2003). Some techniques that can be applied for this purpose are the use of trap crops, mulch, biofertilizers such as bokashi and mycorrhiza, and biopesticides like Beauveria and Trichoderma. These techniques could suppress the plant pests and diseases (Ownley et al., 2004; Shelton & Badenez-Perez, 2006; Shahabuddin et al., 2015, Sharma et al., 2017, Saleh et al., 2018) as well as increase crop yields (Hart & Trevors, 2005; Vinale et al., 2008; Lalitha et al., 2010; Álvarez-Solís et al., 2016).

The successful implementation of the above-mentioned technology is strongly dependent upon the production factors including characteristic of the farmers (Christoporus, 2017). These factors along with the technology characteristics such as relative advantages, compatibility, simplicity, and trialability are important to be considered to ensure that the adoption of the technology by the farmers (Rogers, 2003). This study aims to evaluate the contribution of eco-friendly technology introduced to the shallot farmers for supporting sustainable farming systems. Particularly, the study examines the adoption level of the technology introduced to the shallot farmers, and the effects of the introduced technology on shallot production, farmer income and budget for chemicals.

MATERIALS AND METHODS

The study was conducted in the Guntarano village, Tanantovea sub-district, Donggala district, one of the central areas of shallot production in Central Sulawesi, Indonesia. The study was carried out from February to September 2018. The shallot farmer population in the study area was 216 people. A census method was used to determine the number of adopters so that all populations were selected as respondents. Of all respondents, 35 farmers were practicing the technology (adopters) and 181 farmers were not (non adopters). A simple random sampling method was used to select the number of non adopters. Based on Slovin's formula Ryan, 2013) and a sampling error of 10%, thus the sample size of non adopters farmers was 64 respondents.

Data collection was done by interview method using a structured questionnaire (Fig. 1). The data collected is then calculated to analyze the adoption level of technology by the farmers and farm profitability. The level of adoption was measured by means of scoring techniques based on the score weight and the percentage of each technology component applied by the farmers according to the following formula (Santoso et al., 2005).

$$\text{Adoption score} = \frac{\text{p}}{\Sigma \text{S}}\, x\, s \qquad (1)$$

where P – Percentage of farmers who apply technology; S – Score weight; ΣS – Total score weight.

The adoption level of above technology is categorized as follow: **low** if the score is between 0–33.33%, **medium** if the score is between 33.34–66.66, and **high** if the score is between 66.67–100%. Data on the characteristics of respondents that can influence the adoption level particularly their age, education, and cultivated land was collected.

Farmer profit is calculated using a budgetary technique which involves the cost and returns analysis. The model specification is given below:

Figure 1. The interview process with the shallot farmer based on the prepared questionnaire.

$$\pi = TR - TC \quad (2)$$

$$TR = Pq \times Q$$
$$TC = \text{Total Cost } (VC + FC) \quad (3)$$

where π – Total profit; TR – Total Revenue; Pq – Unit price of output; Q – Total quantity of output (production), VC – variable cost, and FC – fixed cost.

Differences in the total revenue of the adopters and non adopters were analyzed by using t-test of the independent sample, $\alpha = 0.05$ (Sokal & Rohlf, 2012).

The technologies applied were (1) trap crops, (2) biofertilizer consisted of bokashi composting and mycorrhizal arbuscular and (3) biopesticides consisted of *Trichoderma* sp., and *Beauveria bassiana* and (4) plastic mulch.

Twenty-four of the 3×2 m^2 plots were used to grow shallots. Plastic mulch was installed at each plot and 76 holes (7 cm in diameter) with 15×15 cm^2 in spacing was made for sowing the shallot seeds (Fig. 2). The cucumbers used as the trap crop were planted 2 weeks before the shallot planting with a spacing of 40×40 cm^2. Bokashi (5 t ha^{-1}) was applied one day before the shallot planting. Bokashi was made from chicken, cow and goat manure (50:25:25 m m^{-1}) and enriched with effective microorganism solutions (EM4, PT. Songgololangit Persada, Indonesia). Subsequent fertilization was implemented 14 days after planting using 400 kg ha^{-1} of NPK. Shallot seeds dipped for 5 minutes into Trichoderma liquid before planting and then mycorrhiza (5 g shallot^{-1}) was applied. Beauveria (10 g L^{-1}) was applied once a week after planting from week 2 to 9.

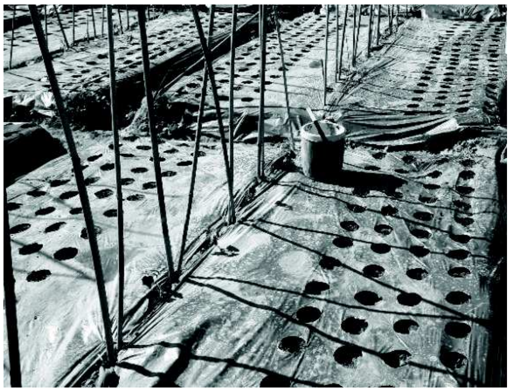

Figure 2. Some experimental plots showing the installed mulch with holes in similar size and space for shallot seed sowing and the trap crop (cucumbers) grown beetwen two shallot plots.

RESULTS AND DISCUSSION

The results showed that farmers who applied the technology (the adopters) at the research location had different adoption rates. Most of the adopters (80%) applied the technology package as a high category and only 2.86% of them are considered as low adopters (Table 1). Majority of the respondents (94.29%) are categorized as productive labor or in the level of active work participation (an average of 42.3 years). In the context of education, 65.71% of the respondents experienced ranging from six to nine years of formal education or graduated from junior high school. The land area size cultivated by the respondent farmers is relatively low varied between 0.35 ha – 1.35 ha or 0.78 ha on average.

Table 1. Adoption level of introduced technology by the adopters

No.	Adoption level	Number of adopters	Percentage
1	Low	1	2.86
2	Middle	6	17.14
3	High	28	80.00
	Total	35	100.00

The high level of technology adoption was supported by the characteristics of the farmers particularly their age, level of formal education as well as the farm field size (Table 2). The farmers are mostly in their productive age and therefore they have a high capability to adopt the new technology. Similar results were also shown by Zhou & Yang (2010) who analyzed the factors affecting the decisions of farmers on using fertilizer and found that the young farmers had higher adaptability toward the change and more responsive to new information than the old farmers.

The level of education of the shallot farmers also plays an important role in adopting the new technology. Individuals with a good level of education are more open-minded in adopting new technology into their farming activities. They also have sufficient capability in response to new technologies, as an effort to increase farm production and income. This situation is expected to improve their ability to manage a business related to the farm, thereby giving a positive impact on an individual or societal economic growth. Previous research emphasized the significance of the farmers' education in increasing technical efficiency on the shallots cultivation (Christoporus, 2017). However, the adoption of new technology in farming activity is not necessarily affected by the farmer's education level (e.g. Arshad et al., 2007).

Table 2. Farmer characteristics at the study area

No.	Farmer characteristics	Mean ± Sd
1	Age (year)	42.3 ± 5
2	Formal education (year)	6 ± 3
3	Cultivated area size (ha)	0.78 ± 0.2

Another factor influencing the farmer's productivity is the size of the cultivated area. Keskin & Sekerli (2016), Christoporus (2017) and Ahmad et al. (2018) noted that the size of farm field has a significant positive correlation with the adopted technology and farmer's productivity. The more extensive of the land cultivated, the higher the production if it is supported by good farming techniques (Anik et al., 2017). The farmers with the larger size of land usually have sufficient resources to manage their crops so that they will be more quickly in adopting new technology than smaller land holdings (Arshad et al., 2007, Ahmad et al., 2018). Therefore, an increase in the shallot area size in our study area presumably can lead to greater farmers' productivity and profitability.

In addition to the characteristics of the farmers that support technology adoption, the high adoption of the eco-friendly technology also indicates that it is quite easy to implement and can be combined with the existing conventional cultivation techniques. Therefore the introduced technology fulfills the elements of adoption factors particularly the compatibility and simplicity of technology as stated by Rogers (2003).

