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SPEED OF HYBRID MAIZE ADOPTION IN THAILAND: AN APPLICATION OF DURATION ANALYSIS

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ABSTRACT

Hybrid maize was released in Thailand in 1980s, and has become widely adopted among maize growers. During the early years of introducing hybrid maize, the adoption was infinitesimal due to unsurpassing yield and high seed price. However, after a substantial increasing role of private seed companies in varietal development and seed commercialization during the early 1990s, the adoption of hybrid maize has been escalating. At present, hybrid maize covers nearly all maize production areas in Thailand making Thailand one of most adopted hybrid maize in developing countries. Despite the success of disseminating hybrid maize in Thailand, none of existing studies could answer the reasons why different farmers adopt hybrid maize at different at time. Thus, this paper aims a determining factors influencing the timing or speed of adoption by employing a duration model in a dynamic framework. The results showed that educated and younger farmers are among the early adopters. Being closer to input dealers and higher seed price would speed up the adoption, but the communication with public extension officers in fact decreased the speed of adoption while communication with the private seed companies did not influence the speed of hybrid maize adoption.

Key words: duration model, technology diffusion, modern varieties

INTRODUCTION

Maize is the cereal of the largest cultivation area, and production of maize has been increasing due to increasing demands for feed and biofuel. Maize also plays an important role for food security in many countries in Sub-Saharan Africa and Latin America where it is a staple crop. Hybrid maize varieties have shown to provide yield superiority over open-pollinated varieties (OPVs). Due to a remarkable yield advantage and uniformity characteristics, soon after the commercialization of hybrid maize in the early 1930s, it is vastly adopted in the Corn Belt of the U.S. (Griliches 1960). Adopting modern plant varieties has shown to improve farmers' income and food security in many developing countries (Beyene and Kassie 2015; Ghimire and Huang 2016; Khonje et al. 2015; Shiferaw et al. 2004). Thus, many development programs supported by international organizations such as the Rockefeller Foundation, USAID, Bill and Melinda Gates Foundation aim at introducing hybrid technology into developing countries throughout most of Africa, Latin America, and Asia. However, the adoption of hybrid varieties in many countries remains limited (Heisey et al. 1998). Although maize is not a traditional crop in Asia, it became important to Thailand's economy. Thailand is ranked the 20th largest maize producer in the world, and the 4th largest maize producer in Asia (FAO, 2016). Hybrid maize was first introduced in Thailand in 1982 by the National Corn and Sorghum Research Center in response to a drastic expansion of poultry and livestock industry. Compared to maize production in 1982 of 3.55 million tons (average yield of 2.113 tons/ha), in 2012 Thailand produced about 5.09 million tons of maize annually with the yield of 4.317 ton/ha (FAO, 2016), a 40% increase in production and double of yield. A remarkable increase in Thailand's maize output and yield is mainly attributable to the conversion of OPVs to hybrid varieties (Morris, 1998 cited Thomson, 1994). The adoption of hybrid maize was initially slow but after after the release of single-cross hybrids by private companies in the early 1990s, the adoption of hybrid maize considerably increased (Suwantaradon, et al. 2012), and after two decades, its adoption reached 90%, and nearly all maize cultivation in Thailand are hybrid varieties today (Napasintuwong, 2014). Over the past three decades, there have been several government policies to promote hybrid maize adoption such as direct subsidy programs for hybrid maize seed, corn production development program and seed exchange program during 1989/90 and 1993/94 that invited private companies to buy grain from farmers at a guarantee price or higher, extension programs to promote hybrid maize adoption by supplied single-cross hybrid seed and other inputs at no cost to farmers, and privatization of maize seed industry (Ekasingh and Thong-Ngam, 2008; Napasintuwong 2014; Pongsroypech 1994). These changes have influenced the adoption hybrid maize in Thailand.

Hybrid maize in Thailand is an example of a successful modern varieties adoption in a developing country. A review of the history of maize seed industry in Thailand by Napasintuwong (2017) emphasizes different roles of public universities, public research institutes, private companies and collaborative efforts with international organizations. There have been limited studies described the adoption of hybrid maize in Thailand in a static framework (Jamroonpong, 1996; Ekasing et al., 2004) but no earlier study using a dynamic framework to capture the rate and process of the adoption of hybrid maize through time. Recent exceptions are Poolsawas and Napasintuwong (2012) who showed that characteristics such as farm and farmers' characteristics in Thailand describe their innovativeness which in turn affect the timing of hybrid maize adoption, and Beyene and Kassie (2015) who found that the speed of adopting improved maize varieties in Tanzania is influenced by social and environmental factors, and government support during crop failure.

Numerous economic studies have analyzed the determinants of agricultural technology adoption decisions; however, most of them employ micro-level cross-sectional data at a particular point of time that cannot explain the timing of the adoption decision. Technology diffusion studies, on the other hand, evaluate the timing of adoption and adoption rate at the aggregate level (Arora and Bansal, 2012; Batz et al. 1999; Frisvold et al. 2009; Griliches, 1960; Poolsawas and Napasintuwong, 2012), but fail to address specifically why individual farmers adopt a technology earlier than the others. Understanding the timing of adoption provides important information, particularly when it is considered to be linked with specific events (Beyene and Kassie, 2015; Matuschke, and Qaim, 2008). Understanding the speed of technology adoption which is subject to policy choices allows for understanding the economic development process (Feder and Umali, 1993). Through the process of adoption which affects economic performance, resource availability, and environmental quality, understanding the adoption process will also help better planning for input supply and resource management (Castillo et al. 2018).

To address what make individual farmers adopt a technology at a particular point in time, limited number of recent studies employs a duration model. A duration model was initially applied to biomedical research, called survival analysis, where the duration of interest is the survival time of a subject. It was first applied to social sciences by Lancaster (1978) to study factors influencing unemployment spells, and became widely used in labor economics, mainly in the analysis of unemployment duration (Arranz and García-Serrano, 2014; Arranz and Muro, 2004; Lancaster, 1978; De Una-Alvarez *et al.*, 2003). Recently, it has been applied to capture the dynamic aspects of technology adoption in agricultural sector (Abdulai and Huffman, 2005; Beyene and Kassie, 2015; Burton *et al.*, 2003; Dadi *et al.*, 2004; D'Emden *et al.*, 2006; Fuglie and Kascak, 2001; Matuschke and Qaim, 2008; Nazli and Smale, 2016).

Because there have been several changes in policy instruments and social and economic conditions that affect the dynamic of hybrid maize adoption in Thailand, the main objective of this study is to identify both time-varying and time-invariant factors on the duration farmers waited before they first adopted hybrid maize varieties. There has been no other study that employs duration analysis for the adoption of hybrid maize varieties in developing countries, and particularly in the situation that the adoption is nearly complete the production area.

MATERIALS AND METHODS

Building upon Keifer (1988) and Lancaster (1990) on the hazard function, individual farmers have different time origin for durations they experience. For the adoption of hybrid maize, the time that hybrid variety became available or the time individual farmers first started cultivating maize might not be the same. Burton *et al.* (2003) defined technology adoption as the start or entrance date can be set either at the time when the first adoption of an innovation took place or at the time of its creation. The exit date, or the end of a spell, is the time the adoption of innovation takes place. The duration or a spell length for an individual wait to adopt hybrid varieties is given as T*, a random variable. The start date in this study would be set either at the time when the hybrid maize was first available or the time of farmer's entry if the farmer entered after the hybrid maize was released. The end of a spell is the time when a farmer adopted the hybrid maize. However, this time spell, may possibly be censored if at the time of survey, the farmers still have not adopted hybrid maize at the time of data collection. For these farmers the ends of their spells are unknown although they might occur in the future so the duration is right-censored at the end of the observation period.

Let T be a non-negative continuous variable and represents the length of time farmers waited before the adoption. The cumulative distribution function of T is defined as

$$F(t) = P(T \leq t), t \geq 0. \tag{1}$$

It demonstrates that the probability that duration time T is smaller or equal to some value t. Thus, the probability density function of T can be derived as

$$f(t) = \frac{\partial F(t)}{\partial t}. \tag{2}$$

In the case of farmer waiting before adoption, the survival function is the probability of an individual not adopts the technology until or beyond time t is defined as

$$S(t) = 1 - F(t) = \Pr(T > t). \tag{3}$$

The hazard function indicates the instantaneous rate of leaving per unit time period at t (Lancaster, 1990) or represent the probability that farmers adopt the new technology at time $t + \Delta t$. The hazard function for T is defined as

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t}$$
$$= \lim_{\Delta t \to 0} \frac{f(t)}{1 - F(t)} \tag{4}$$

Therefore, $$h(t) = \frac{f(t)}{S(t)} \tag{5}$$

given that the hazard rate $(\frac{\partial h}{\partial t})$ may be constant, positive or negative.

The hazard function can be separate into two components: the first part that is dependent on individual farmer's characteristics and the other one that is not. The latter is sometimes called a baseline hazard which can be semi-parametric following Cox proportional hazards model (Cox, 1972). However, parametric models are more efficient in their use of data because they do not reject what happens to covariates where adoptions occur. Therefore, functional forms that have been used for parametric duration models include the exponential, Weibull, Gompertz, logistic, lognormal and log logistic probability distribution (Cleves et al. 2008). Among all of them, the two most commonly used are the exponential and Weibull distributions.

The exponential distribution is characterized by a hazard function with a constant rate, $h(t) > \lambda$ where $\lambda > 0$, implying that the duration time (length of spells) does not affect the hazard rate. The baseline hazard is given as:

$$h_0(t) = \lambda \,,\; \lambda = \exp(\beta_0)$$

$$\text{or } h_0(t) = \exp(\beta_0) \tag{6}$$

where β_0 is the only parameter to be estimated. The result of this model is the expected remaining time to adoption and is independent of prior survival times.

The Weibull distribution is characterized by the hazard function,

$$h(t) = \lambda p t^{p-1} \;;\; \lambda > 0 \text{ and } p > 0 . \tag{7}$$

It exhibits an increasing hazard rate when $p > 1$ while the hazard rate would be decreasing if $p < 1$. When $p = 1$, it exhibits a constant hazard rate and collapses to the exponential distribution model.

The explanatory variables can be introduced in a number of ways, and the most common is to assume a proportional hazard model in estimating the distribution of durations. The simplest ways to include covariates are those which do not change over time, such as farm location and farm size may be assumed to be time-invariant.

$$h(t, X) = h_0(t)\exp(\beta, X) \tag{8}$$

Where $h_0(t)$ denotes the baseline hazard which is independent of covariates X and a second term $\exp(\beta, X)$ exhibits multiplicatively on the baseline hazard models.

Based on the literatures, the factors influencing the speed of adoption of new crop varieties are divided into two components; time-invariant and time varying factors as shown in Table 1.

Table 1. Summary of explanatory variables (n=335)

Variable	Description
Time-invariant factors	
Edu	Number of year for formal education received (years)
HH size	Number of people in household (persons)
Distance	Distance from farm to the nearest input market or input dealer (km)
Meet pub	Number of times farmer meet with public officers/researchers /breeders (times per year)
Meet priv	Number of times farmer meet with private staff/researchers/sale persons (times per year)
Res center pub	Public research center exists in the district
Res center priv	Private research center exists in the district
Ext pub	Farmers received hybrid maize information from public officers/ research center at time of adoption. = 1 if yes; = 0 otherwise
Ext priv	Farmers received hybrid maize information from private companies/ sale persons at time of adoption. = 1 if yes; = 0 otherwise
Credit pub	The farmer's accessibility to credit at adoption year from public organization or public research center. = 1 if yes; = 0 otherwise
Credit priv	The farmer's accessibility to credit at adoption year from private companies or private research center. = 1 if yes; = 0 otherwise
Time varying factors	
Age	Age of farmer when first adopted hybrid varieties (years)
Size	Total maize cultivated land when first adopted hybrid varieties (hectare)
Seed price*	Price of hybrid maize seed when first adopted hybrid varieties (baht per kg)
Output price**	Price of maize grain when first adopted hybrid varieties (baht per kg)

Remarks: *, ** The real price of hybrid maize seed and maize grain were calculated based on consumer price index from Bureau of Trade and Economic Indices, Ministry of Commerce (2016).

The empirical model of the speed of hybrid maize adoption employing duration model can be specified as follows:

$$\begin{aligned} h(t,X) = \beta_0 + \beta_1 Edu + \beta_2 HHSize + \beta_3 Distance + \beta_4 Meetpub + \beta_5 Meetpriv \\ + \beta_6 Rescenterpub + \beta_7 Rescenterpriv + \beta_8 Extpub + \beta_9 Extpriv + \beta_{10} Creditpub \\ + \beta_{11} Creditpriv + \beta_{11} Age(t) + \beta_{12} Size(t) + \beta_{13} Seedprice(t) + \beta_{14} Outputprice(t) + \alpha \end{aligned} \quad (9)$$

The factors that are static over time are defined as time-invariant factors includes education of farmers, size of household, distance from farm to input market and attitude of farmers toward hybrid maize traits. Farmers with higher education levels are hypothesized to adopt earlier (Burton et al. 2003; Dadi et al. 2004; Matuschke and Qaim, 2008) while the farmer with larger size of household member are hypothesized to have a negative effect on the adoption (Hintze et al. 2003). A distance from farm to input market which represents input accessibility and infrastructure effort, is hypothesized to negatively affect the adoption therefore the farmers who has farm close to input market tend to adopt earlier (Matuschke and Qaim, 2008; Ahsanuzzaman, 2015). Moreover, some factors related to public and private sector are included in the study. Rogers (2003) discussed the important roles of social communication as a mean to stimulate technology adoption. The relationship between social meetings and adoption of new crop varieties, districts with public or private research center located are in the study of Matuschke and Qaim (2008) and Dadi et al. (2004) with the positive effect hypotheses. The farmers who participated in field trials or have crop visits both formal and informal meetings are hypothesized to adopt earlier. Furthermore, extension services by public and private research center and credit are also included to be the important factors of technology adoption with positive impact (Sain and Martinez, 1999; Ahsanuzzaman, 2015).

The factors that change value over time are included as time varying factors. Age of maize farmers when they adopted hybrid varieties is hypothesized to have negative impact on the adoption, it represents that the younger farmers tend to adopt new technology or innovation earlier (Dadi et al. 2004). The size of farm at the first adoption which represents wealth of farmers and possibly accessibility to credits and is hypothesized to have a positive impact to the speed of adoption (Sain and Martinez, 1999; Dadi *et al.*, 2004). Price of hybrid maize seed at the first adoption and farm price of maize grain are also hypothesized to have an impact on the adoption (Matuschke and Qaim, 2008; Mugisha and Diiro, 2010). In this study, we estimated the real price in each timing period based on consumer price index from Bureau of Trade and Economic Indices, Ministry of Commerce (2016).

Since this research involves farmers who adopted hybrid maize varieties, the start year (t = 0) is 1979 when the first hybrid maize was in the field-trial and its information was first available. Because there were two groups: farmers who started maize cultivation before 1979 and farmers who started maize cultivation after 1979, the time to adoption was defined by applying the study of Matuschke and Qaim (2008). For farmers who started maize cultivation before 1979, the spell was the time difference between 1979 and the year they first adopted hybrid maize. For farmers who started maize cultivation after 1979, the spell was calculated from the time difference between the first year of maize cultivation and the year of hybrid maize adoption. The farmers who used hybrid varieties in the first year when they started maize cultivation, the spell comprise to one. It was assumed that the farmers received the information of those hybrid varieties one year before the maize cultivation. Once an appropriate parameterization is selected, maximum-likelihood estimation was used for parameters estimates.

A three-stage stratified sampling technique was adopted in data collection. Because the different in intensities of maize production may suggest different levels of extension services, access to information and social activities of maize farmers which were hypothesized to be important factors for the adoption decision, in the first stage, the intensity of maize planted area (proportion of maize area to total crop area) was used as a proxy for the levels of production capacity in each province. Thirteen maize producing provinces were classified into major maize production zone where the intensity of maize production area is more than 10.08% and minor maize production zone cover fifteen provinces where the intensity is less than 10.08%. In the second stage, the existence of research center, either public and private, was used to stratify provinces following the hypothesis that farmers who stayed closer to research center can get more access to information and might adopt faster (Matuschke and Qaim 2008). Five provinces were randomly selected: three were major maize zone where public research center, private research center and none of research center was located, and two were minor maize zone where public research center and none research center located (no private research center was located in the minor maize zone). The last stage, one district from each province was randomly selected (Table 2). The number of respondents were 341 samples based on Krejcie and Morgan (1970) sampling technique and a five percent statistical significance level was assumed.

Table 2. Three stage stratified sampling and sample size of the study

Stage I: Intensity of maize area	**Stage II: The establishment of research center**	**Stage III: Sample districts**	**Total Maize farming households**	**Expected Sample size**	**Expected sample proportion**	**Actual sample size**	**Actual sample proportion**
Major maize province	*Public*: Nakhon Ratchasima	Pak Chong	169	19	0.05	22	0.06
	Private: Lopburi	ChongSarika	735	84	0.25	76	0.23
	None: Petchabun	Namron	949	108	0.32	106	0.32
Minor maize province	*Public*: Nakhon Sawan	Suksamran	832	95	0.28	101	0.30
	Private: -	-	-	-	-	-	-
	None : Kampangphet	Angthong	312	35	0.10	30	0.09
		Total	2,997	341	1.00	335	1.00

RESULTS AND DISCUSSIONS

The statistics of explanatory variables which hypothesized to have an influence on the speed of adoption are summarized in Table 3. On average, farmers have only five years of formal education, and age around 37 years at the time of adoption. The average farm size is approximately seven hectares considered relatively large compared with other crop production. About 37% of maize farms are in the provinces where the public research center is located, 23% in the provinces where private research center is located, and the rest are in the provinces where neither public nor private centers exist. The survey found increasing prices of maize seed and grain during the past three decades. At the time of adoption, the real price of hybrid maize seed was approximately 134.24 baht/kg, about 23 times that of maize grain which was about only 5.82 baht/kg. A larger number of farmers receive information or extension service from the private seed companies than from the public institutes while a much larger proportion of farmers gets credit loan from public sector than from the private sector. It showed that maize production information and knowledge was more accessible from the private sector whereas the financial support was more available from the public organizations.

Table 3. Summary statistics of explanatory variables (n=335)

Variable	Mean	S.D.	Percentage
Time-invariant factors			
Edu	5.31	3.30	-
HH size	4.08	1.54	-
Distance	9.00	7.67	-
Meet pub	1.91	2.91	-
Meet priv	0.26	0.60	-
Res center pub	-	-	36.72%
Res center priv	-	-	22.69%
Ext pub	-	-	13.43%
Ext priv	-	-	28.06%
Credit pub	-	-	45.97%
Credit priv	-	-	3.88%
Time varying factors			
Age	36.90	11.75	-
Size	7.19	13.02	-
Seed price*	134.24	1.55	-
Output price**	5.82	0.18	-

Remarks: *, ** The real price of hybrid maize seed and maize grain are calculated based on consumer price index from Bureau of Trade and Economic Indices, Ministry of Commerce (2016).

The attitudes toward the advantages of hybrid maize over OPVs and local varieties are shown in Table 4 and were measured using a 5-point Likert scale approach with 1 if strongly disagree, 2 if disagree, 3 if neutral, 4 if agree and 5 if strongly agree. Hence, the summed scores ranged from 8 – 40 points. The farmers who gave responses less than 24 points were allocated into unfavorable attitudes and the farmers who gave responses equal to or greater than 24 points were allocated to favorable attitudes. The majority of the maize farmers have positive attitudes toward hybrid varieties with regard to high yielding, grain weight and shape, tolerance to drought, ease of harvesting, and resistance to diseases.

Table 4. Attitudes toward the advantage of hybrid maize over OPVs and local varieties.

Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
- Higher yielding	0.60	6.27	8.36	38.81	45.97
- Earlier maturity	5.07	32.84	12.84	35.22	14.03
- Better grain weight & shape	1.19	6.57	10.45	37.01	44.78
- More drought tolerant	2.09	17.31	11.04	36.72	32.84
- More pesticide and chemical resistance	1.19	20.90	27.76	42.39	7.76
- Easier to harvest	0.90	17.61	13.73	36.72	31.04
- More rust or downy mildew resistant	1.49	12.54	27.76	36.42	21.79
- Higher maize grain price	7.46	42.99	11.94	21.49	16.12

Table 5 describes the characteristics of current hybrid maize production. From our study, all farmers adopted hybrid varieties produced by private companies that OPVs information was not included for comparison. Average hybrids yields were 7,384.87 kg/hectare and 112 days maturing period. Seed used, on average, was 20.39 kg/hectare with 127.74 baht/kg at current price while current grain price was 5.65 baht/kg.

Table 5. Production characteristics of hybrid maize in Thailand

Variables	**Mean**	**Standard Deviation**	**Min**	**Max**
Yield (kg/hectare)	7,384.87	2,381.36	1331.25	14,062.50
Maturity (days)	111.80	7.79	90	150
Seed used (kg/hectare)	20.39	3.80	9.37	41.25
Current seed price (baht/kg)	127.74	13.51	50	180
Current grain price (baht/kg)	5.65	1.37	2.64	12.36

Figure 1 presents a non-parametric, Kaplan-Meier estimator, of the survival function. It illustrates the relationship between proportion of non-adopters and the adoption spell, which is the time difference between the year of first maize cultivation and the year of hybrid varieties adoption. More than 40% of farmers adopted hybrid varieties within one year, and the rate of non-adoption constantly decreased after two years. For the parametric estimation, we assume that the baseline hazard has a Weibull distribution. The Akaike information criterion (AIC) is employed to choose the best fit model (Akaike, 1974), and can be defined as $AIC = -2\ln L + 2(k + c)$, where k is the number of independent variables, c is the number of model-specific distribution parameters (=1 for exponential and = 2 for Weibull distribution). Based on our samples, the AIC for the exponential distribution is 1,045.961 and the Weibull distribution is 1045.133. Therefore, the Weibull distribution has the lower AIC and fits the model better. Thus, we adopted the Weibull distribution for hazard model estimation (equation 8), and coefficient estimates are reported as hazard ratios ($\exp(\beta, X)$). A value greater than one is interpreted as a positive impact on the hazard rate of adoption, implying faster adoption process, and vice versa for the value less than one.

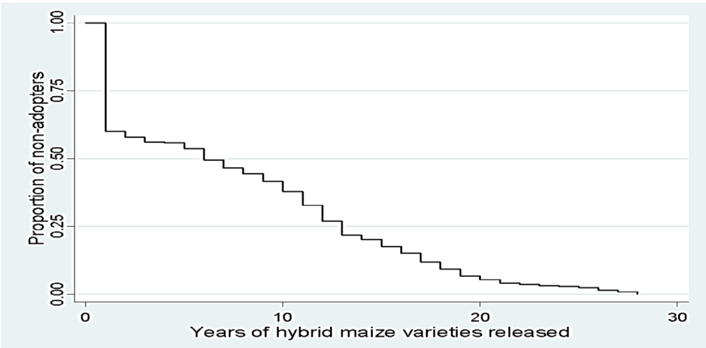

Fig. 1. Kaplan-Meier estimator of the survival function

For time-invariant factors, it was found that the formal education of farmers has significant impact on the speed of hybrid maize adoption with the hazard ratio at 1.055 (Table 6). More educated farmers have higher probability of adopting earlier, conforms to previous studies from Dadi *et al.* (2004). Farmers who have their farms closer to input markets or seed dealers were easy to access technologies and tended to adopt earlier similar to Ahsanuzzaman (2015) and Sain and Martinez (1999).

In terms of the public and private roles in adoption process, frequent meeting with public researchers and farm locating in the districts where public research centers exist, have a negative influence to the hazard rate. It showed that a unit increase in numbers of meeting with public staff and existence of public research center in the district decreased the hazard at 0.956 and 0.659, respectively. Fewer meeting with the public staff may actually increase the hybrid maize adoption as the information from public staff may complicate the technologic choice especially in this situation when public sector does not provide hybrid seeds to the market. All of the expected variables related to the private sector had no significant impact on the speed of adoption compared to previous study by Matuschke and Qaim (2008).

Table 6. Coefficient estimates of Weibull distribution hazard model for the adoption of hybrid maize varieties (N=335)

Variables	Hazard ratio	Standard Error	Z	p-value
Edu	1.074	0.021	3.60	0.000***
HH size	0.983	0.038	-0.43	0.670
Distance	0.977	0.007	-2.81	0.005***
Meet pub	0.956	0.020	-2.13	0.033**
Meet priv	0.967	0.044	-0.73	0.468
Res center pub	0.659	0.095	-2.86	0.004***
Res center priv	0.908	0.149	-0.59	0.557
Ext pub	0.884	0.157	-0.69	0.490
Ext priv	0.975	0.128	-0.19	0.849
Cre pub	0.968	0.116	-0.27	0.788
Credit priv	1.340	0.398	0.99	0.324
Age	0.972	0.005	-4.70	0.000***
Size	0.999	0.001	-0.78	0.438
Seed price	1.005	0.002	2.32	0.020***
Output price	1.027	0.022	1.24	0.213
Log-likelihood	-505.56			
Chi^2	85.96			

Remarks: ***, **, ands * indicates statistically significant at 1%, 5%, and 1% levels respectively.

This implies that while public communication and access to public research information may inversely influence the speed of hybrid maize varieties, the communication with the private companies did not appear to be significant factor to the speed of hybrid maize adoption as expected. One possible explanation is that the hybrid maize varieties were well-accepted among farmers from significant yield improvement, compared to OPVs. Even without public extension services or private seed companies' promotion, the speed of hybrid maize adoption most likely depended on the expected benefit (i.e. relative advantage of producing hybrid maize rather than the OPVs) and availability of seeds in the seed market. This can be seen from the impact of accessibility to inputs (located near input dealers) on the speed of adoption discussed above. In addition, public institutes still produced hybrid varieties together with OPVs in the earliest stage. Through public communication of these hybrids that had higher relative price but not perceived as higher yield than existing OPVs could be a cause of decrease in the speed of adoption. Although private companies started commercial trials of hybrid maize varieties in 1981, but the adoption of hybrid varieties was slow at the beginning. Only until the release of CP-DK 888 by Charoen Pokphand in 1991 that provided more access to uniform and high yielding hybrid varieties and highly demanded by its integrated feed industry (e.g. orange-yellow color), the adoption of hybrid maize significantly increased (Napasintuwong 2017) as well as the number of adopters (Fig 1). In this case, the attributes of technology (trialability and observability of relative benefits) could be more important than social communication. Private companies' communication at the time that farmers decided to adopt hybrid varieties varied depending on the seed companies' strategies and the period of adoption. Private companies' extension evolved from farmer's field demonstration, seed exhibition, to agrodealer promotion. Our results show that these do not have significant influenced on the speed of adoption (not the adoption per se), and might be more influenced by perceived relative advantage and the availability and affordability of hybrid seeds (i.e. influenced by agrodealers) rather than direct communication with private seed companies.

For time-varying factors, the age at the time of adoption had negative impact at 0.972 times, whereas younger farmers tended to adopt hybrid maize earlier (Dadi et al 2004). Seed price also positively increased the rate of adoption whereby a unit increase in seed price increased the hazard by 1.005; this is different than earlier study by Mugisha and Diiro (2010). This could be because the share of seed cost was relatively lower than other cost of inputs, and it continuously increased over time so even if it increased, farmers still see more benefits of adopting hybrid varieties. Farm size and grain price were expected to positively shift the probability of adoption but both factors had no effect on the speed of adoption in our study which is contrary to a previous study by Sain and Martinez (1999) and Dadi et al. (2004). On average, most Thai maize farmers had small farm area which offers less risk from adopting new technology. Regarding the insignificant effect of grain price, it was determined that hybrid grain and OPVs grain were sold at the same price because there were no significant difference in grain characteristics therefore it did not affect the adoption.

CONCLUSIONS

The findings from the duration analysis of a farm survey from five major maize provinces of Thailand suggested that to increase the speed of hybrid maize adoption, policy makers may promote new crop varieties to the young and educated farmers. Increasing input accessibility would also increase the adoption. Increasing the price of hybrid seed or other new technology may still increase more adoption when the price of output increases correspondingly. However, the communication from public sector may not necessarily increase the speed of adoption particularly in this case where the technology is provided by the private companies. The availability of technology could be more important factor to speed up the adoption like in this case where perceived benefits (i.e. significant yield improvement) is prominent.

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DISEASE RESISTANCE SCREENING PROTOCOL AGAINST RICE (*Oryza sativa* L.) BROWN SPOT (*Bipolaris oryzae* Shoem.) AND BLAST (*Magnaporthe oryzae* Hebbert Barr) DISEASES USING ABSCISSIC ACID (ABA) ASSAY

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ABSTRACT

Broad spectrum resistance can combat wide array or strains of a pathogen. Developing broad spectrum resistance requires understanding and screening sources of resistance. Abscissic acid (ABA), a known plant resistance response, was used to differentiate resistance and susceptibility response against brown spot and blast fungal rice diseases in IR64 wild type and mutants. To validate the association of ABA into brown spot and blast resistance, ABA assay was conducted. The study was conducted in International Rice Research Institute in 2013. ABA acid assay was effective in differentiating response of rice against brown spot and blast diseases at 7 days after inoculation (DAI). This study also suggests that IR64 can be used as resistance source against blast and brown spot diseases.

Keywords: pathogen, broad-spectrum disease resistance, mutants, ELISA

INTRODUCTION

Rice, *Oryza sativa* L., is the staple crop of two-thirds of the human population. It provides 21% of global human per capita energy and 15% of per capita protein (Leong 2004). In 2017, rice contributed 1,156.59 grams of calories per day per person in the Philippines. (PSA 2018), however, rice diseases have been one of the major constraints in rice production, causing a yield loss of 24-41% (IRRI 2012) thus, demands for rice are hardly reached. Fungal diseases like blast and brown spot reduce rice yield.

Rice blast is caused by the pathogen *Magnaporthe oryzae* Couch. (Couch and Kohn 2002) a hemibiotic fungal pathogen that gets its nourishments from living and non living tissues (Talbot 2003). The anamorph stage *is Pyricularia oryzae*. The *Magnaporthe oryzae* Couch was used as updated sstandard scientific name for rice blast pathogen as recommended by the Natural History in the University of the Philippines Los Baños, Laguna. The rice blast pathogen infects leaf blades, leaf collar, culm, culm nodes and at the panicle neck node (Webster and Gunnell 1992). The rice blast disease cause significant yield losses in India (5% to 10% from 1960 to 1961), 8% in Korea (mid-1970's), 14% in China (1980-1981), and 50 to 85% in the Philippines (http://www.knowledgebank.irri.org).

The life cycle of Magnaporthe starts when the spores adhere to the host tissue which then becomes hydrated. The attachment of the spore on the host tissue is facilitated by a special adhesive released from the tip of each spore. After germination, the spores differentiate into a specialized infection cell, appressorium at 20-24 hours. At the optimum temperature (24-48 °C), plant tissue will be penetrated after 20-28 hrs. The appressorium enters the leaf through the stomata, cuticle and leaf surface (Ribot et al. 2008). This specialized infection cell facilitates invasion of underlying leaf tissue by generating enormous turgor pressure that ruptures the cuticle. The biotrophic stage of rice blast involves the movement of the fungus from cell to cell that occur by means of plasmodesmata. The fungus search for pit during invasive hyphae movement to adjacent epidermal cells (Wilson and Talbot 2009). Preformed barriers against the entry of the pathogen such as pectin, lignin, and phenolic compound will prevent breakage of cells, thus, can enhance resistance to the blast fungus through restriction of fungal penetration and hyphal growth. Penetration is followed by invasive growth (2-6 days) that leads to lesion formation (5-7 days after penetration). Finally, sporulation will take place and the pathogen spreads to new plants that require 6-15 days at optimal temperature.

Brown spot disease of rice is caused by the fungus *Bipolaris oryzae* (Breda de Haan) Shoem. Syn. *Drechslera oryzae* (Breda de Haan) Subram. and Jain *Helminthosporium oryzae* teliomorph, *Cochliobolusmiyabeanus* (Ito and Kuribayashi) Drechsler ex Dastur (Padmabhan 1973; Ou 1985). The pathogen also infects other cereal crops such as barley (*Hordeum vulgare*), oats (*Avena sativa*), wheat (*Triticum aestivum* L. em. Thell), maize (*Zea mays* L), and wild rice (*Zizania aquatica*) (Ou 1985). It has both an asexual and a sexual stage. The asexual stage is *Bipolaris oryzae* (Breda de Haan) Shoemaker (Dela Paz et al. 2006). The sexual stage is *Cochliobolus miyabeanus* (Ito and Kurib) Drechsler ex Dastur. Nectrophs like *Bipolaris oryzae* kills the host by producing toxin and lytic enzymes (Kan 2006). Brown spot reduced rice yield from 50% to 90% in Bengal (Padmanabhan 1973; Thuy 2002). Similar disease incidence was also reported in rice growing countries in South and Southeast Asia (Savary et al. 2000), America, and Africa (Ou 1985;Mew and Gonzales 2002). Symptoms of this disease are found on the rice leaves and glumes. Disease symptoms may also appear on the coleoptiles, leaf sheaths, panicle branches, but appear rarely on roots of young seedlings and stems (Ou 1985).

The disease cycle of brown spot starts with the germination of the conidia by germ tubes from the apical and basal cells. The germ tube is covered with a mucilaginous sheath which adheres to a solid surface and an appressorium is formed at the tip. After formation of appressorium, an increase in protoplasmic streaming is observed and the cell nuclei move to a position near the appressorium (Ou 1985). The germ tube may also enter the leaf through the stomata without forming appressoria (Nisikado 1926). It is then followed by the hyphae attacking the middle lamella and penetrating the cells. The middle lamella will start to separate and will caused the formation of yellowish granules. Then, 2 or 3 cells die, and mycelia develop in the cells. Appearance of minute spots follows (Ou 1985).

Using resistant varieties is one of the control measures used against brown spot and blast diseases. However, breeding for host single race-specific resistance (R) gene is only specific against particular strains or races of one pathogen species or pathovar. Moreover, the initially developed R genes can be outdone by races of pathogens, which can lose effectiveness rapidly in cases when the pathogens are capable of evading the recognition by changing its corresponding effector (also called avirulence or Avr) genes (Madamba et al. 2009; Zhao et al. 2005). These research findings led to developing plants resistant to broad-spectrum diseases.

Breeding for broad-spectrum disease resistance requires identification of germplasm containing resistance against wide array of pathogens or strains of a pathogen (Skamnioti and Gurr 2007). The objectives of these experiments were to develop and optimize a protocol that will determine resistance and susceptibility response against blast and brown spot. Efficient disease resistance screening protocol is necessary for fast and reliable screening of germplasm. Increase in abscissic acid (ABA) is one of the resistance responses of plants (Flors et al. 2009; DeVleesschauwer et al. 2010) that could be used to differentiate resistance and susceptible reactions. To validate the association of ABA into brown spot and blast resistance, sensitive and efficient ABA assay needs to be developed.

MATERIALS AND METHODS

Plant materials. The IR64 wild type was mutated by Wu et al. (2005) using diepoxybutane mutagen at the International Rice Research Institute (IRRI), Philippines. The IR64 mutants, D10808 and D6766 were used to compare with the IR64 wild type in response to brown spot and blast diseases. The utilization of IR64 mutants which have differences in mutation sites might give clues to determine the mechanism in loss of resistance to two diseases and conversely, determining the mechanism of loss of resistance to two diseases might elucidate the resistance mechanism for these two diseases.

Brown Spot and Blast Disease Inoculation and Symptom Assessment

Brown spot preparation of inoculum. Unlike blast, there are few studies on resistance against brown spot. Further, blast and brown spot differs in screening procedures including inoculum preparation. This is due to the toxin produced by the fungi *Bipolaris oryzae* that needs to be removed, thus, optimized procedures are necessary. The toxin of brown spot is not needed for the pathogenicity test of the experiment.

The brown spot isolate maintained by the Plant Pathology and Molecular Genetics Laboratory of IRRI was used for screening. The virulent SM2 isolate was revived from stock cultures by transferring 1-2 cut filter bit with fungal growth at the center of Potato Dextrose Agar (PDA) plates. Ten plates were used to prepare inoculum for the isolate. The isolate was grown under combination of NUV and fluorescent light with 12 h photoperiod, but in a room with temperature 28 ± 2^0C as optimal for growth of fungus (Hau 1980). Preliminary experiment showed that high temperature and incubation with fluorescent light caused watering in the media thus, affecting the growth of fungi. Modification of growth chamber with screen rather than closed door to maintain optimum temperature solved this and the required alternate light and darkness to maintain the optimal growth of fungus.

To clean the spore suspension, the toxin and mycelia fragments were generally eliminated. Brown spot suspension were filtered using layers of muslin cloth. The toxin was removed because of toxicity effects on leaves. Browning, yellowing of leaves, or worse early death of plants at early stage of disease development (1-2 DAI) manifest the toxicity effect of toxin thus, hinders the study on disease development. Toxins were eliminated by collecting the spores in 50 mL Falcon tube and using sterilized glass slides to scrape the spores form the surface of the agar. Then, the spore suspension was filtered through layers of muslin cloth, transferred to a sterile tube and centrifuged at 2000 rpm for 2 minutes. Centrifugation of inoculum allowed the toxin mixed in the suspension to settle down. This method is a modification from previous brown spot inoculation procedures which did not use centrifugation. Filtering lessened the concentration of inoculum hence, evaluation of spore concentration before filtering should be done to determine the change in concentration due to filtering. Spore concentration was determined using a hemacytometer. The standardized spore concentration for this protocol was 5 X 10^4 per mL, with additional 0.02 % Tween 20 to aid in the adhesion of the inoculum to the leaves.

Blast preparation of inoculum. The inoculum maintained by the Plant Pathology and Molecular Genetics Laboratory of IRRI was prepared as described by Chen (1994). Ca89 stock cultures in paper disks were revived in prune agar slants (3 pieces prune, 5-g lactose, 1-g yeast extract, and 20-g agar bar in 1 L, pH 6-6.5). About 10-mL sterile distilled water was added to the slant and mycelial growth was macerated with a sterile needle. The suspension was poured onto prune agar plates. The plates were incubated for seven days at room temperature, after which, mycelial growth was scraped with sterilized spatula and exposed to fluorescent light for four to five days to induce sporulation. Conidia were harvested by washing each plate with 10-20 mL water. The conidial suspension was filtered through four layers of nylon mesh and the concentration was adjusted to 5 X 10^4 per mL using a hemacytometer. Approximately 0.02 % Tween 20 was added to aid in the adhesion of the inoculum to the leaves.

Inoculation using brown spot and blast inoculum. Separate prepared spore suspension of brown spot and blast were sprayed onto 18-day-old rice seedlings planted in plastic trays using a motor sprayer. The motor sprayer was washed with alcohol and rinsed with distilled water for every isolate inoculated to prevent mixing of spore suspension and contamination. The inoculated rice plants were incubated inside a moist chamber covered with jute sacks for 24 hours with an air temperature of 28ºC to stimulate symptom development (Bonman et al. 1996). Then, plants were transferred to humidified room (mist room) with 25-30ºC and sprinkled with water DAI for the development of lesions.

Disease assessment. Quantitative scoring was done at seven days after inoculation by obtaining Percent Diseased Leaf Area (0-82) (Fig. 1). Plants with 0-4% DLA were considered resistant while plants with 8-82 % DLA were considered susceptible.

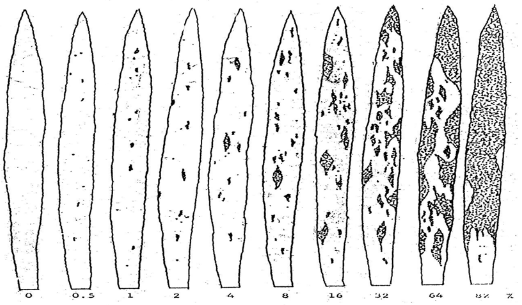


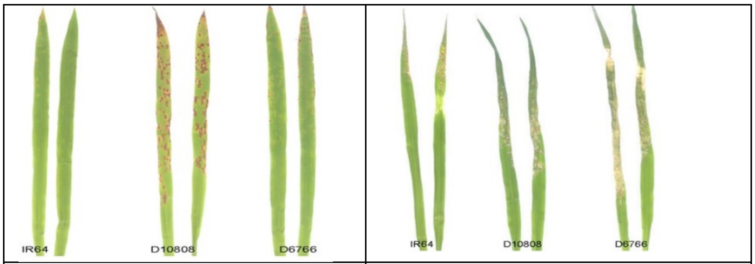
Fig. 1. Scale of disease measurement for % diseased leaf area in blast and brown spot (Roumen et al.1992)

Developing abscisic acid content assay in leaves for brown spot and blast inoculated of IR64 wild type and mutants. To associate resistance and susceptibility of ABA content on brown spot and blast response, ABA extraction and analysis assay in IR64 wild and mutants was developed. Collected leaf tissues before and at 1, 2, 3, and 7 DAI of *B.oryzae* and *M. oryzae* were ground using liquid nitrogen. Three replicates of one gram of fresh tissue per sample were homogenized with 80% (v/v) methanol and 1 mmol (220 mg)/L butylated hydroxytoluene (BHT). The extract was filtered through a C18 column and transferred to a 2 mL epi-tube. The ABA ELISA (enzyme linked immunosorbent assay kits) was used for ABA determination. One reading in three samples per treatment was quantified using UV-VIS spectrophotometer. Statistical Analysis System 9.1 (SAS) was used for data analysis. For each inoculation experiment, the RCBD with two factors (genotype x four time series) in three replicates was used. Treatment comparison was carried out using least significant difference (LSD) technique at 5% level of significance ($P<0.05$).

RESULTS AND DISCUSSION

Brown spot and blast disease assessment in leaves of IR64 wild type and mutants. The formation of typical brown spot lesions was observed in inoculated D10808 mutant plants. As for IR64 wild type and D6766 inoculated plants, small brown specks or pinhead –sized spots with halo was observed 7DAI (Fig.2.a). Based on symptoms, it can be inferred that the D10808 mutant is susceptible to the disease while IR64 wild type and D6766 are resistant. The prominent lesion type on D10808 are type 3, 4 and 5 lesions which are said to be the sporulating type of lesions while non-sporulating lesion type (type 1and 2) was observed in inoculated IR64 wild type and D6766 plants 7 DAI (Fig. 2.a). Further, a difference between D10808 and IR64/D6766 in terms of percent diseased leaf area (DLA) was observed at 7 DAI (Fig.2.a). The mutant D10808 showed the highest percent DLA (30.15) and was significantly higher compared to IR64 wild type (1.35) and D6766 (1.60) (Fig. 2). The formation of the typical brown spot lesions coupled with high percent DLA reading again suggest that D10808 is susceptible to the disease while IR64 wild type and D6766 are resistant. Response of IR64 wild type and two mutant genotypes (D10808 and D6766) to blast infection were also observed. After 7 DAI, D10808 and D6766 showed elongated lesion with whitish center. Inoculated IR64 wild type plants, on the other hand, showed small brown lesions with grayish center (Fig.2.b). Analysis revealed that the % DLA mean (Fig.2) of three genotypes used in the experiment are statistically different from each other. D6766 showed the highest percent DLA (18.60) followed by D10808 (10.42) and IR64 wild type (6.76). Here, using the % DLA readings, it can be inferred that D6766 and D10808 in comparison to the moderately resistant plant (IR64 wild type) are susceptible to the disease. However, between D6766 and D10808, D6766 is more susceptible.

The IR64 wild type showed resistant phenotype response to both brown spot. Conversely, D10808 showed susceptible response to both diseases while D6766 had resistant response to brown spot but susceptible response to blast. These suggest that mutation is effective in disrupting resistance in blast for D6766 and D10808 mutants. The mutation in D10808 appears to be important for loss of resistance to two diseases. Comparison of the mutation sites between D10808 and D6766 appears to be important. The differences in mutation sites between D10808 and D6766 might give clues to determine the mechanism in loss of resistance to two diseases and conversely, determining the mechanism of loss of resistance to two diseases might elucidate the resistance mechanism for diseases to these two diseases.



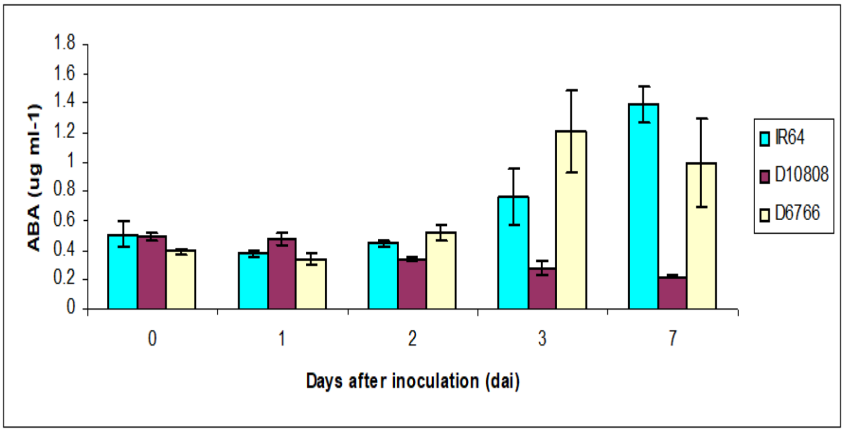
(a) Brown spot disease **(b) Blast disease**

Fig. 2. Diseased leaf Area (DLA) of IR64 wild type, D6766, and D10808 infected with (a) brown spot and (b) blast at 7 DAI.

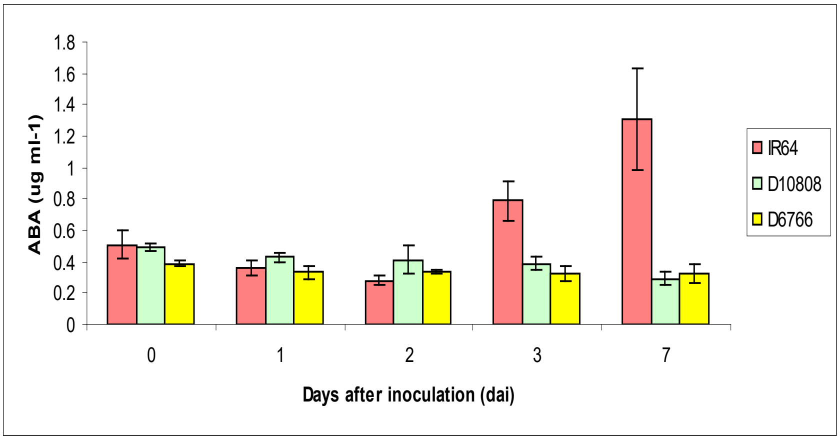
Abscisic acid content after brown spot inoculation. When plants are exposed to biotic and abiotic stresses, several plant components and processes are involved to mitigate the effect of diseases. The mean ABA of the three genotypes at 0, 1, 3, and 7 days after *B. oryzae* inoculation is presented in Figure 3.a. Baseline ABA levels of the three genotypes were not significantly different. Significant differences on the ABA levels of the 3 genotypes tested were measured starting at 3 until 7 DAI with brown spot pathogen. ABA levels of brown spot resistant genotypes IR64 wild type and D6766 were significantly higher than the ABA of susceptible mutant D10808 at 3 until 7 DAI. Increased ABA activity in the leaf from 3 DAI (colonization stage) until 7 DAI (disease symptoms) appears strongly and positively associated with resistance response of the host. Conversely, the inability of D10808 mutant to increase its ABA level soon after successful penetration of the pathogen (1 DAI) appears associated with its loss of resistance to brown spot.

Abscisic acid content after blast inoculation. The mean ABA of uninoculated and up to 2 DAI of blast pathogen in IR64 wild type, D10808, and D6766 were not significantly different (Fig. 3.b). By 3 DAI, the ABA level of susceptible mutant D6766 and D10808 was significantly lower than IR64 wild type and by 7 DAI, the ABA content of resistant genotype IR64 wild type was significantly higher compared with both susceptible genotypes D10808 and D6766. The ABA level of D10808 and D6766 at 7 DAI were similarly low. Higher leaf ABA at 7 DAI appears strongly and positively associated with resistant reaction to blast disease. Similarity in the inability of the two IR64 mutants to increase ABA activity at 7 DAI could have contributed to their loss of resistance to blast.

Baseline ABA levels of the three genotypes before brown spot and blast inoculation were not significantly different. When inoculated with the brown spot and blast pathogen, significant differences in the ABA levels of the 3 genotypes were observed. Increased ABA was associated positively with resistance response. Starting 3 days after inoculation (colonization stage), differences in ABA of resistant and susceptible genotypes could be detected but significant differences were observed at 7 DAI (disease symptoms appearance). This suggest that ABA assay developed could be used to differentiate and screen resistant and susceptible genotypes.



(a) *B. oryzae* inoculated



(b) *M. oryzae* inoculated

Fig. 3. Comparison of mean ABA in wild type IR64, D10808,and D6766 at different days after inoculation, (A) *B. oryzae* and (B) *M. oryzae.* Columns with the same letter in the same DAI are not significant at $p = 0.5$

CONCLUSION

The abscissic acid assay was effective in differentiating response of rice against brown spot and blast diseases. The optimized protocol are as follows: inoculation (at 18- day- old seedlings using 5 X 10^4 per mL concentration of filtered spore suspension added with .02 % Tween 20), incubation (at humidified room with 25-30ºC for 7 days), extraction (grounding of 7 DAI leaf samples using liquid nitrogen), homogenization (one gram of fresh tissue per sample homogenized with 80% (v/v) methanol and 1 mmol (220 mg)/L butylated hydroxytoluene (BHT), filtration (using C18 column), ELISA (enzyme linked immunosorbent assay kits), and quantification (using UV-VIS spectrophotometer).

The modification of brown spot inoculation protocol used in this study were successful in phenotyping for brown spot disease resistance. This adopted and modified protocol are as follows: ten-days old SM2 isolate cultured and incubated alternately for 12 hours near UV light and 12 hours darkness at 28ºC for 10 days to induce sporulation, collected spores in 50 mL Falcon tube were centrifuged at 2000 rpm for 2 minutes to lessen or removed the toxin in the inoculum, sterile distilled water with tween 20 was poured into the plates and sterilized glass slides were used to scrape the spores form the surface of the agar, the spore suspension was filtered through layers of Muslin cloth and was transferred to a sterile tube, spore concentration was determined using a hemacytometer and spore concentration was 5 X 10^4 per mL. The optimized protocol in this experiment were used in different phenotyping experiment for brown spot disease resistance studies such in 200 indica MAGIC (Multi-parent Advanced Generation Intercross) and 500 out of diverse 3k accessions from T.T. Chang Genetic Resources Center of the International Rice Research Institute. Using the effective protocol in phenotyping, these studies were able to identify putative genes associated for brown spot disease resistance in rice. Further, the protocol was used in genetic analysis and mapping study of the population generated by intermating the mutants D10808 and IR64 wild type that validated the effectivity of the protocol. Using the protocol, the different studies were able to discriminate between resistant and susceptible rice plants.

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SUSCEPTIBILITY OF ONION ARMYWORM, *Spodoptera exigua* (HÜBNER) (LEPIDOPTERA: NOCTUIDAE), LARVAE TO *Spodoptera exigua* MULTIPLE NUCLEOPOLYHEDROVIRUS (SeMNPV)

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ABSTRACT

Bioassays were carried out to determine the effect of *Spodoptera exigua* multiple nucleopolyhedrovirus (SeMNPV) to the different larval instars of *Spodoptera exigua* from May to September 2018 at the National Crop Protection Center, University of the Philippines Los Baños. Fresh castor leaves were treated with crude SeMNPV concentrations of 10^3-10^8 polyhedral inclusion body (PIB)/ml and were fed to five larval instars. Larval mortality increased with increasing crude SeMNPV concentrations. The 1st instar larvae were the most susceptible with >80% mortality, while 10-93% mortality was recorded in older larvae. The virus caused disintegration of larval body and distortion in pupae. Based on probit analysis, lethal dose $(LD)_{50}$ ranged from 7.05 x 10^5 to 1.71 x 10^9 PIB/ml. Higher SeMNPV doses are required to cause lethal infection in older larvae population. The LD_{50} and LD_{95} from 1st to 5th larval instar increased by 94 and 33,333 times, respectively. The virus significantly affected the growth and development of the larvae by prolonging the larval period and decreasing pupation rate (0-60%) and adult emergence (0-40%). Less than 50% of the treated 4th and 5th larval instars pupated and emerged into adults. This research suggests that SeMNPV is infective to various larval instars of *S. exigua* resulting in high mortality and reduced growth and development.

Key words: SeMNPV, onion armyworm, polyhedral inclusion bodies, biological control, *Spodoptera exigua*

INTRODUCTION

Onion armyworm, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae), had an outbreak in onion growing provinces in the Philippines particularly in Nueva Ecija, Pangasinan, and Tarlac in 2016 (Navasero et al. 2017). About 4,089 onion farmers in 14 municipalities with a total land area of 5,330 ha were affected by the pest outbreak. Armyworm infestation resulted in defoliation, blighting, and drying of onion leaves. Other crops such as *Capsicum annuum*, *Cucurbita maxima*, *Momordica charantia*, *Zea mays*, and *Vigna unguiculata* were also damaged by this insect pest (Candano et al. 2019). Likewise, this polyphagous insect was observed in several weed hosts such as *Achyrantes aspera*, *Amaranthus viridis*, *Centrocema pubescens*, *Commelina benghalensis*, *Eleusine indica*, *Synedrella nodiflora*, *Rottboellia cochinchinensis*, and *Tagetes sp*. The severe infestation of armyworm resulted in increased cost in farm production and crop loss.

Long distance migration from other countries northeast of Philippines as triggered by El Niño may have caused the pest outbreak (Navasero et al. 2017). Likewise, misapplication of pesticide and use of smuggled and banned insecticides were believed to contribute to the outbreak of this pest. Onion growers reported that the pest easily withstand chemical spray, which may suggest pesticide resistance development due to malpractices in pesticide application. The control of insect pests such as armyworm is mainly based on the use of chemical insecticides. However, an integrated pest management program (IPM) should be implemented to eliminate reliance to chemical insecticides and possible development of pesticide resistance. Thus, the use of biological control agents must be an option to manage this serious pest. The damage of armyworm is limited by the natural parasitoids and predators (Capinera 2017). The fungal species (*Erynia sp*. and *Nomuraea rileyi*) and nuclear polyhedrosis virus (NPV) also cause larval mortality (Ruberson et al. 1994).

NPVs cause epizootic death to lepidopteran pests by infecting the midgut cells that leads to chronic infection (Kumar et al. 2008). They are host specific and virulent making them promising biological control agents. An in-depth study on the use of NPVs for beet armyworm had been explored by Smits (1987). Among the 5 multiple NPVs evaluated, *S. exigua* multiple NPV (SeMNPV) had the highest biological activity against beet armyworm. The application of SeMNPV at 1 x 10^8 polyhedra/ml resulted in 95-100% larval mortality in chrysanthemum, gerbera, kalanchoe, and tomato crops. SeMNPV was also identified to infect *S. exigua* larvae in the Philippines (Cayabyab, personal communication, 2019). Filtered and crude SeMNPV extracts caused 62.5% and 72% mortality *in vitro*.

With the promise on the use of NPVs in controlling the pest, preliminary studies were conducted to assess the potential of SeMNPV as biological control agent against onion armyworm *in vitro*. Primarily, this research work investigated the effects of SeMNPV on larval mortality and development of *S. exigua*.

MATERIALS AND METHODS

Preparation of crude *Spodoptera exigua* multiple nucleopolyhedrovirus (SeMNPV). SeMNPV infected larvae were macerated and filtered with cheesecloth to prepare the stock suspension. Dilutions were made by adding distilled water to the stock suspension to enable counting of polyhedral inclusion bodies (PIB) using a haemacytometer under 400x magnification. Six (6) concentrations of SeMNPV with 10^3 to 10^8 PIB/ml were prepared by diluting the stock suspension with specific volume of distilled water.

Bioassay procedure. Different concentrations of crude SeMNPV were used in the assays and each was replicated three times. A total of 10 larvae of *S. exigua* were used per instar in each replicate. Ten 1st and 2nd larval instars were initially cultured in sterile disposable Petri plates and were single-cultured when they grew as 3rd instar. For 3rd, 4th, and 5th larval instars, 1 larva was cultured per plate.

Leaf discs of fresh castor leaves were prepared using a cork borer. These leaves were surface sterilized in 0.5% sodium hypochlorite solution for 10 minutes and washed thrice in sterile distilled water (Magholi et al. 2014). After airdrying, leaf discs were dipped in crude concentrations of SeMNPV for 1min then airdried prior to introducing them to the larva. Leaf discs dipped in distilled water were used for control. In each Petri plate, the tested larvae were placed in between castor leaves and allowed to feed for 24h. After which, fresh untreated and surface-sterilized castor leaves were given to the tested larvae daily. The experimental set-up was incubated and overlaid in blotter to maintain humidity under ambient temperature.

Mortality was observed daily until the larvae either died, pupated, or emerged. Percentage mortality was corrected using the equation: $M [\%] = [(t - c)/ (100 - c)] \times 100$, where: M – corrected mortality; c – percentage mortality in controls; t – percentage mortality in treatments (Abbott, 1925). Lethal dose (LD) estimates were calculated using PriProbit ver 1.63. The effect on growth and development of SeMNPV on larval instars of onion armyworm were also observed. Percentage pupation, larval period, and adult emergence were calculated. One-way ANOVA was performed and means were compared using Tukey's Honestly Significant Difference Test (HSD).

RESULTS AND DISCUSSION

Effect of crude SeMNPV on larval mortality of *Spodoptera exigua*. Crude SeMNPV concentrations effectively caused mortality to onion armyworm, *S. exigua*. Mean values of mortality are shown in Figure 1. Increasing concentrations of the virus affected more larvae. Highest mortality was recorded in 1st instar larvae (>80%), which appeared to be the most susceptible stage. Larval mortality ranged from 10-93%, 17-93%, 17-47%, and 57-63% for 2nd, 3rd, 4th, and 5th instars, respectively. Briese (1986) noted that susceptibility of lepidopteran insects to NPVs decreases with age and correlated to the increase in larval weight as development proceeds.

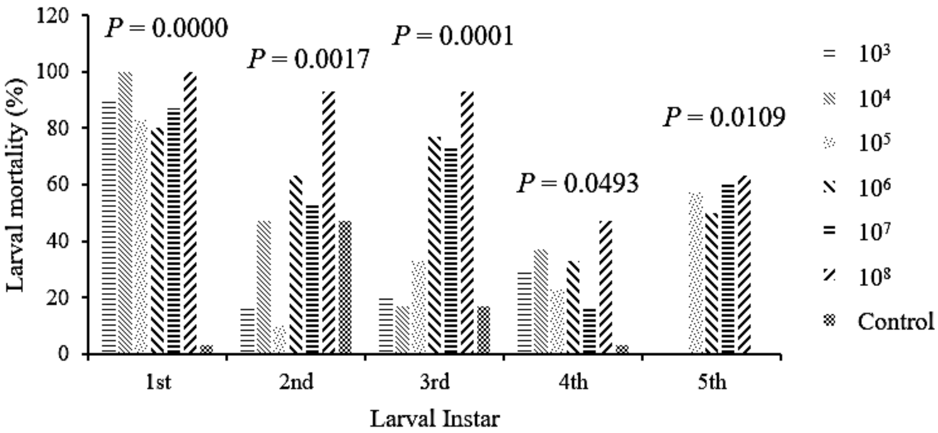

Fig. 1. Mean mortality of different instars of *Spodoptera exigua* larvae due to crude SeMNPV at 7 days after treatment. Means are significant at $P< 0.05$.

Dead larvae showed discoloration of a portion of the larval body (Fig. 2). SeMNPV also caused infection to half of the larval body as well as complete disintegration of the exoskeleton. These observations can be attributed to the infection of the midgut epithelial cells due to ingestion of NPVs along with the food (Smits 1987). The proteinaceous occlusion bodies dissolved under the alkaline conditions (pH >9) in the larval gut allowing the virions to spread and infect the cells and tissues resulting in cell lysis. The infected larvae died several days later after most tissues have been infected and completely disintegrated. In our bioassays, we also observed that infected pupae were distorted and failed to emerge into adults.

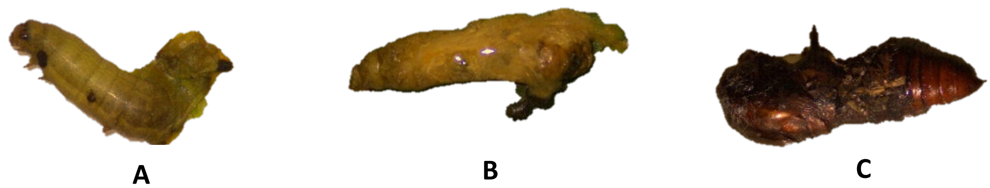

Fig. 2. Pathological appearance of *Spodoptera exigua* due to crude SeMNPV showing infection of half of larval body (a), disintegration of the body (b), and distorted pupa (c).

Probit analysis of mortality resulted in calculation of lethal dose (LD) estimates (Table 1). First instar larvae were susceptible to SeMNPV doses at 1.61 x 10^7 to 2.13 x 10^7 polyhedral inclusion body

(PIB)/ml, which could infect 10-95% of its larval population. However, LD_{10} and LD_{50} values of 1st (1.61 x 10^7 and 1.82 x 10^7 PIB/ml) larval instar are higher than the 2nd (2.53 x 10^5 and 6.70 x 10^6 PIB/ml) and 3rd (8.46 x 10^3 and 7.05 x 10^5 PIB/ml) larval instars. The 1st larval instar is usually one day only (Navasero et al. 2019) and feeds in small amount, hence, the need to be exposed to higher concentration of the virus. Their low feeding ability as compared with older larval instars also imply the need for longer exposure to SeMNPV treated leaves.

Table 1. Calculated lethal dose estimates of crude SeMNPV treated larval instars of *Spodoptera exigua*.

Larval Instar	Lethal Dose (LD) Estimates			Slope	Intercept
	10	50	95		
1st	1.61 x 10^7	1.82 x 10^7	2.13 x 10^7	24.264	-176.155
2nd	2.53 x 10^5	6.70 x 10^6	4.49 x 10^8	0.901	-6.148
3rd	8.46 x 10^3	7.05 x 10^5	2.06 x 10^8	0.667	-3.902
4th	7.66 x 10^7	1.31 x 10^8	2.62 x 10^8	5.481	-44.492
5th	1.56 x 10^7	1.71 x 10^9	7.10 x 10^{11}	0.628	-5.800

The calculated LD estimates also suggest that increasing crude SeMNPV doses are required to kill higher number of larvae in the later stages (4th to 5th instars). Calculated LD_{50} ranged from 7.05 x 10^5 to 1.71 x 10^9 PIB/ml. LD_{50} increased by 94 times from 1st (1.82 x 10^7 PIB/ml) to 5th (1.71 x 10^9 PIB/ml) larval instar. LD_{95} also rose to 33,333 fold from 1st (2.13 x 10^7 PIB/ml) to 5th (7.10 x 10^{11} PIB/ml) larval instar. High LD values calculated in our assay particularly for 5th instar imply that lethal infection at later larval age will occur if older larvae consume more virus-treated foliage and higher virus dosages. This was also observed in *S. exigua* (Smits and Vlak 1988), for *Pieris rapae* granulosis virus (Payne et al. 1981), and for *Mamestra brassicae* MNPV (Evans 1981).

Previous findings support our result on increasing LD values during larval development (Smits 1987; Trang and Chaudhari 2002). Growing larva increases its foliage consumption and changes its feeding behavior resulting in higher intake of polyhedra (Smits 1986). LD_{50} between 1st and 2nd instar of *M. brassicae* larvae rose to about 7 to more than 900 polyhedra with the corresponding MbMNPV (Evans 1981). LD_{50} values for older instars were 5 to 250 times of the 2nd instars. On the other hand, the LC_{50} for *S. litura* increased by 1,500,000 fold from 1 x 10^3 PIB/ml for 2-day old larvae to 1.5 x 10^9 PIB/ml for 8-day old larvae (Trang and Chaudhari 2002). This observation suggests that insects like beet armyworm become less susceptible to SeMNPV with age (Smits and Vlak 1988). The LD_{50} values for *S. exigua* due to SeMNPV were 4, 3, 39, 102, and 11,637 occlusion bodies for the neonate, second-, third-, fourth-, and fifth-instar larvae (Smits and Vlak 1988). On the other hand, reported LD_{50} values for *S. exigua* were 2.5, 11.2, 5.5, 32.4, and 181.8 polyhedral occlusion bodies for neonate, second-, third-, fourth-, and fifth-instar larvae (Takatsuka and Kunimi 2002). The lower calculated LD_{50} of 3rd instar in our experiment conforms with the observation of Takatsuka and Kunimi (2002) wherein the median lethal dose of SeMNPV increased with host instar of *S. exigua* except for the third instar.

The calculated LD_{95} value (7.10 x 10^{11} PIB/ml) for 5th instar in our assay can be explored in field trials to meet the potential field control efficacy. Weekly application of technical grade lyophilized preparation of SeMNPV at rates of 2.5 x 10^{11} and 12.5 x 10^{11} occlusion bodies/ha significantly reduced plant damage due to beet armyworm (Kolodny-Hirsch et al. 1993).

Effect of crude SeMNPV on growth and development of *Spodoptera exigua*. The growth and development of the larval instars were significantly affected by SeMNPV (Fig. 3 to 5). Generally, the virus prolonged the larval duration of *S. exigua*. Larval duration was extended for up to 5 days in virus-infected 3rd and 4th larval instars. Both treated and control 1st instar larvae did not pupate (data not presented). Pupation rate and adult emergence of 2nd to 5th larval instars significantly decreased when treated with crude SeMNPV particularly at higher concentrations. Pupation rate was reduced in SeMNPV treated larvae (0-60.00%) as compared to control (43.33-90.00%). No pupation was observed when treated with higher crude extract at 10^6-10^8 PIB/ml in 2nd instar and 10^7-10^8 PIB/ml in 3rd instar larvae. Likewise, exposure to the virus resulted to less pupae emerging into adults. Adult emergence was remarkably lowered in SeMNPV (0-40.00%) than in control (43.33-66.67%). Less than 50% of the treated larvae pupated and emerged into adults in 4th and 5th larval instars.

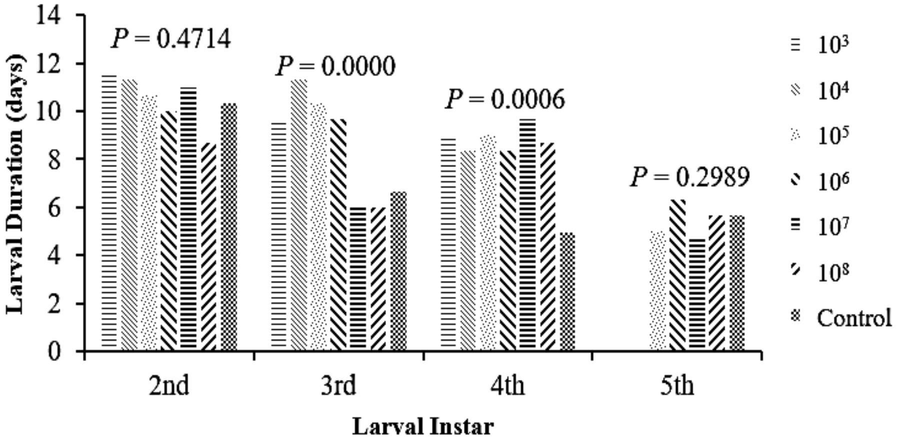

Fig. 3. Mean duration of the larval instars of *Spodoptera exigua* exposed to crude SeMNPV. Means are significant at P< 0.05.

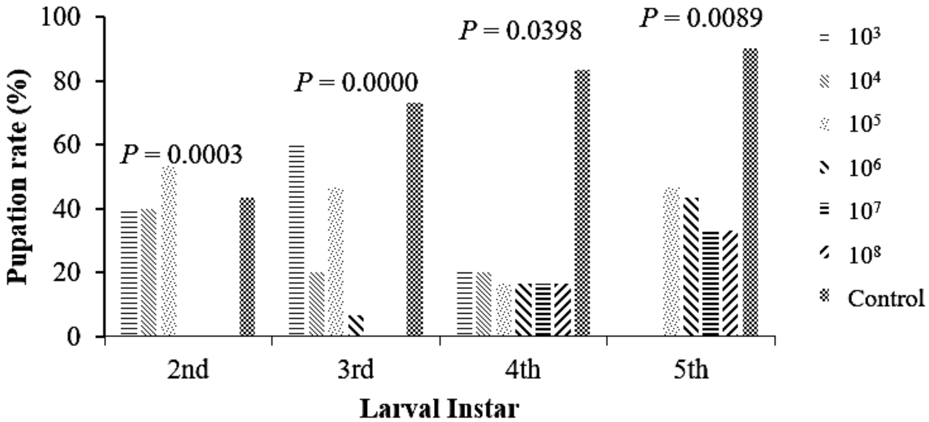

Fig. 4. Mean percent pupation rate of *Spodoptera exigua* exposed to crude SeMNPV. Means are significant at P< 0.05.

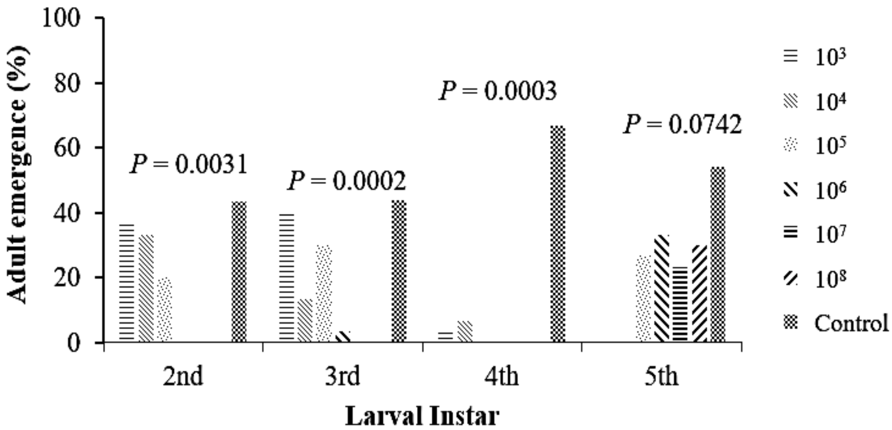

Fig. 5. Mean percent adult emergence of *Spodoptera exigua* exposed to crude SeMNPV in their larval stages. Means are significant at $P< 0.05$.

Our findings on the effect of NPVs in prolonging larval period and reducing pupation rate and adult emergence agree with earlier findings (Magholi et al. 2014). NPV infections result in debilitating effects such as prolonged development, lower pupal weight, and reduced reproductive capacity (egg production and hatching success of eggs) (Rothman and Myers 1996). The impaired development and reproductive success result in an additional 22% reduction in population growth. The prolonged developmental time has great impact on the reduction of the rate of population buildup and allow more time of exposure to the natural enemies, insecticides, and environmental stresses. Likewise, fewer generations per season can be expected due to longer generation time for the insects, hence, less potential damage to crops.

The lethal effect of SeMNPV as shown in our bioassays confirms its potential for *S. exigua* management. SeMNPV was reisolated from beet armyworm populations in California (Gelernter and Federici 1986), Florida (Kolodny-Hirsch et al. 1993), and Japan (Takatsuka and Kunimi 2002). Likewise, the efficacy of SeMNPV has been demonstrated for the control of beet armyworm in several vegetable crops (Kolodny-Hirsch et al. 1993). NPV was also effective against *S. litura* in onion field trials in Bongabon, Nueva Ecija, Philippines in 1993 (Cultural Practice 2019). This microbial along with *Bacillus thuringiensis* (Bt) and NPV + Bt remarkably reduced the larval counts and improved yield than insecticide (Karate) application.

CONCLUSION AND RECOMMENDATION

Spodoptera exigua multiple nucleopolyhedrovirus (SeMNPV) was infective against different larval instars of *Spodoptera exigua* infesting onion. Larval feeding with crude SeMNPV-treated castor leaves resulted in high larval mortality and reduced growth and development. Our significant observations on the potential of SeMNPV as entomopathogen for *S. exigua* implies that this biocontrol agent can be considered as a management option for onion armyworm. Hence, further experiments must be conducted to formulate the SeMNPV and evaluate its control efficacy in the field.

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NUTRIENT DYNAMICS AND UPTAKE OF RICE IN IRRIGATED LOWLAND SOILS OF AGUSAN DEL NORTE SUBJECTED TO EPISODIC FLOODING

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ABSTRACT

The dynamics of N, P, K, Ca and Mg in irrigated lowland soils subjected to episodic flooding and uptake of these nutrients at different growth stages were evaluated in Agusan del Norte, Philippines to address the recurring and persistent problems of nutrient deficiencies resulting in poor crop growth and subsequently low yield. The study was conducted at PhilRice – Agusan Experiment Station for two cropping seasons from June 2017 to March 2018. Five fertilizer treatments were laid out in randomized complete block design and crops were managed following the PalayCheck® system. Nutrients such as N, P, K, Ca and Mg both in soil and plant tissue were collected at various growth stages and analyzed in the laboratory. Unlike N and P, K is the most dynamic in the soil when subjected to flooding. The medium to high level of exchangeable K inherent in the soil can drop to a critical level during flooding but could rise to optimum level after the flooding episodes. Soil total N and available P are high and less affected by flooding incidents. The exchangeable Ca and Mg are very high and resulted in a very wide (Ca + Mg):K ratio of 176:1 and Mg:K ratio of 86:1. The wide exchangeable Mg:K ratio and very low exchangeable Ca:Mg ratio in the soil significantly reduced Mg content at all growth stages, far below the critical limit for rice. Discovering K – induced Mg deficiency in irrigated lowland rice in Agusan del Norte is the breakthrough of this study. Thus, further study on soil K and Mg interactions and their management should be prioritized.

Keywords: nutrient management, nutrient absorption, flooding episodes, imbalanced cations

INTRODUCTION

Rice is grown in bunded fields or paddies that are flooded either from rainwater or through irrigation canals. However, flooding the soil can lead to both increase and decrease in soil nutrient content; thus, soil nutrient dynamics in lowland rice ecosystems are highly complex. During flooding, soil becomes highly reduced or can cause hypoxia, resulting to a decrease in pH of alkaline soils that leads to an increase in the mobility of soil nutrients such as N, P, K, Mg, Ca and Na. The overall effect of submergence is to increase the pH of acid soils and to depress the pH of sodic and calcareous soils. Thus, submergence makes the pH values of acid soils (except those low in iron) and alkaline soils converge to 7. Furthermore, the organic matter decomposition rate is reduced, leading to low soil nutrient content release to plants, thus affecting crop growth and productivity (Ponnamperuma 1972).

In the lowland rice areas of Agusan del Norte for instance particularly in the Philippine Rice Research Institute – Agusan Experiment Station where episodic flooding has been regularly experienced, previous soil analysis indicated that K and S are at sufficient levels while Ca and Mg are at very high levels. However, with the Minus – One Element Technique (MOET) test revealed that K and S are the most deficient based on the growth of the test plants (Nemeño and Paculba 2012). Thus, it is hypothesized that K may be present in the soil at a sufficient level but may be less available for plant uptake due to nutrient imbalance or antagonistic effect with the Ca and Mg level in the soil and presence in the flood water.

Previous studies found that high Ca levels in soils suppress Mg and K uptake by crops because of the competition between Ca, Mg and K (Marschner 1995). An imbalance between plant available Mg, Ca and K ions may lead to Mg and/or K deficiencies to crops. Thus, abundance of soil Ca, