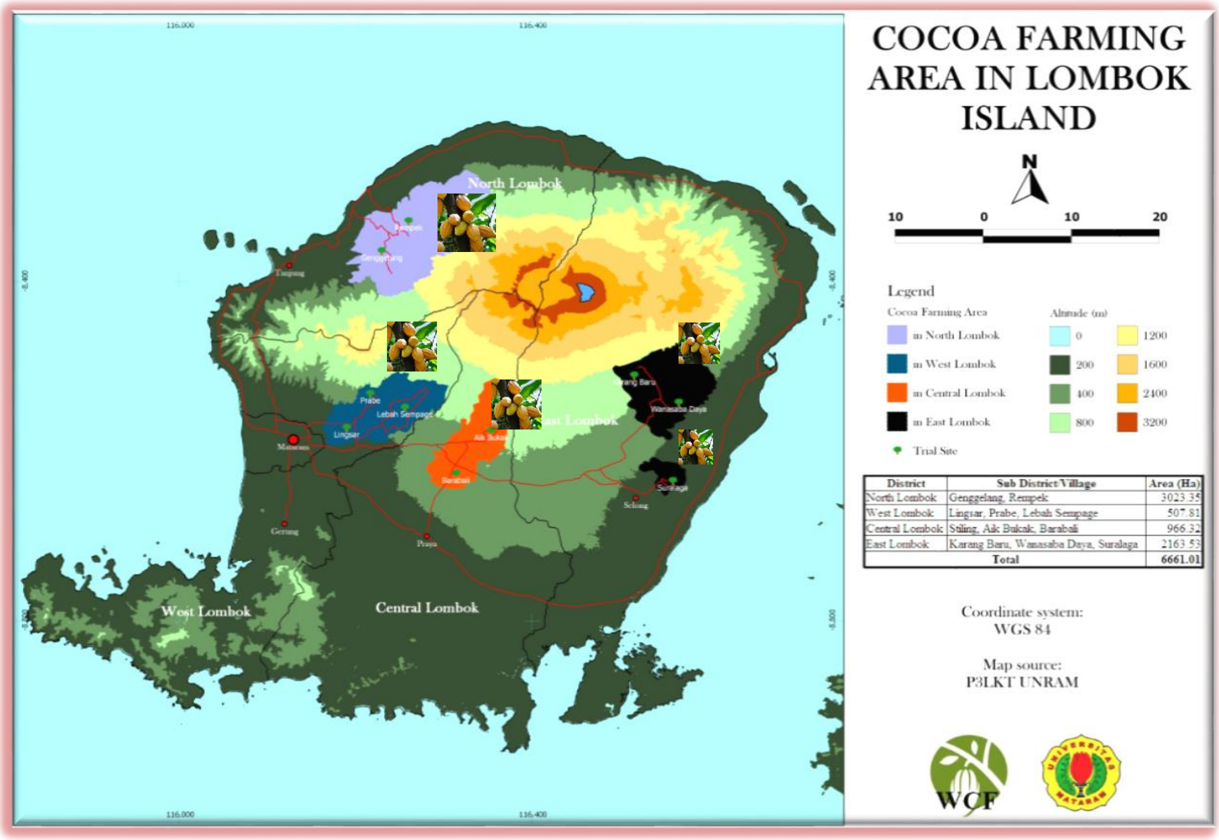
World Cocoa Foundation

RESEARCH REPORT

for

INDONESIA APPLIED RESEARCH AND EXTENTION GRANTS PROGRAM WORLD COCOA FOUNDATION

DEVELOPING AN INTEGRATED PEST AND DIASES CONTROL FOR COCOA IN LOMBOK ISLAND BY UTILIZING LOCALY AVAILABLE MATERIALS



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MATARAM, AUGUST 2016

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Executive Summary

Pest and disease attacks (PDAs) was a common problem of cocoa farming in Lombok Island of cocoa farming in Lombok Island causing its low productivity and profitability. To deal with the case, a new technology termed as healthy farming was proposed in this research. The new technology emphasizes on utilization of local materials, mainly a liquid-silicate rock fertilizer (Si^{Plus}) to improve the healthiness and resistance of plant to PDAs. The specific objectives of this research were to evaluate the true effectiveness of the new technology to overcome PDAs and increase productivity and profitability of cocoa farming, and to disseminate the new technology to local cocoa farmers and relating stakeholders.

In general, the research was run well and greatly achieved its targets. The main results of the research are summarized as follows:

1. Outputs and Outcomes:
    a. Information about cocoa farming business in Lombok Island was updated (2015). The total cocoa farming area was 6,661 hectares, distributed mainly in North Lombok and East Lombok regencies. The number of cocoa farmers in the areas was 7,936 households, each had 0.98 hectares of cocoa farming land in average. The common PDAs were cocoa pod borer (CPB) *helopeltis*, attacking 70 – 75 % of cocoa pods; and black pod caused by fungus attacking 10 - 15 % of cocoa pods in the areas. Those PDAs has contributed to the low productivity of cocoa farming in the area (< 500 kg dry beans/ha/year); and cocoa farming contributed < 5 % of farmers' income.
    b. Controlling PDAs by implementing healthy farming concept, which was technically by applying Si^{Plus}, with or without botanical pesticide (*neem*) or pest predator (black ant), was proven as an effective and efficient method. The method did not only reduce PDAs, but also remarkably increased quantity as well as quality of cocoa production. Importantly, this technology was highly applicable for smallholder cocoa farmers, environmentally sound, and sustainable.
    c. Sending farmers to the cocoa research centers (e.g., ICCRI-Jember, East Java) for training was much more effective than the conventional training methods (e.g., workshop and field school), significantly improving farmers' knowledge and skill in cocoa farming, and directly stimulated their spirit to be productive cocoa farmers.
    d. The gender main stream, mainly relating to the involvement of male and female in cocoa farming activities, had no change or was not affected by the implementation of this research that has not significant impacts yet on the increase of farmers' income. At present, much more male (husband) than female (wife) worked for pruning, fertilizer application, and sanitation. Inversely, more female than male worked for harvesting, pod breaking, and pricing/selling cocoa beans.
2. Key impacts:
    a. The implementation of this research has directly increased the attention and participation of many parties, including farmers, researchers, and local governments, in developing cocoa farming in Lombok Island.

b. The great result of field trial has improved the trust and confidence of cocoa farmers to apply the healthy farming technology in their farm. Further, it will positively impact to the improvement of cocoa farming productivity and profitability in Lombok Island.
c. The training for farmer leaders in ICCRI Jember has directly motivated cocoa farmers to apply the standard of GAP, especially are pruning and sanitation. Moreover, they have practiced side and top grafting and seedling to substitute the non-productive plants. Positively, those activities are followed by many other farmers.
d. The possible impacts of this project to the change of gender main stream is predicted to occur when the cocoa farming has contributed significantly to the improvement of farmers' income.

It was concluded that the healthy-cocoa farming concept with its simple technique, emphasizing on utilizing local farming materials, especially a foliar fertilizer of Si^{Plus}, is an appropriate technology to improve productivity and profitability of cocoa farming. This technology, therefore, is ready to be applied or/and further tested in larger scales (nationally or internationally). Disseminating the method to other farmers in other areas is required.