Economic benefits of the introduced technologies

The results of the farm profit analysis showed that the shallot productivity generated by the adopters was greater than those by the non adopters. Consequently, the adopters have a greater net income (Table 3). The study denotes that with the application of the technology, the productivity and the total income of the adopters were higher about 1.3 and 1.8 times than the non adopters, respectively. On the contrary, the budget for chemicals spent by the adopters decreased 3.3 times lower than the non adopters (Table 4).

Table 3. Farm profit analysis of the respondents

No.	Description*	Adopters (n = 35)	Nonadopters (n = 64)
1	Yields (kg ha^{-1}) :		
	a. Shallots	3,917.75	3,024.79
	b. Cucumber	1,120.55	0
2	Price (IDR ha^{-1}) :		
	a. Shallots	27,450.50	26,510.93
	b. Cucumber	3,500.00	0
3	Gross income (IDR ha^{-1}) :		
	a. Shallots	107,544,196.38	80,190,000.00
	b. Cucumber	3,921,925.00	0
	Total Gross Income :	111,466,121.38	80,190,000.00
4	Cost :		
	a. Fixed cost (IDR GS^{-1}):		
	- Equipment maintenance	245,335.55	203,237.06
	- Land rent	666,666.67	666,666.67
	- Others (tax, ceremonial, etc.)	586,976.74	586,976.74
	Sub Total a : (IDR)	1,498,978.98	1,456,880.47
	b. Variable cost (IDR)		
	- Labor	13,095,125.75	12,292,182.09
	- Shallot seed	22,250,765.50	23,295,833.33
	- Cucumber seed	750,155.55	0
	- Chemical fertilizers	5,500,000.00	15,969,383.26
	- Chemical pesticides	0	2,067,797.36
	- Bio-fertilizer (Bokashi manure)	4,708,333.00	0
	- Biopesticides (Mycorrhiza, Trichoderma, Beauveria	14,683,484.00	0
	- Plastic mulch	4,000,000.00	0
	Sub Total b: (IDR)	64,987,863.80	53,625,196.04
5	Total cost (4a + 4b) (IDR ha^{-1} GS^{-1})	66,486,842.78	55,082,076.51
6	Total profit (IDR ha^{-1} GS^{-1})	44,979,278.60	25,107,923.49
7	RC ratio	1.67	1.45

Note: * GS: Grown Season.

Table 4. Economic advantages of the technology introduced to shallot farmers

Variables	Adopters (a)	Nonadopters(b)	Differences (%)*
Shallot yield (kg ha^{-1})	3,917.75	3,024.79	29.5
Cucumber yield (kg ha^{-1})	1,120.55	0	100
Gross income (IDR ha^{-1})	111,466,121.38	80,190,000.00	39.0
Total profit(IDR ha^{-1})	44,979,278.60	25,107,923.49	79.1
Chemicals cost (IDR ha^{-1})	5,500,00.00	18,037,181.00	69.5

Note: *Differences between both groups was obtained by using formulae; (a-b/b) x100.

In accordance with the results of the t-test of independent sample (*p-level* < 0.05), there is a significant difference in income between the adopters and the non adopter's farmer. The total profit differences between both groups were IDR. 19,871,354.51. The additional income of 3.65% of the adopters was due to the contribution of income generated from cucumber plants used as trap crops. This clearly shows that the intercropping of shallots with cucumber plants provides economic benefits for farmers. Meanwhile, the RC ratio of the adopters is higher than that of the non adopters (1.67 vs. 1.45). This indicates an increase of 0.22 in the RC ratio if the farmer implements the introduced technology or there is an increase of IDR 220.00 in revenue for every IDR 1,000 spent. This higher RC ratio is achieved as a consequence of higher production and production prices.

The shallot farmers have generated relatively high economic benefit by adopting the novel technology introduced in our study area. It has been known that the relative advantages of technology determine the level of technology adopted by the farmers (Rogers, 2003; Foster & Rosenzweig, 2010; Obayelu et al., 2017).

An extensive study in Africa found that the application of trap cropping and intercropping system at maize and sorghum fields, tremendously increasing the farmer's income (Khan et al., 2014). In addition, intercropping system combined with bokashi significantly favored the yield and quality of pepper and shallot in Mexico (Álvarez-Solís et al., 2016).

Environmental benefits of the implemented technology

In addition to the economic benefits, the novel technology implemented in this study also provides some environmental benefits. The trap crops protect the main crops from being attacked by pests (Shelton & Badenez-Perez, 2006) and increase the diversity of natural enemies (Shahabuddin et al., 2015, Saleh et al., 2018). The plastic mulch replaces the herbicides for controlling the weeds, ameliorates the microclimate and contributes to pest control (Frank & Liburd, 2005; Lalitha et al., 2010). The use of bokashi enhance the fertility and nutrients availability of the soil as well as the crop yields (Xiaohou et al., 2008, Álvarez-Solís et al., 2016; Lasmini et al., 2018). Mycorrhizae improves nutrient uptake and induces plant resistance against pathogen and herbivore (Cardoso & Kuyper, 2006; Sharma et al., 2017). While Trichoderma and Beauveria act as biological control agents against pests and pathogens of the crops (Ownley et al., 2004; Vinale et al., 2008).

Integrating all eco-friendly technologies has successfully reduced the use of chemical fertilizers and pesticides by the farmers (see Table 4) and replaced them with habitat management, bio-fertilizer, and bio-pesticides. Thus, the novel technology applied in this study provides both economic and environmental benefits to the shallot farmers. Previous study in our study area has been documented the enhancing of the shallot yield by application the bokashi as biofertilizer (Lasmini et al. 2018) and increasing of the farmers income by participating in good agricultural program for shallot (Christophorus et al. 2016). However, by combining the agronomical and socioeconomical approach, this study was succesfull to show the economic and environmental benefits simultanously by implementing of the eco-friendly technology.

This study was conducted only for one growing season when the weather is quite dry so it is quite normal that the effect of the biotic factor particularly the pest infestation was relatively low (see Saleh et al., 2018), however it is expected that the pest infestation will be higher during wetter season and presumably decreased the shallot production. So it is suggested to conduct a longer study period covering several planting season to evaluate the effect of weather fluctuation. It is also important to search the best crop management to mitigate the detrimental effect of the climate change on the agriculture and food security (see Tubiello et al., 2008). The application of biological control in papaya farming in Pakistan had succeeded in providing benefits from economic and environmental aspects (Bajwa et al., 2018). Accordingly, the eco-friendly technology could solve problems faced by the farmings that intensively use chemical inputs leading to tremendously decreased productivity in the global scale (FAO, 2017).

The agricultural system in the last decade has been a shift from a traditional to a sustainable agricultural system. In this new paradigm, the driving factor of the farming system is not only farmers' tradition or habits that put the emphasis more on the economic aspects (higher, faster and easier production) but has highly considered the environmental and human safety factors. The user preferences, information, and the market has become the main driving factors, accordingly. The consumers prefer to buy safe products, free from pesticide residues (Shinohara, 2011). Shortly, in a sustainable farming system, economic, environmental and social goals must be achieved simultaneously (Sullivan, 2003). In this context, the technology introduced to the shallot farmers at the research location has good prospects to be developed and applied to other commodities in a wider area to support sustainable farming systems.

CONCLUSIONS

Based on the results of the study, it was concluded that the adoption level of the shallot farmers to the technology introduced is high and it was supported by the age and education of the farmers. Implementation of this eco-friendly technology elevates the shallot production and the farmers' total profit by 29.5% and 79.1%, respectively. Moreover, the adopters could reduce the chemicals input cost about 69.5%. The application of such eco-friendly technologies as trap crops, biofertilizers, biopesticides and plastic mulch provides a high advantage to the adopters compared to non adopters. The additional benefits of the technology introduced in terms of the environmental aspects are able to minimize the farmers' dependency on the chemicals and to produce shallot safer to consume.

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