INCREASING FRUIT YIELDS AND INCOME OF RED CHILI FARMING BY USING CHEMICAL AND BIOLOGICAL FERTILIZERS IN RAINFED RICE FIELDS

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ABSTRACT

This study aims to determine the effect of a combination of chemical fertilizers and biological fertilizers on the fruit yield of red chilies and the income obtained by farmers. The research was conducted on rainfed lowland land in Nagari Pariangan, Tanah Datar Regency, West Sumatra in September 2016 - February 2017. The research design used a Randomized Block Design with 4 treatments and 6 replications. The treatments used were NPK fertilizer 750 kg/ha (A0, recommendation), NPK fertilizer 500 kg/ha+biological fertilizer 6 l/ha (A1), NPK fertilizer 750 kg/ha+biological fertilizer 6 l/ha (A2), and NPK fertilizer 1,250 kg/ha+biological fertilizer 6 l/ha (A3). The results showed that the application of NPK and biological fertilizers had a significant effect on the growth and yield of red chilies. The use of NPK fertilizer 750 kg/ha+biological fertilizer 6 l/ha gave the best results on plant height, fruit circumference and fruit yield. The highest fruit yield was 11.35 tonnes/ha, an increase of 31.52% compared to without application of biological fertilizers. The increase in chili yield decreased with the increase in the NPK dose (from 750 kg/ha to 1,250 kg/ha), which was an increase of 29.2% from the yield obtained at the recommended NPK dose (A0). The highest income obtained by farmers was IDR 88,286,200/ha, also obtained in the treatment of using NPK fertilizer 750 kg/ha+biological fertilizer 6 l/ha (A2), and the smallest profit was in the treatment of using NPK fertilizer 750 kg/ha without biological fertilizer, namely IDR 46,866,200/ha. Thus the optimal yield and benefits of red chilies are obtained from the use of efficient inputs by applying the NPK fertilizer technology innovation according to the recommendations plus the provision of biological fertilizers (NPK 750 kg/ha+biological fertilizer 6l/ha).

Keywords: Red Chilies, NPK Fertilizer, Biological Fertilizer, Recommendations, Income

INTRODUCTION

Red chili (Capsicum annuum L.) is one type of horticultural commodity which is commercially cultivated. Red chilies have high economic value, so they are planted in almost all parts of Indonesia, including in West Sumatra Province. Besides being used for household needs, red chilies are also used as raw material for the food and pharmaceutical industry (Bhattarai & Mariyono, 2016; Bhutia et al., 2018). Therefore, the Government of West Sumatra has an interest in increasing production by expanding the planting area and increasing productivity.

In the last five years, the average productivity of chili in West Sumatra was higher than the average national chili productivity, namely 8.51 tonnes/ha compared to 7.49 tonnes/ha. This indicates that the climate suitability in West Sumatra is suitable for developing chili plants. (Taskovics et al., 2010; Kesumawati et al., 2018) suggest that plant growth is determined by several environmental factors, especially light, air temperature, humidity and rainfall. Therefore, the development of chili plants must be adapted to environmental conditions to get maximum results.

Although the contribution of West Sumatra chili to national chili production is relatively small (5.16%), chili production in West Sumatra has a positive trend both in terms of production, harvested area and productivity. In the last five years, production has increased from 68,101 tons in 2013 to 131,239 tons in 2018 with an average increase of 14.66%/year. The increase in production was due to an increase in harvested area by an average of 7.48%/year and an increase in productivity by an average of 7.18%/year (BPS Indonesia, 2014-2019). The increase in production obtained cannot be separated from the role of farmers in chili production activities. Farmers use a variety of production inputs, especially using inorganic fertilizers to provide the nutrients the plants need immediately. Without realizing it, the continuous use of inorganic fertilizers will have a negative impact on soil fertility and cause serious ecological disturbances, especially pollution of soil and water resources (Khaitov et al., 2019). Therefore, the use of chemical fertilizers needs to be balanced with fertilizers that are friendlier to the environment, namely biological fertilizers.

Biological fertilizer is a type of fertilizer that contains several microorganisms from the bacteria and fungi (Kalay et al., 2016). Biological fertilizers have the advantage that the nutrients contained in them are easily absorbed by plants and when given in the soil the organisms will help the process of breaking down nutrients in chemical fertilizers to become available to plants. Therefore, a research was conducted by applying chemical fertilizers and biological fertilizers to chili plants. This study aims to determine the effect of the combination of NPK and biological fertilizers on the fruit yield of red chilies and the income obtained by farmers.

MATERIALS AND METHODS

Experimental Area

The research was conducted on rainfed rice fields in Nagari Pariangan, Tanah Datar Regency, West Sumatra Province, starting in September 2016- February 2017. The materials used were red chili seeds of Pariangan variety, NPK fertilizer, biological fertilizer, manure, water, and pesticides. While the tools used are hoes, sprayers, bamboo, wood meters, rollers, calipers, scales, and others.

Design and Treatments

The study used a Randomized Block Design (RBD) with six replications. The treatments used were a combination of chemical fertilizers and biological fertilizers with 4 treatments that were repeated 6 times. These treatments are:

A0=750 kg/ha NPK (recommended dose)
A1=500 kg/ha NPK+6 liters of biological fertilizer
A2=750 kg/ha NPK+6 liters of biological fertilizer
A3=1,250 kg/ha NPK+6 liters of biological fertilizer

NPK chemical fertilizers contain 15% N, 15% P2O5, 15% K2O, and 10% S, while the biological fertilizers used contain seven types of microbes, namely: (1) *Rhizobium* sp.13,3x107sel/ml; (2) *Azotobacter* sp.1,7x107 cell/ml; (3) Phosphate Solubilizing Bacteria 5,7x107 cells/ml; (4) *Lactobacillus* sp. 3.7x107 cells/ml; (5) *Actinomycetes* sp.5,8x107 cells/ml; (6) *Citrobacter* sp.4,8x102sel/ml; and (7) *Acetobacter* sp. 1.3 x 105 cells/ml.

NPK fertilizer is given 5 times, namely: i) when cultivating the soil as a basic fertilizer with doses of 450 kg/ha (A0), 200 kg/ha (A1), 450 kg/ha (A2) and 950 kg/ha (A3), and ii) at the age of 4 weeks after planting (MST), 8 MST, 10 MST and 12 MST each treatment at a dose of 75 kg/ha, while biological fertilizer is given 3 times, namely: i) one week after tillage, ii) one month after the first fertilization, and iii) one month after the second fertilization, each fertilizing with a dose of 2 liters/ha.

Implementation Procedure

The soil is cultivated once, then a 1 mx 30 m bed is made. Each treatment uses one bed with six treatments so that there are a total of 24 beds. The processed soil is given basic fertilizer in the form of manure at a dose of 20 t/ha and NPK fertilizer. Furthermore, the red chili seeds that are 4 weeks old (have 4-5 leaves and seed height between 5 - 10 cm) are transferred to planted beds with a spacing of 50 cmx40 cm. After 4 MST, NPK and biological fertilizers are given as the first follow-up fertilizers. NPK and biological fertilizers are given at different times, the next fertilizers are according to the set schedule.

Weeding is done between the beds and around the clumps of red chili plants manually. Pruning branches/twigs is carried out continuously until it leaves the V branch (slingshot). Pest control using chemical pesticides depends on the level of attack and crop damage. Harvesting is done when the fruit is ripe at 1 week intervals, 16 times.

Observation and Data Analysis

To see the growth and production of red chilies, the observed variables were plant height (cm), fruit stalk length (cm), fruit length (cm), fruit circle (cm), weight 100 fruit (cm), and fruit yield (t/Ha). Furthermore, analysis of diversity and Duncan Difference Test (UBD) was carried out. To see the relationship between variables, a correlation analysis was performed. To find out the income from red chili farming, it is analyzed by knowing the production costs and revenues obtained by farmers. Farming costs are the total costs used during the production process, namely production input costs (seeds, fertilizers, pesticides) and labor wages, while income is the difference between revenue and production costs (Ila et al., 2019; Halid et al., 2017)) as follows :