LIST OF CONTENT

INTRODUCTION

Backgound

Lombok Island is an important cocoa farming area in Indonesia. In 2010, the area of cocoa farming in this island was about 5,500 hectares, distributed mainly in North Lombok (3,000 hectares) and East Lombok (1,300 hectares); and the remaining areas was in Central Lombok and West Lombok (P3LKT Unram, 2010). However, the productivity and profitability of cocoa in the area was very low due to several constraints associating to technical as well as socio-economic aspects. In term of technical aspect, a common and serious farming problem is pest and disease attracts (PDAs). Unfortunately, not much could be done by local farmers to control PDAs. An appropriate method for handling PDAs should, therefore, be found out. Importantly, the method must be applicable for smallholder cocoa farmers, environmentally sound, and sustainable.

Responding to the requirements for developing cocoa farming in Lombok Island, we introduced a new method for handling the PDAs on cocoa by utilizing the locally available natural materials. This method was based on the concept of healthy farming, in which PDAs is not handled by suppressing population of pests and pathogens (e.g., by using toxic-synthetic pesticides), but by improving the healthiness and resistance of the plant to biotic and abiotic stresses, thus minimizing the negative effects of PDAs on yield (cocoa beans). Technically, this new method is implemented by applying foliar fertilization with of a silicate basis fertilizer containing all plant-essential nutrients (e.g., Si^{Plus}).

The concept of healthy farming was inspired by the facts that the plant receiving optimum supply of essential nutrients will grow optimally and has high natural defense system (Dordas, 2008). Moreover, the supply of Si may thicken and strengthen the cell walls, maximizing the resistance of plant to PDAs (Ahmad and Haddas, 2008; Biel, et al., 2008; Priyono and Muthahanas, 2012). Based on those facts, therefore, to avoid significant damage on plant products due to PDAs, the plant must be supplied with sufficient quantity of fertilizers containing complete and proportional nutrients including silicate (e.g., Si^{Plus} fertilizer), and it will result not only reduce PDAs cocoa, but importantly the fertilization also provides high quantity and quality of cocoa production.

The foliar fertilizer of Si^{Plus} is made mainly from silicate rock, a nearly endless local material; and it is processed by applying a low cost technology without using any strongly reacting chemicals. The fertilizer contains relatively high concentration of soluble silicate (0.5 – 1 % Si) and all plant-essential nutrients in a matrix solution of dilute organic. The results of field trials compiled by Priyono (2014) show that the application of Si^{Plus} on various food crops and horticultures significantly increased the quantity as well as quality (nutritional values) of yields and reduced PDAs. However, whether or not those positive results are also applicable for cocoa, remains in puzzle. Consequently, field trials need to be carried out to provide an appropriate evident or answer for the puzzled question.

Objectives and Targets

The general objective of this research project was to improve productivity and profitability of cocoa farming in Lombok Island. Specifically, it was aimed to evaluate the true effectiveness of a new method for handling PDAs on cocoa by using the locally available materials, which were liquid-silicate rock fertilizer (Si^{Plus}), botanical pesticides (e.g., extract of neem leaf) and pest predators (e.g., black ant). Further, the positive results of this research should be adopted by local farmers.

The main targets of output and outcome from this applied research activities are summarized in Table 1. The targets were related to the initial activities in the proposal of this research project. However, minor modification and additional activities were made with approval of WCF in order to make more effective in reaching optimum achievements in this research.

METHODOLOGY AND MATERIALS

This research project was set and carried out appropriately to meet the proposed objectives and targets described in Table 1; and the activities were divided into three steps (years) described as follows:

<u>Activities in the first step (2014):</u>

1. Conducting a baseline study (field survey), which was aimed (1) to identify and map the distribution of cocoa farming land, characteristics of pests and diseases attacking cocoa plants in Lombok Island, and the agro-ecological variables that closely related to the distribution of pests and diseases of cocoa and (2) to identify local remedial plants and pest predators which were possibly suitable for use to control PDAs on cocoa. The survey also recorded the initial condition of gender main stream, especially of that relating to the involvement of male and female in each component of cocoa farming practices, and socio-economic characteristics of cocoa farmers in the areas. Based on results of this survey, the cocoa farming areas in Lombok Island were grouped into 3 clusters accordingly to the unique characteristics of agro-ecological condition and existing pests and diseases in each cluster.

2. Conducting field trials in the 3 cluster areas, which were in Rempek and Genggelang (North Lombok), and Wanasaba (East Lombok). In each cluster, the cocoa trees were classified into three groups on the basis of the growing stage, i.e. A = early growing stage (< 2-year old, not productive yet), B = mature/productive stage, and C = the too old stage (much less productive, requiring rejuvenation). A completely randomized design was applied in each trial with 10 replications. The treatment was the frequency of spaying plant with Si^{Plus}, consisting of 4 levels: 0 (control), 1, 2, and 3 times/month, and the interval of applying Si^{Plus} was 10 days. Thus, there were 4 x 10 = 40 samples of cocoa trees in each trial unit (growing stage), 120 trees/cluster, or 420 trees in 3 clusters (all trial units). Before the treatments were applied, all cocoa fruits on the sample trees being attacked by pest or/and dieses were taken off, thus the samples were initially free from PDAs. The fertilizer (Si^{Plus}) was first diluted 60 times with fresh water in a 15L-spraying tank (250mL/15L), then the diluted fertilizer was applied directly onto cocoa leafs, steams, and fruit accordingly to the treatment.

Table 1. The main targets of research project

No	Activities ((Inputs)	Objective	Outputs	Outcomes
1.	<u>The 1^{st} Step (2014):</u> Baseline study Field trial I	• To update current condition of cocoa farming in Lombok Island • To identify the effectiveness of Si^{Plus} to control pest and dieses and its optimum application rate	• Up to date data for the main characteristics of cocoa farming in Lombok Island • Field trials in each cluster of cocoa farming area, evaluating the effectiveness of the applications of Si^{Plus}	1. Appropriate information for the current figures of cocoa farming in Lombok Island. 2. Proves for the high effectiveness of Si^{Plus} or/and neem leaf and black ant to control PDAs and improve quantity and quality of cocoa production. 3. Improvement of farmers' knowledge and skill in cocoa farming by applying healthy farming concept and technique 4. A manual for the best practice of pest and disease control using Si^{Plus}. 5. Well shared beneficial information to farmers and stakeholders 6. At least there are 5 skillful farmer leaders 7. Scientific publications
2.	<u>The 2^{nd} Step (2015):</u> Field trial II Cross visit among cocoa farmers	• To identify and demonstrate the effectiveness of local materials (Si^{Plus}, neem leaf, and black ant) for controlling PDAs • Sharing knowledge and skill of cocoa farming practices among farmers in Lombok	• Field trials in 3 clusters, demonstrating the effectiveness of local materials for use to control PDAs • Field meetings participated by farmers researchers, and officers discussing abut cocoa farming in Lombok	
3.	<u>The 3^{rd} step (2016):</u> Dissemination Evaluation	• To improve the knowledge and skill of farmers in Lombok Island in managing their cocoa farming. • To improve the attention involvement of farmers and related-local agricultural institution to the development program of cocoa. • To evaluate the running project	• Workshops in all clusters of cocoa farming areas. • Field school of applying 'healthy farming' concept on cocoa farming. • Training for farmer leaders • Field survey and focus group discussion	

The main parameters observed in the trials were (1) the type and incident-intensity attacks of pest, disease, and combination of those on cocoa pods and (2) the quantity and quality of production (total weight of dry beans and weight of 100 dry beans, respectively). Type and intensity attack of pest and disease were observed every 40 days (10 days after the 3^{rd} spray). The intensity of PDAs was calculated as the percentage of attacked pods relative to total pods on each tree. The ripe cocoa pods were harvested weekly, directly were opened, and the beans were oven dried at about 40^{o} C for 10 – 14 days to reach a constant weight.

Data of the trial were analyzed accordingly to the characteristics of data or type of observed parameters. The main questions that should be answered in this trial associate to the following aspects:

a. The relative effectiveness of Si^{Plus} in reducing the intensity attacks of pests or/and diseases on cocoa.
b. Kinds of pests or pathogens that were mostly affected by the treatments.
c. The effects of the treatments on quantity and quality of cocoa beans.
d. The optimum frequency of Si^{Plus} application.

Activities in the second step (2015)

The main activities were conducting an action research (demonstration plots) for the application of Si^{Plus} and facilitating cross visits among cocoa farmers in Lombok Island. For comparison purposes to Si^{Plus}, the other materials used in the trial were the extract of neem leaf (NL) as botanical pesticide and black ant (BA) of *Doliccoderus thoracicus* as a pest predator.

1. The action research or field trials were carried out as follows:
   a. Prior to run the trials or demonstration plots, several meetings between the research team with cocoa farmers were conducted to identify appropriate sites and volunteering farmers who willing to involve in the trial activities. Those farmers should be the land owners, cooperative, and able to implement the standard of GAP (good agriculture practices) in the trial areas as necessary, especially of that for sanitation. In addition, the condition of cocoa trees in each trial area should be in productive stage and relatively uniform to meet the common standard of experimental method. In fact, however, there were only a trial site that could fulfill those requirements, which was in Genggelang I (see Table 2). Consequently, the other selected sites were only suitable for applying 2 – 4 treatments, or/and the trees were not in productive stage (young plants).
   b. A completely randomized design was applied in each trial site with the treatments shown in Table 2. Each of those treatments was applied on 10 selected trees. The liquid fertilizer of Si^{Plus} or combination of Si^{Plus} and botanical pesticide (Si^{Plus} + NL) was applied fortnightly, whereas black ants were those staying on the samples of cocoa trees; or those were taken from other places, nested on a plastic bag containing dry banana leaf, and was put on a cocoa branch.

      Before the treatments were applied, all cocoa pods on the samples trees that were attacked by pest or/and diseases were taken off. The trials were monitored regularly (monthly) up to 12 months, to identify type and intensity attacks of pests and diseases. The ripe pods were harvested weekly, directly unshelled, weighted, and then oven-dried at 40^{o} C for 10 – 14 days. Samples of dry beans were taken for measurement of polyphenol content. Some samples of dry pod shell were also collected for measurement of polyphenol and lignin contents.

      Due to the most ideal trial site which met to all standard requirements of the experimental method was only Genggelang 1, statistical interpretation was fully applied only for data of trial in this site, whereas for data of other trial sites were interpreted using simple comparison methods.

2. Conducting a cross-visit program, which was aimed to facilitate cocoa farmers in Lombok to communicate each other and share their experiences in managing cocoa farming. The proposed impact from this activity was the improvement of their attention and care to cocoa farming, and willing to learn and implement the standard of GAP on their cocoa farming.

Table 2. The selected trial sites and applied treatments

No	Trial Sites	Applied Treatments
A.	Cluster I:	
	1. Genggelang 1	Control, Si^{Plus}, Si^{Plus}+ NL, Si^{Plus} & BA, and BA
	2. Genggelang 2	Si^{Plus} and Si^{Plus} + NL
	3. Genggelang 3	Si^{Plus} & BA, and BA
B.	Cluster II:	
	1. Rempek 1	Si^{Plus} and Si^{Plus} + NL
	2. Rempek 2	Ant, Si^{Plus}& Ant
C.	Cluster III:	
	1. Bebidas	Si^{Plus}, Si^{Plus} + NL, Si^{Plus} + BA, and BA
	2. Lendang Nangka	Si^{Plus}+ BA, and BA
	3. Wanasaba	Si^{Plus}, Si^{Plus} + NL
	4. Kotaraja	Si^{Plus}, Si^{Plus} + NL

Notes:

- NL = neem leaf (botanical pesticide), BA = black ant (pest predator)
- When the trial was started, only in Genggelang 1 area that all cocoa trees were really in productive (mature) stage.

The activity was carried out in the end of October 2015 in Bebidas – East Lombok. In that event, 10 cocoa farmers from North Lombok were facilitated to meet their friend in East Lombok at the trial site of Bebidas. In addition to research team, the meeting was attended by the officers of East Lombok District Plantation (*Dinas Perkebunan*), field extensions, local formal and informal leaders, and a WCF officer (Ms Virginia).

Activities in the third step (2016):

The main activities in the third step were dissemination of appropriate cocoa farming, especially about the method to handle PDAs by using Si^{Plus} or healthy-cocoa farming, and evaluation. The dissemination was carried out through workshops followed by field school. In addition, a special training was conducted for farmer leaders in ICCRI (Indonesian Coffee and Cocoa Research Institution) in Jember – East Java. This training was an additional activity offered by WCF with additional budget for 2 farmers, and of that for 3 other farmers was from the reallocated initial research budget. Project evaluation was carried out in the end of project implementation period (July – August, 2016).

The activities in the third step are described as follows:

1. Cocoa farming workshop.
   The workshops were conducted in the village of Genggelang (North Lombok) on January 9 and March 20, 2016, and in the villages of Beriri Jarak and Wanasaba (East Lombok) respectively on January 16 and 23, 2016. The participants were local cocoa farmers, village leaders, agriculture extension service officers, plantation service officers, and regional planning officers. The main target was that most cocoa farmers in Lombok Island understand about 'healthy farming concept and technique' and they adopted those into cocoa farming practices.

   The topics delivered in the workshops were related to efforts for developing cocoa farming in Lombok Island, which mainly a new technique for handling PDAs by utilizing the local natural materials. The new technique was based on the concept of 'healthy farming' in which PDAs on cocoa was handled not by killing organisms (pests and pathogens) by using toxic-synthetic pesticide, but by maximizing the healthiness and defense system of plant. Technically, the plant was supplied directly (through foliar application) with the fertilizers containing all plant-essential nutrients and silicate, e.g., Si^{Plus}. For preventive purposes, botanical pesticides (e.g., made from neem leaf) may be added to Si^{Plus}, or combined with the application of pest predators (e.g., black ant).

   After participating in the workshops, all participants got 1 – 2 bottles/person of liquid-silicate fertilizer (Si^{Plus}) for free, which fertilizer should be applied on their cocoa trees. Regular visits by research team to those farmers were carried out to know whether the knowledge and skill (healthy farming) given in the workshops were applied by farmers/participants or not.

2. Training for farmer leaders
   A special training for cocoa farmer leaders was conducted by sending 5 farmers to ICCRI (Indonesian Coffee and Cocoa Research Institution) in Jember – East Java, in June 29th to July 2nd, 2016. The farmers represented each cluster of cocoa farmers in Lombok, which were 2 persons from Genggelang (claster I), a person from Rempek (Cluster II), and 2 persons from Wanasaba and Beriri Jarak (claster III). The main objective of the training was to improve farmers' knowledge and skill in cocoa farming techniques which those were then shared to the other cocoa farmers in Lombok Island.

   The training materials were theories and practices about cocoa as well as coffee, the farming aspects including (1) methods to identify superior entries and clones, (2) techniques of top and side grafting (vegetative seedling), (3) identification of the most suitable agro-ecological condition for growing cocoa and coffee, (4) the standard of GAP (good agriculture practices: frequent harvesting, pruning, sanitation, and fertilization) and its implementation), and (5) identification and the methods of proper handling of pests and diseases attaching coffee and cocoa (which were different than the healthy farming technique mentioned in the previous sections).

3. Project evaluation

   Project evaluation was carried out through field observation, directly questioning stakeholders (especially cocoa farmers), and conducting dep interview and focus group discussion with cocoa farmers in all cluster areas. The issues concerned in the evaluation included technical, socio-economic, and gender (the involvement of male and female) aspects.

RESULTS AND DISCUSSION

Key Outputs

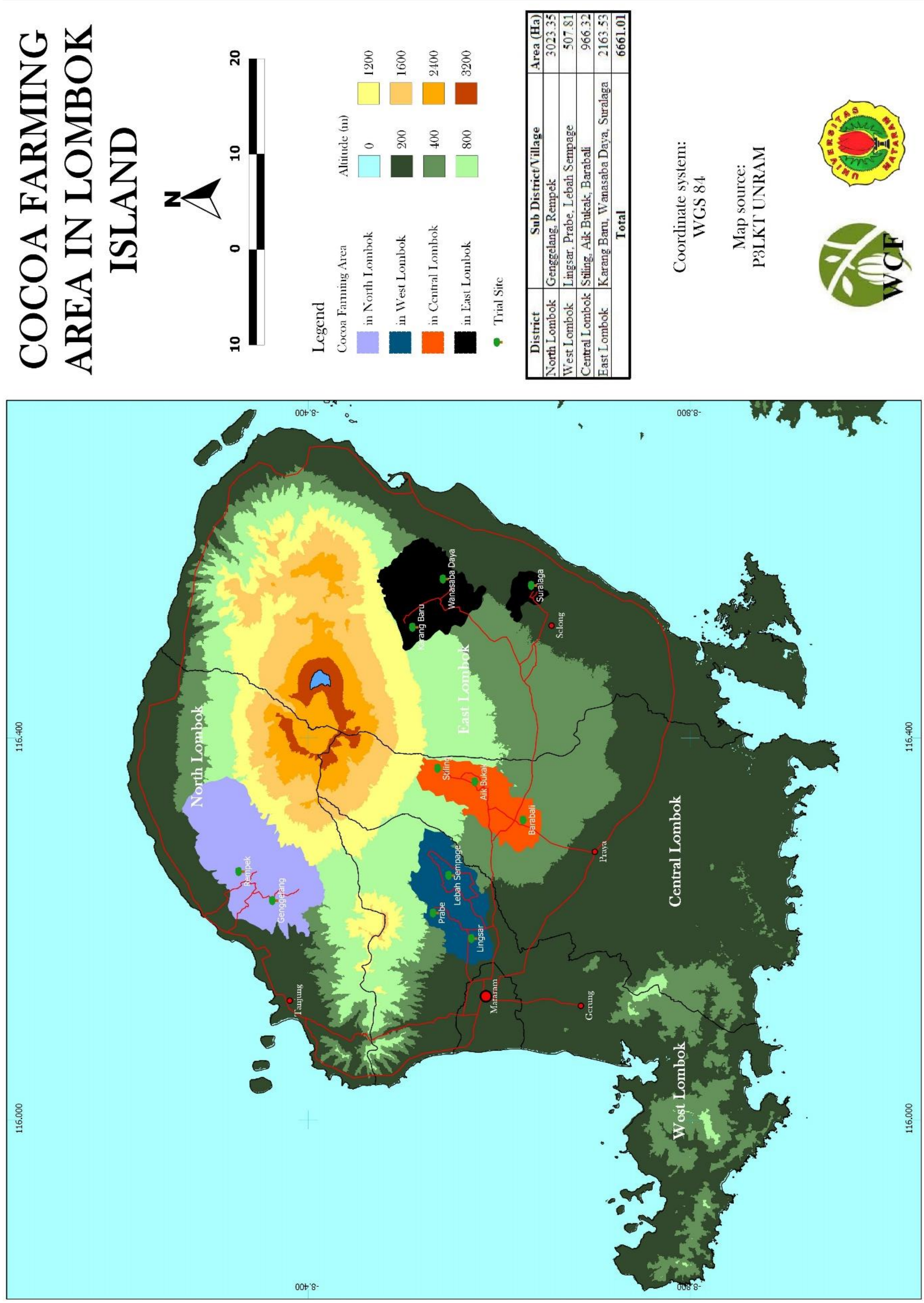
1. The characteristics of cocoa farming in Lombok Island:
   a. The total areas of cocoa farming land in Lombok Island was about 6,900 hectares, distributed mainly in North Lombok and East Lombok regencies, whereas the remaining areas were in Central Lombok and West Lombok (see Table 3).

   Table 3. Distribution of cocoa farming areas in Lombok Island in 2015

Regency	Age of Trees (Years)			Total
Areas	< 5	5 - 10	> 15	(ha)
Central Lombok	324	466	174	963
East Lombok	784	1,127	156	2,066
North Lombok	1,957	656	410	3,023
West Lombok	8	297	508	813
Total				6,866

   b. The cocoa farming areas in North Lombok were distributed mainly from Genggelang to Rempek villages, and those in East Lombok were spotted at various sites in Wanasaba and Lendang Nangka districts; whereas the areas in Central and West Lombok were distributed in many spots in the southern part of those regency's territories (Figure 1).
   c. Pest and disease population in all areas were quite similar. The common pests were cocoa pod borer (CPB) *Conopomorpha cramerella* and *helopeltis*, attacking 70 – 75 % of cocoa pods; while the diseases were black pod caused by fungus of *Phytophthora palmivora* and *Colletotrichum gloeosporioides*, attacking 10 - 15 % of cocoa pods in the areas.
   d. Most cocoa farmers in Lombok Island never practiced the complete standard techniques of cocoa farming, including pest and disease control, fertilizer application, sanitation, and pruning in their farm. That may be the main cause for the occurrences of intensive pest and disease attacks, contributing significantly to the very low productivity of cocoa farming in the areas (< 500 kg dry beans/ha/year).

2. Characteristics of cocoa farmers in Lombok Island:
   a. Total cocoa farmers in Lombok Island (2015) was 7,936 families. In average, each farmer (family) had 0.98 hectare of cocoa farming land. Based on 56 respondents of cocoa farmers in North Lombok and East Lombok, 41 % were purely cocoa farmers, 23 % were cocoa and food crop farmers, and 36 % were cocoa farmers who also have non-farming jobs. It was reasonable that the variety of jobs or income sources determine their time and attention being allocated for cocoa farming business.



District	Sub District/Village	Area (Ha)
North Lombok	Genggelang, Rempek	3023.35
West Lombok	Lingsar, Prabe, Lebah Sempage	507.81
Central Lombok	Stiling, Aik Bukak, Barabali	966.32
East Lombok	Karang Baru, Wanasaba Daya, Suralaga	2163.53
	Total	6661.01

Figure 1. The map of cocoa farming area distribution in Lombok Island.

a. The average yield of cocoa was only 0.223 t/ha/year, and its value was only about US$ 500/year. In contrast, the yield values from food crop farming in average was about US$ 11,000/year. Thus, cocoa farming contributed < 5 % to total of farmers' income. It may be the main reason why most cocoa farmers in Lombok Island allocate less working time for cocoa farming business.

2. Gender main stream in cocoa farming businesses
   a. The gender main stream, especially of that relating to the proportion of female (wife) and male (husband) involving in cocoa farming business, before and after the project was not much changed. In fact, the distribution of working duty for wife and husband in Lombok (*Sasak* tribe) family was affected more by local socio-cultural system than by economic aspect. Due to this research has no effect yet on farmers' income, the possible positive impact of this research project to the gender main stream was unlikely to affect the initial gender inclusion in farming activities.
   b. In cocoa farming activities, more male (husband) than female (wife) working for pruning, fertilizer application, and sanitation. Inversely, more female than male worked for harvesting, pod breaking, and pricing (see Figure 2).

Figure 2. The proportion of male and female involving in cocoa farming activities in Lombok Island. The percentage values were the number of male or female involving in each farming activity relative to the total number of cocoa farmer (respondents).

3. Results of field trials:
   a. The foliar application of Si^{Plus} alone, or in combination with botanical pesticide (extract of neem) or with pest predator (black ant) significantly reduced PDAs for 15 – 20 % relative to the control (Figure 3), increased the quantity as well as quality (weight of 100 beans and its polyphenol content) of cocoa production (Figures 4 and Table 3). The increase in quantity of production due to Si^{Plus} application was remarkable (about double relative to control). Moreover, most of the attacked pods (> 90 %) of the treated cocoa trees with Si^{Plus} still contained good quality of beans (see Figure 5). Meaning that the PDAs did not severely damage the bean, the attacks (CPB and *hellopeltis*) only injured pod shell, or it was not deep enough to damage the beans. The possible explanation was that the supply of Si element thicken the cell wall of pod and stimulate lignification in it (Table 3), which both mechanisms strengthen the cocoa pod shell, avoiding the damage of beans inside pods due to PDAs.

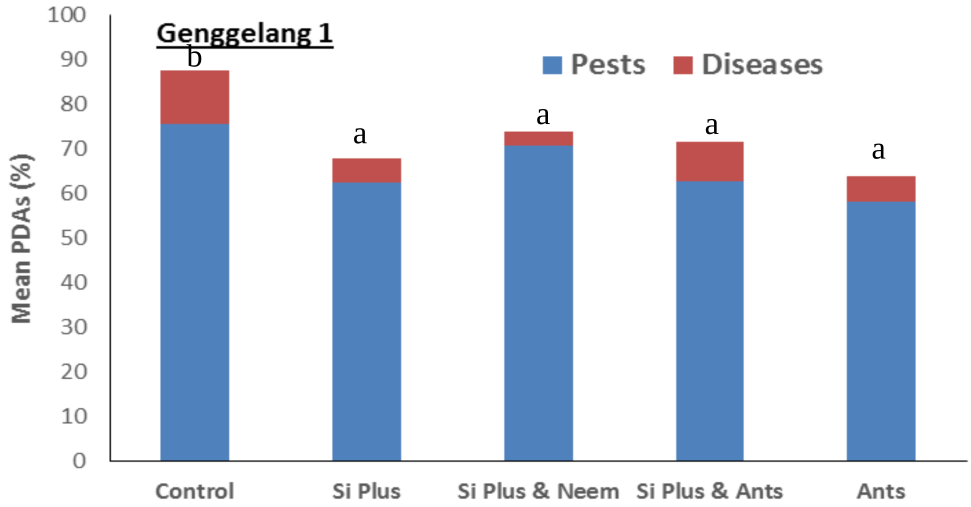


Figure 3. Mean incident-intensity of PDAs in the trial site of Genggelang 1 – North Lombok in relation to the treatments. The values (bars) followed with different letters letter are significantly different based on LSD$_{\alpha\ =\ 0.05}$

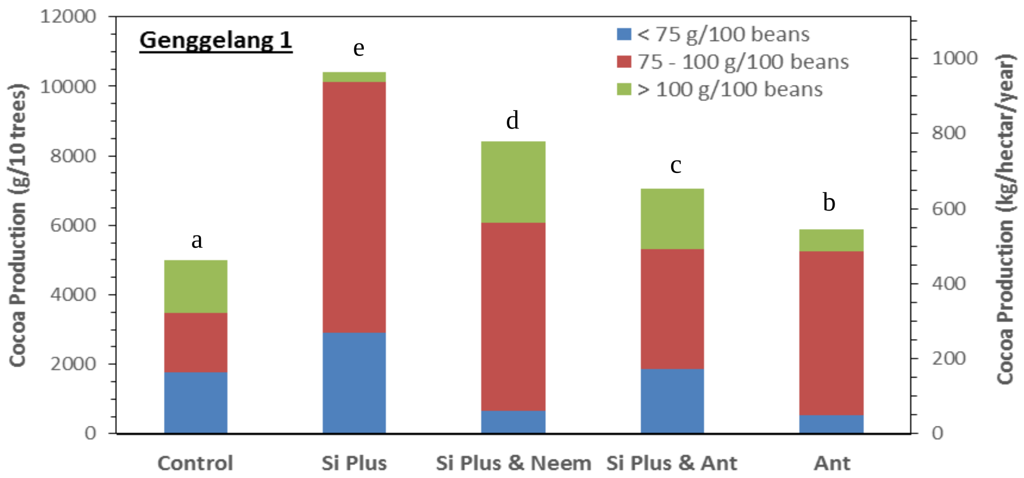


Figure 4. Total production (dry cocoa beans) in the trial site of Genggelang 1 - North Lombok in relation to the treatments. The values (bars) followed with different letters are significantly different based on LSD$_{\alpha\ =\ 0.05}$

Table 3. Polyphenol and lignin contents

Treatments	Polyphenol (%)		Lignin (%)
	Bean	Shell	Shell
Control	9.63	5.70	20.25
Si^{Plus}	9.68	7.12	28.03
Si^{Plus} + Neem	9.51	9.33	29.28
Si^{Plus} + Black ant	10.30	7.61	20.54
Black ant	9.13	10.18	23.04

Figure 5. Examples of cocoa pod attacked by pod bored and helopeltis, the beans were still in good quality, did not damaged by those pest attacks.

b. The foliar application of Si^{Plus} on young cocoa threes stimulated flowering, speeding up the cocoa plant to reach its generative growing stage.

4. Transferring knowledge and technology to farmers and stakeholders (dissemination). As described in the methodology section, dissemination was carried out through workshops, field school, and training. The main results of these activities were:
   a. The concept and technique of healthy-cocoa farming by utilizing local materials of Si^{Plus}, botanical pesticides, and pest predators had been delivered and understood by participants consisting of 30 – 40 farmers in each cluster area, 2 – 6 local leaders, field extension service officers, and district agriculture service (*Dinas pertanian*) and development planning officers.
   b. Basically, all participants accepted the concept and techniques being offered in the workshops. However, they required more proves in field condition for the true effectiveness of the technology. Accommodating the requests, we provided 1 – 2 bottles (liters) of Si^{Plus} for free to all participants that should be applied cocoa in their farm.
   c. Established good communication between P3LKT Unram with cocoa farmers in Lombok and agricultural officers especially in East Lombok and North Lombok, which network will produce good collaborations in developing cocoa farming in Lombok Island for next years.
   d. Five farmer leaders have appropriate knowledge and skill of cocoa farming obtained from ICCRI-Jember, East Java. The training has improved their spirit to become productive cocoa farmers and broaden their view about cocoa farming businesses. Those all may positively influence other surrounding farmers.

Key Outcomes

1. Information about cocoa farming in Lombok Island which may be used as a reference for many parties. It describes the distribution of cocoa farming land, common and specific characteristics cocoa farming in Lombok Island. The cocoa farming land is potentially expanded, especially in North Lombok and East Lombok areas.

2. An appropriate technology for use to handle PDAs effectively and efficiently and improve the quantity as well as quality of cocoa production. The technology may be termed as healthy farming or healthy-cocoa farming, which may be described as follows:
   a. In the healthy-cocoa farming concept, PDAs may not be handled by suppressing the population of pests and pathogens using synthetic pesticides, but by maximizing the healthiness and resistance of plant to PDAs, minimizing the number of cocoa beans being damaged by the PDAs.
   b. Theoretically, the plant receiving sufficient supply of essential nutrients and functional element (Si) will grow optimally (healthy plant) and has high natural resistance to biotic as well as abiotic stresses (including PDAs), thus the plant will produce maximum quantity and quality yield.
   c. Practically, the plant is fertilized with foliar fertilizers containing Si and all plant-essential nutrients (e.g., Si^{Plus}) since its early growing stage.
   d. In this research, it has been proved that the foliar application of Si^{Plus} fertilizer fortnightly on productive cocoa trees reduced the intensity of PDAs, significantly increased the quantity and quality of bean production. Moreover, the application also stimulated flowing and sped up the young cocoa plant to generative stage. Importantly, this technology utilizes natural-local resources, so that it is environmentally friendly and sustainable.
   e. This technology is in ready stage to be applied in larger scale.

3. There are demonstration plots of appropriate cocoa farming practice, especially in Genggelang village, to which cocoa farmers in Lombok may use those as the reference and learning tool of the proper management of cocoa farming.

4. The training for leader farmers by sending them to ICCRI Jember gained a great result. This activity was appreciated by local governments and they promised to follow up the program by sending more cocoa farmers to the training center. In short, the training was an appropriate method for improving farmers' knowledge and skill of cocoa farming in relation to speeding up the development of cocoa farming development in Lombok Island.

5. There will be scientific publications. A draft of publication article is presented in Annex 2.

Key Impacts

e. The implementation of all activities in this research has directly elevated the attention of many parties to cocoa business, encouraging local farmers and governments to more intensively develop cocoa farming in Lombok Island. At this moment, the government of North Lombok has cooperated with Faculty of Agriculture, University of Mataram to construct the short and middle terms of cocoa development planning program in North Lombok.

f. The positive proves of the highly effective and efficient 'healthy-cocoa farming' technology as shown in this research, potentially improves the trust of cocoa or/and food crop farmers to apply the method in their farm, and that will positively impact further to the improvement of cocoa farming productivity and profitability in Lombok Island.

g. All leader farmers trained in ICCRI have directly applied their cocoa farming knowledge and skill on farm, which are especially pruning, sanitation, top and side grafting, and growing new cocoa plant (seedling). Their action has great impacts to the neighboring cocoa farmer who eagerly learn to the leaders. Moreover, they requested us (P3LKT Unram) to guide them in preparing proposals for gaining supports of funding from local government; and we are happy to do guide them.

h. At the present time, the ratio of male and female involving in cocoa farming business seems to be proportional. The possible impacts of this project to the change of gender main stream may occur when the cocoa farming provides significant economic impacts to the farmers.

CONCLUSION AND RECOMMENDATION

In general, this research project was successfully carried out, fully achieving its specific objectives and targets. It was proven that healthy farming using a liquid-silicate rock fertilizer (Si^{Plus}) was an effective, efficient, environmentally sound, and sustainable technology to handle pest and disease attacks and maximize the production of cocoa. This new technology is ready to be applied in larger scale nationally, and most possibly internationally. In addition, the best results will be obtained if this technology is applied since the early growing stage of cocoa.

Based on the great results of this research, especially in developing a highly effective and applicable technology (healthy-cocoa farming) on farm level, it is recommended that this technology is applied in the other central areas of cocoa farming in Indonesia, e.g., Makasar (Sulawesi) and Medan (Sumatera).

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ANNEX 1. Several photos of research activities

Observation in Beriri Jarak - East Lombok

Spraying Si^{Plus} on cocoa in Wanasaba – East Lombok

Breaking cocoa pods by female. Good and bad quality of beans are mixed

Drying cocoa beans is mostly handle by female

Spraying Si^{Plus} onto cocoa trees by female

Cocoa treated with black ants

Workshop in Beriri Jarak – East Lombok

Workshop in Wanasaba – East Lombok

Disseminating use of healthy farming using Si^{Plus} in Genggelang

After training in ICCRAI: top (left) and side (right) grafting techniques shown by a farmer leader to other cocoa farmers in Genggelang

ANNEX 2. Draft of article for publication

APPLYING A LIQUID-SILICATE ROCK FERTILIZER REDUCED PEST AND DISEASE ATTACKS AND INCREASED THE PRODUCTION OF COCOA

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Abstract

A field trial was carried out to identify the most appropriate method to control pest and disease attacks (PDAs) and improve the quantity as well as quality production of cocoa in Lombok Island, by utilizing local materials which were liquid silicate rock fertilizer (LSRF), extract of neem leaf (NL) as a botanical pesticide, and black ant of *Doliccoderus thoracicus* (BA) as a predator. A completely randomized experimental design was applied for this trial with a treatment consisting of (1) control, (2) LSRF, (3) LSRF + NL, (4) LRSF + BA, and (5) BA, and each of those was applied on 10 productive cocoa trees for 14 months (November 2014 – December 2015). Results revealed that all the PDA-controlling methods reduced the intensity of pest and disease attacks followed by the increases of quantity and quality production (cocoa dry beans). The increases of production due to the application of LSRF alone or in combination with NL or BA were much higher than of that for the application of BA alone, suggesting the compounding effects of LSRF application. – fertilizing and reducing PDAs on cocoa trees. Therefore, applying LSF may be the most appropriate method to reduce PDAs and improve cocoa production.

Key words: botanical pesticide, cocoa, liquid-silicate fertilizer, predator, pest and disease attacks,

Introduction

A common constraint of cocoa farming in Lombok Island is pest and disease attacks (PDAs) which was suspected to be the main cause of the low quantity and quality of cocoa production in the area. Preliminary observation indicates that the main pests are cocoa pod borer (CPB) of *Conopomorpha cramerella* and *Helopeltis spp*; and the main existing disease is *vascular streak dieback* (VSD) of *Oncobasidium theobromae*. The other diseases present in smaller quantities are black pod caused by fungus (*basidiomycete*) of *Moniliophthora roreri*, and pod rot or black pod caused by *Phytophthora spp*. To improve the cocoa production in the area requires proper method to control the PDAs.

So far, efforts to overcome the cocoa farming problems have been focused more on controlling or eliminating the direct cause of PDAs, which are pests and pathogens, either by killing the organisms using synthetic pesticides, preventing the plant from PDAs using botanical pesticides, or suppressing the population of pests by employing predators. In other world, the main target of those PDA-handling techniques is the organisms causing the problem, not the plant itself. In fact, however, applying synthetic pesticides must be avoided due to its negative effects on environment and quality of farming product, whereas the latter two techniques seem to be ecologically better. Another method that receives less attention is by increasing the resistance of plant to PDAs through proper fertilization. This method may not only reduce PDAs, but surely also maximize the production of cocoa. Alternatively, better results may be achieved by combining those approaches, i.e., applying the mixture of fertilizer with botanical pesticide, or applying fertilizer and predators. The true effectiveness of those methods, however, needs to be identified on farm level.

It is commonly accepted that the healthy plant receiving optimum supply of all essential nutrients will grow optimally with maximum defense system (Dordas, 2007) and produce maximum yield. Many researchers (e.g., Bélanger et al., 2003; Fauteuex et al., 2005; Dann and

Muir, 2006) reported that supplying Si improves the resistance of plants to biotic and abiotic stresses. Those ideas may be applicable for handling cocoa farming problems. Technically, cocoa trees are supplied with the fertilizers containing Si and all plant-essential nutrients being set in balanced proportion. Applying the method may not only minimize PDAs, but also satisfy the plant with optimum supply of essential and functional nutrients, resulting high quantity and quality of cocoa production. The objective of this research was to verify the true effectiveness of those methods for controlling PDAs and improving cocoa production.

Materials and Method

Experimental Setting

The trial was conducted in a cocoa planting area in Genggelang village – North Lombok, Indonesia, from November 2014 to December 2015. The materials used for treating cocoa trees were (1) liquid silicate fertilizer (LSF) made from volcanic rock from Rinjani Mt in Lombok Island, (2) botanical pesticide (the extract of *neem* leaf after being fermented for 24 hours) (NL), and (3) black ant (BA) of *Doliccoderus thoracicus*.

The trial applied a completely randomized design with a treatment consisting of applying (1) LSF, (2) LSF + NL, (3) LSF + BA, (4) BA, and (5) the control. Each of those was applied onto10 cocoa trees which were relatively uniform in growth performance, productive, and free of pest and disease attacks. The LSF or LSF + NL were applied fortnightly, while BA were employed on the sample of cocoa trees at the start of trial.

Parameters and Measurement

The observed parameters mainly were (1) intensity incident of PDAs, (2) weights of total and 100 dry beans, and (3) the contents of polyphenol (for beans and pod shell), and lignin and cellulose (for pod shell). The intensity incident of PDAs was observed monthly for all pods, and the percentage of PDAs was calculated as the percentage of total number of pods being attacked by pests or/and diseases to the total number of pods harvested from 10 threes. The ripe pods were harvested weekly and were directly broken, and then the beans were separated into groups of bad and good quality, oven-dried at 40^o C to have constant weight. Sub samples of dried beans and pod shell were taken for measurements of polyphenol content using method of Singliton et al., (1965) and polyphenol, lignin, and cellulose contents using method of Goering et al. (1970).

Analysis of Data

Analyses of variance or/and least significant difference were applied for each type of data (parameter). The relationship between cocoa production with the average percentage intensity attack of pests and diseases was identified by a multi-regression method using the SigmaPlot Program 11.

Results and Discussion

Pest and Disease Attacks

During the trial, the common pests attacking cocoa pods were *Hellopeltis* and *Conopomorpha cramerella*; whereas of that for diseases were cocoa black pod (CPB) caused by *Phytophthora palmivora* and *Colletotrichum gloeosporioides*. The average percentage of incident of PDAs on cocoa in relation to the applied treatments is presented in Figure 1.

Insert Figure 1

Figure 1 shows that the intensity attack of pests and diseases on the treated was consistently lower than of that for untreated (control) cocoa trees. The intensities of pest attack on the treated were 60 – 70 % in comparison to that for the untreated cocoa was 80 %; and that for disease attack on the untreated were 3 – 9 % and for untreated was about 12 %. In short, the applied PDA-controlling methods were effective to reduce PDAs on cocoa.

Further specific observation was made for beans in the pods that were attacked by *Hellopeltis* or/and CPB. The observation consistently confirmed that most the beans from the pest-damaged pods taken from cocoa trees being treated with LSF alone or in combination with NL or with BA were still in good condition (data are not shown in this paper). This result indicates that those pest attacks only damaged the outmost parts of cocoa shell, did not affect most of beans inside the pods. In addition, the shallow injection or attacks of *Helopeltis* onto the cocoa shell could be associated to the hardening of cocoa shell due to LSF applications. In addition, the LSF application caused the increase of lignification (see Figure 3) in which the content of lignin in cocoa shell for the control is lower than of that for the treated ones. Another possible explanation for the case, referring to Buer (2008), may be associated to the function of Si from the applied LSF in strengthening or hardening the cell wall of cocoa shell.

Cocoa Production

The quantity and quality of cocoa dry beans in relation to the treatments are presented in Figure 2. Statistically, the treatments significantly increased quantity (kg beans/10 trees/year) as well as quality (weight of 100 beans) of cocoa production. The increases in quantity of cocoa production due to the treatments were 18 to 110 % relative to that of the control; and the order of production was of that treated by LSF > LSF+NL > LSF & BA > BA > control. For the quality of cocoa production (mean weight of 100 beans), the increases were < 10 % relative to the value for control. Clearly, the liquid silicate fertilizer may be effectively used to improve the quantity and quality of cocoa bean production.

Insert Figure 2

A multivariate analysis was made to identify if there was a cause-effect relationship between the percentages of PDAs and cocoa bean production. Results of the analysis indicated that the intensity of PDAs (pest and disease attacks together) contributed only about 41 % in determining variation of cocoa production. Because the other factors in this trial were assumed to be the same, the remaining determination values (about 59 %) might be attributed to the contribution of another function of LSF, which was as a supplier of essential nutrients and Si for cocoa trees. Clearly, the multi functions of LSF caused the higher bean production of cocoas that were treated with LSF alone, in combination with neem (LSF + NL) or with black ant (LSF & BA) than of that for cocoa that was only treated with BA. Therefore, applying LSF, LFS + NL, or LFS & BA may be used as the effective methods to overcome PDAs and maximize the production of cocoa.

Polyphenol and Lignin Contents

Analyses of polyphenol content was carried out for cocoa pod shell and bean, whereas analysis of lignin was only for cocoa pod shell, and the results are presented in Figure 3. Statistically, the application of LSF significantly increased polyphenol and lignin contents in pods shell. However, there was not much effect of applying LSF on polyphenol content in cocoa beans; only polyphenol content of the treated LSF & Ant was statistically higher than of that for the control.

Insert Figure 3

Polyphenol has important rule due to its antioxidant capacity being beneficial to human health (Hii et al., 2009). On the other hand, lignin – a part of cell structure, has important role in the defense system of plant to PDAs. Nyadanu et al. (2012) showed that lignin has important role in reducing CPB or *Phytophthora* species infection on cocoa pods. Based on these references, an important result of this trial may be interpreted that applying LSF, LSF + NA, BA significantly increased the nutritional values of cocoa bean and shell due to the increase of polyphenol content, and the resistance of cocoa pod to PDAs due to the increase of lignin content.

Conclusion and Recommendation

Applying liquid silicate fertilizer only (LSF), LSF in combination with a botanical pesticide of the extract of neem (LSF + NL), and black ant (LSF & BA), or black ant (BA) reduced the intensity attacks of pests and diseases and increased the quantity and quality of cocoa bean production. The order of the quantity production was LSF > LSF+NL > LSF & BA > BA > control. The positive effects may be associated to the increases of polyphenol and lignin contents in cocoa shell due to the application of those materials. It is recommended that applying the silicate-containing multi nutrient fertilizer (SLF) is the most appropriate method to control pest and disease attacks and increase quantity and quality of cocoa bean production.

Acknowledgement

We would like to thank and deeply appreciate to World Cocoa Foundation (WCF) for its funding for carrying out this research. Special thanks to MS. Virginia Sofila and Mr. Ben Breman for their helps in the project administration and implementation of the project.

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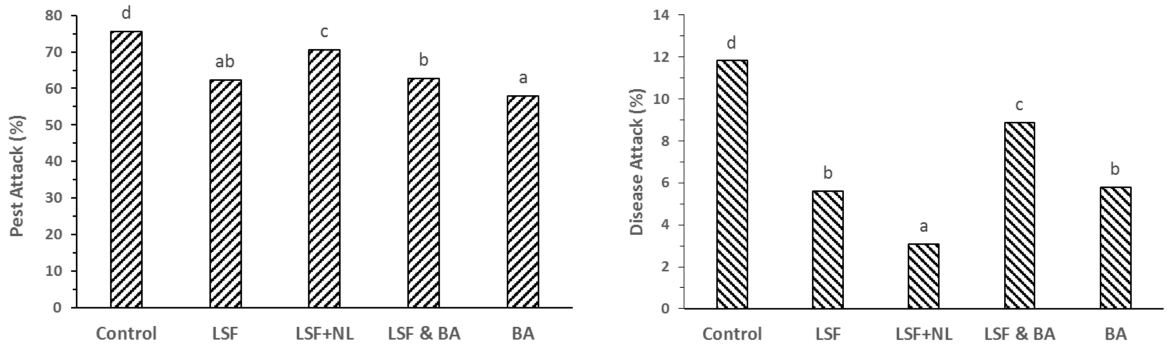


Figure 1. The percentages of cocoa pods being attacked by pests (leaf) and diseases (right) in relation to the application of liquid silicate fertilizer (LSF) alone, in combination with neem (LSF + NL), with black ant (LSF & NA), and black ant alone (BA). The bars (values) followed with the same labels in each graph were not significantly different based on LSD at α = 0.05.

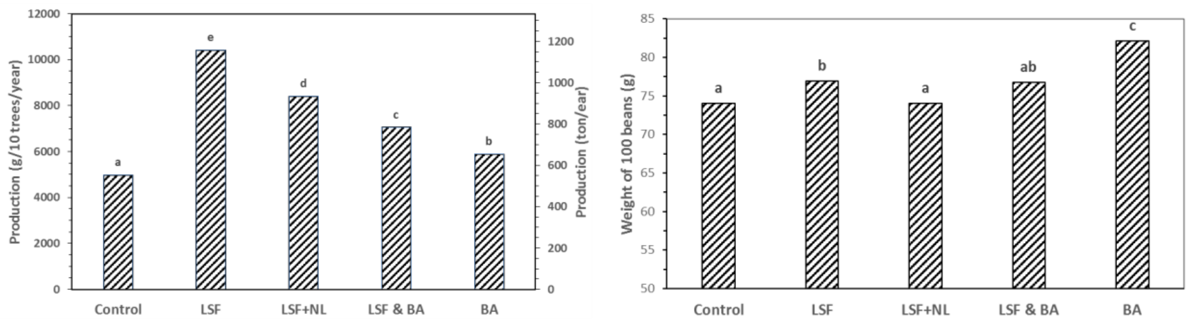
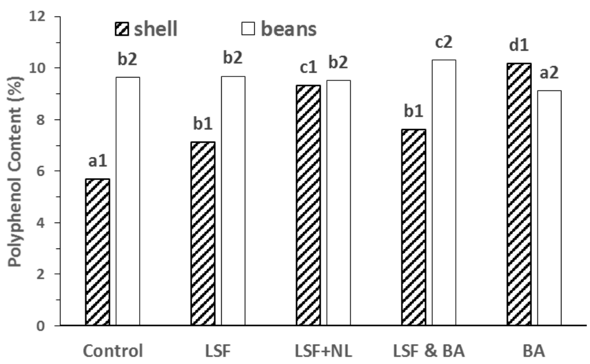


Figure 2. Total production of dry beans (left) and mean weight of 100 beans (right) in relation to the application of liquid silicate fertilizer (LSF) alone or in combination with neem (LSF + NL), with black ant (LSF & NA), and ant alone (NA). The bars (values) followed with the same labels in each graph were not significantly different based on $LSD_{\alpha = 0.05}$.



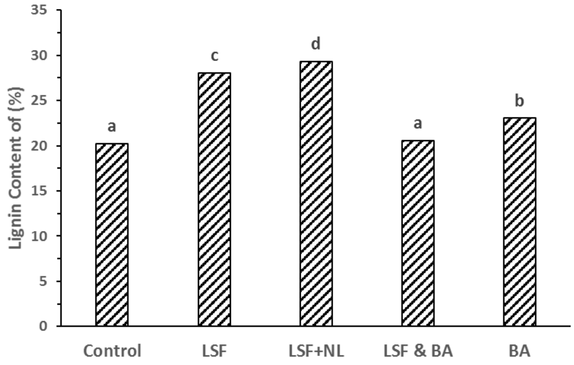


Figure 3. Polyphenol content of cocoa pod shell and bean (leaf) and lignin content of pod shell in relation to the application of liquid silicate fertilizer (LSF) alone or in combination with neem (LSF + NL), with black ant (LSF & NA), and ant alone (NA). The bars (values) followed with the same labels in each graph were not significantly different based on $LSD_{\alpha = 0.05}$.