Note :
π=income
TR=total revenue
TC=total cost

RESULTS AND DISCUSSIONS

Technical Aspects of Red Chilli

The results of the analysis of plant height variability showed that the treatment of chemical fertilizers and biological fertilizers had a significant effect on plant height at the age of 8 weeks after planting (MST), 12 WAP, and at the last harvest (Table 1). At the age of 8 WAP, the highest plant was obtained in the A3 treatment (750 kg/ha of NPK+6 l/ha of biological fertilizer), namely 54.0 cm and the lowest was in treatment A0 (750 kg/ha of NPK fertilizer), which was 47.5 cm. statistically; the treatment shows a significant difference at the 95% confidence level. Plant development until the age of 12 WAP showed a significant increase in height between treatments A3 and A1, and A3 was significantly different from A1, not significantly different from A2 and A0, while at the last harvest it showed that the highest plants were obtained in treatment A2 which was not significantly different from A3 and A0, but significantly different from A1 and plant height in treatment A1 is the shortest compared to plant height in other treatments. This is because in A1 treatment the lowest NPK fertilizer dose used (500 kg/ha) compared to other treatments, however, plant height in A1 treatment was not significantly different from plant height in the control treatment (A0: 750 kg NPK).

Table 1
THE EFFECT OF NPK AND BIOLOGICAL FERTILIZER ON THE AVERAGE HEIGHT OF CHILI PLANTS AT VARIOUS OBSERVATION TIMES

Treatment	Time Observation					
	8 MST		12 MST		Harvest time	
A1	49.5	bc	59.6	b	88.5	b
A2	53.5	ab	70.8	a	105	a
A3	54	a	72	a	104.8	a
A0	47.5	c	70.5	a	99.8	ab
KK (%)	5.12		7.33		7.56	

Note : Figures followed by the same letter in the same column are not significantly different in UBD with real level of 5%.

Based on these results, even though the plants were given biological fertilizers, if the NPK fertilizers were given below the recommended dosage it would cause plant growth to be inhibited. This is because biological fertilizers act as a stimulus so that if the availability of nutrients in the soil is not sufficient for plant needs, it has not had a significant effect on plant vegetative growth. (Wardhani et al., 2014) argued that the absence of biological fertilizers and low fertilizer doses in treatment A0 and A1 so that nutrient removal from the soil in plants without biological fertilizers was not as effective as plants given biological fertilizers, thus affecting plant growth.

The results of the analysis of variance showed that the treatment of chemical fertilizers and biological fertilizers had a significant effect on the length of the fruit stalk, fruit length and fruit circle (Table 2). The longest fruit and fruit stalks were obtained in treatment A0 (NPK fertilizer 750 kg/ha), namely 4.9 cm and 16.5 which differed significantly from other treatments, while the largest fruit circle was obtained in A2 treatment (NPK 750 kg/ha NPK fertilizer+biological fertilizer), namely 3.2 cm, and significantly different with treatment A0. These results indicate that the length of stalks and fruit is affected by the amount of NPK fertilizer in accordance with the recommendations, while biological fertilizers do not yet have a role in the development of stalk length and length of chilies.

Table 2
EFFECT OF NPK AND BIOLOGICAL FERTILIZER ON STALK LENGTH, FRUIT LENGTH AND RED CHILI FRUIT CIRCLES

Treatment	Time Observation					
	Fruit Stalk Length (cm)		Fruit Length (cm)		Fruit Circle (cm)	
A1	4.3	b	12.5	b	3.1	ab
A2	4.3	b	13.8	b	3.2	a
A3	3.8	c	14	b	3.1	ab
A0	4.9	a	16.5	a	2.8	b
KK (%)	6.05		6.75		7.13	

Note : Numbers followed by the same letter in the same column are not significantly different at UBD with real level of 5%.

The largest fruit circle was obtained in A2 treatment (750 kg/ha NPK+6 l biological fertilizer) which was not significantly different from treatment A1 and A3, but significantly different from A0, and the smallest fruit circumference was obtained in treatment A0. This indicates that the addition of biological fertilizers plays a more important role in the formation of fruit circumference than fruit length, or that the increase in fruit circumference is faster than the increase in fruit length.

The results of the analysis of variance showed that the treatment of chemical fertilizers and biological fertilizers had a significant effect on the weight of 100 chilies and the yield of chilies (Table 3). The largest weight of 100 chilies was obtained in the A3 treatment (591.7 grams) which was not significantly different from treatment A2 (587.9 grams) and A0 (567.7 grams) and significantly different from A1 (488.3 grams), while the highest yield of chili was obtained in treatment A2 (11.35 tonnes/ha) which was not significantly different from A3 (11.15 tonnes/ha) and significantly different from A1 (9.79 tonnes/ha) and A0 (8.63 tonnes/ha).

The treatment without biofertilizer gave a weight of 100 fruit which was higher than the treatment by giving biological fertilizer and NPK fertilizer 500 kg/ha, but gave the lowest yield compared to other treatments. The fruit yield obtained from each plant, so that even though the weight of 100 fruits of treatment A0 was higher than the weight of 100 fruits of treatment A1, the plants treated with A0 had the lowest number of fruits per tree so that the yield per hectare obtained was also the lowest. Thus the treatment of NPK fertilizer added with biological fertilizers plays a role in increasing the yield of chilies. (Wahyuningratri et al., 2017; Koshale et al., 2018) suggest that the content of microorganisms in biological fertilizers works optimally to remodel and facilitate nutrient intake from the provision of NPK fertilizer to form fruit so that the addition of nutrients according to recommendations and the addition of biological fertilizers gives the highest fruit yield (A2), but the addition of NPK fertilizer (A3) causes the chili yield to decrease.

The decrease in chili yields with the addition of NPK fertilizer is thought to be due to the number of microorganisms in the biological fertilizers given that are not suitable for remodeling the nutrients in NPK fertilizers to become available for plants (Sinulingga, Ginting & Sabrina, 2015) so that the addition of nutrients that exceed the recommended dosage is not utilized for plants (Khaitov et al., 2019).

Table 3
EFFECT OF NPK AND BIOLOGICAL FERTILIZER ON WEIGHT OF 100 FRUITS, NUMBER OF FRUITS AND YIELD OF RED CHILI FRUITS

Treatment	Time Observation					
	Weight of 100 Fruits (gram)		Number of Fruits per Stem Fruits (tonnes/ha)		Fruits Yield (ton/ha)	
A1	488.3	b	116,8	a	9.79	b
A2	587.9	a	113,0	ab	11.35	a
A3	591.7	a	110,3	b	11.15	a
A0	567.7	ab	89,7	c	8.63	c
KK (%)	10.18		2.91		3.55	

Note: The numbers followed by the same letter in the same column differ from the real 5% in UBD.

In contrast to Prasetya's research (2014), the addition of the NPK fertilizer dosage results in increased yield/production. It is suspected that the NPK fertilizer dosage of up to 450 kg/ha is still below the recommendation so that it can still increase the yield of chilies.

The chili yields obtained in this study ranged from 8.63 - 11.35 tonnes/ha. The highest yield was obtained in treatment A2 (750 kg/ha NPK+6 l/ha biological fertilizer) and the lowest yield was obtained in treatment A0 (750 kg/ha NPK) so that there was a difference in yield of 2.72 tonnes/ha or an increase of 31.52%, while treatment A1 There was an increase in the production of red chilies by 1.16 tons/ha or an increase of 13.44%, while in the A3 treatment there was an increase in the production of 2.52 tons/ha or an increase of 29.20% from the control treatment (A0). Based on the results obtained, it shows that the optimal yield of chilies is obtained when using NPK fertilizer according to the recommendations (750 kg/ha) and the addition of biological fertilizer 6 l/ha, while the use of NPK fertilizers below or above the recommended dosage and the addition of biological fertilizer 6 l/ha is able increase the production of red chili, but the increase is not optimal.

The increase in yield of red chilies was closely related to other variables, although not significantly different (Table 4). It can be seen that the longer the fruit circle, the higher the fruit yield (r=0.90ns). Likewise with the weight of 100 fruit (r=0.43ns), plant height at last harvest (r=0.52ns), age 12 MST (r=0.29ns), and age 8 WAP (r=0.98*). Conversely, the longer the fruit and the fruit stalk, the lower the fruit yield, with the calculated r value -0.56 and -0.83, respectively.

Table 4
MATRIX OF CORRELATION OF GROWTH COMPONENTS AND YIELD COMPONENTS OF RED CHILI PLANTS IN PARIANGAN DISTRICT, TANAH DATAR REGENCY, 2017.

	TT	TT				Length of fruit stalk	We igth 100	
Variable			TT at harvest	Fruit length	Fruit circle		Fruits	Yield
	8 MST	12 MST						
TT 8 MST	1,00							
TT 12 MST	0,42	1,00						
TT at harvest	0,62	0,97	1,00					
Fruit length	-0,45	0,62	0,42	1,00				
Fruit circles	0,81	-0,14	0,12	-0,84	1,00			
Length of fruits	-0,85	-0,07	-0,24	0,66	-0,75	1		
stalk								
Berat 100 fruits	0,54	0,99	0,99	0,50	0,01	-0,17	1	
Yield	0,98	0,29	0,52	-0,56	0,90	-0,83	0,43	1

Note : TT=plant height and r-table=0.96

Farmers' Income from the Red Chili Business: Production Cost

The cost of producing red chili consists of costs for using production inputs and wages for labor. Statistical summary of red chili production costs is presented in Table 5. The lowest production input costs were obtained in treatment A1, namely the use of 500 kg of NPK fertilizer and 6 liters of biological fertilizer (IDR 36,338,800) and the highest was obtained in the A3 treatment using 1,250 kg of NPK fertilizer and 6 liters of fertilizer. biological (IDR 44,588,800). Likewise, the lowest labor wage was in treatment A0 (IDR 65,550,000) and the highest was in treatment A2 (IDR 71,250,000).

Table 5
INPUTS OF RED CHILI PRODUCTION IN VARIOUS TREATMENTS OF NPK AND BIOLOGICAL FERTILIZERS

No	Type of Input	Cost (IDR)			
		A1	A2	A3	A0

I.	Production inputs :				
1	Seeds	18,00,000	18,00,000	18,00,000	18,00,000
2	Chili seed nursery	20,00,000	20,00,000	20,00,000	20,00,000
2	NPK fertilizer	55,00,000	82,50,000	1,37,50,000	82,50,000
3	Biological fertilizer	4,80,000	4,80,000	4,80,000	-
4	Manure (kg)	1,00,00,000	1,00,00,000	1,00,00,000	1,00,00,000
5	Chemial pesticides	75,50,000	75,50,000	75,50,000	75,50,000
6	Biological pesticides	12,50,000	12,50,000	12,50,000	12,50,000
7	Herbicides	11,08,800	11,08,800	11,08,800	11,08,800
8	Stake	66,50,000	66,50,000	66,50,000	66,50,000
	Total cost I	3,63,38,800	3,90,88,800	4,45,88,800	3,86,08,800
9	Labor :				
	a. Nursery preparation	30,00,000	30,00,000	30,00,000	30,00,000
	b. Biofertilizer application	27,00,000	27,00,000	27,00,000	0
	c. Land processing	22,50,000	22,50,000	22,50,000	22,50,000
	d. Making beds	45,00,000	45,00,000	45,00,000	45,00,000
	e. Install mulch and punch	27,60,000	27,60,000	27,60,000	27,60,000
	f. Plant red chilies	24,00,000	24,00,000	24,00,000	24,00,000
	g. Stitching	7,20,000	7,20,000	7,20,000	7,20,000
	h. Sprinkling	18,00,000	18,00,000	18,00,000	18,00,000
	i Fertilization	66,00,000	66,00,000	66,00,000	66,00,000
	j. Spraying	96,00,000	96,00,000	96,00,000	96,00,000
	k. Stake installation	7,20,000	7,20,000	7,20,000	7,20,000
	l. Strap installation	32,40,000	32,40,000	32,40,000	32,40,000
	m. Weeding	51,60,000	51,60,000	51,60,000	51,60,000
	n. Cutting water	36,00,000	36,00,000	36,00,000	36,00,000
	branches				
	o. Harvest	1,68,00,000	2,22,00,000	2,19,00,000	1,92,00,000

	Total cost II	6,58,50,000	7,12,50,000	7,09,50,000	6,55,50,000
	Total cost (I+II)	10,21,88,800	11,03,38,800	11,55,38,800	10,41,58,800

Labor wages have the highest proportion of costs compared to the cost of purchasing production inputs, namely in the range of 61.41 - 64.57% of the total production costs. The same results were obtained in the study of (Ila et al., 2019) that the proportion of labor wages in the production of red chili in Boga district, Bangladesh reached 48.2% of the total cost and research (Tigari & Swathi, 2019) labor costs reached 35% of the total cost. red chilli production in Arasikere, India. The labor used comes from within the family and outside the family (wage labor). The proportion of labor wages is high because in one planting period it requires labor between 1,092-1,188 HOK at a wage rate of IDR 60,000/day, so the cost of paying labor wages is between IDR 65,550,000 - 71,250,000.

With this difference in costs, the total production cost for treatment A1 is IDR 102,188,800 (lowest cost), A2 is IDR 110,338,800, A3 treatment is IDR 115,538,800 (highest cost) and treatment A0 is IDR 104,158,800.

The Profit of Chili Yield and Financial Feasibility

Table 6 shows the yield of red chilies obtained in various treatments between 8,630 - 11,350 kg/ha. This result is lower than the results obtained in the study (Khan et al., 2017) in Punjab Pakistan of 18,953 - 21,209 kg/ha, but higher than the research (Saidah et al., 2019) which obtained 7,131 red chilies. 5 kg/ha. The highest yield was obtained in treatment A2 as much as 11,350 kg/ha with a selling price of IDR 17,500, so the income obtained by farmers was IDR 198,625,000/ha/planting season, the lowest yield was in treatment A0 of 8,630 kg/ha and revenue of IDR 151,025,000, resulting in a difference in revenue. IDR 47,600,000. The chili yields in treatment A1 and A3 were 9,790 tonnes/ha and 11,150 tonnes/ha, respectively, so that farmers received revenues of IDR 171,325,000 and 195,125,000.

Table 6
RESULTS AND BENEFITS OF RED CHILI IN VARIOUS TREATMENTS

No	Description	Cost (IDR)			
		A1	A2	A3	A0
1	Yields (kg/ha)	9,790	11,350	11,150	8,630
2	Price (IDR/kg)	17,500	17,500	17,500	17,500
3	Revenue (IDR/ha)	17,13,25,000	19,86,25,000	19,51,25,000	15,10,25,000
4	Cost (IDR/ha)	10,21,88,800	11,03,38,800	11,55,38,800	10,41,58,800
5	Profits (IDR/ha)	6,91,36,200	8,82,86,200	7,95,86,200	4,68,66,200
6	BCR	0.68	0.8	0.69	0.45

From several treatments, it shows that the benefits obtained by farmers varied between IDR 46,866,200 - 88,286,200. These results indicate that in any treatment the chili yields obtained by farmers is a profitable economic activity. Identified from the value of the positive financial feasibility of BCR, the smallest value is 0.45 and the largest is 0.80. The BCR value obtained is relatively small when compared to the financial feasibility of red chili in Punjab, Pakistan has a BCR value of 1.70 - 2.02 (Khan et al., 2017), the financial feasibility BCR value of red chili in Konawe Regency, Southeast Sulawesi is 1.92 (Geo et al., 2020). Drip irrigation technology implemented by farmers in chili farming is more profitable than chili farming that does not use drip irrigation, indicated by BCR values of 1.00 and 0.61 respectively (Adriani et al., 2019). Based on several research results, red chili peppers imply that increased yields can be obtained by using production inputs as efficiently as possible by applying appropriate technological innovations based on recommendations.

CONCLUSION

The application of NPK fertilizer and biological fertilizer has a significant effect on the growth and yield of red chilies. Increased yield of red chilies was obtained by adding biological fertilizers to NPK fertilization. Application of NPK fertilizer according to the recommendation (750 kg/ha) and application of biological fertilizer 6 l/ha gave the best results on plant height, fruit circumference and fruit yield. The yield obtained was 11.35 tonnes/ha 31.5% higher than without application of biological fertilizers. The increase in chili yield decreased with the increase in the NPK dose (from 750 kg/ha to 1,250 kg/ha), which was an increase of 29.2% from the yield obtained at the recommended NPK dose and without biological fertilizers.

The highest income obtained by farmers was IDR 88,286,200/ha, namely the A2 treatment (NPK fertilizer 750 kg/ha+biological fertilizer 6 l/ha), and the smallest income was in treatment A0 (NPK fertilizer 750 kg/ha without biological fertilizer), namely IDR 46,866,200/ha. Thus the optimal yield and benefits of red chilies are obtained by using efficient input by applying technological innovations according to recommendations plus the provision of biological fertilizers (NPK 750 kg/ha+biological fertilizer 6 l/ha).

ACKNOWLEDGEMENT

This article is part of a research activity funded by the Assessment Institute for Agricultural Technology (AIAT) West Sumatra. Therefore, authors are highly thankful to AIAT West Sumatra.

CONFLICT OF INTEREST

We declare that there is no conflict of interest dealing with authors and Indonesian Agency for Agriculture Research and Development that facilitated and funded the research activity.

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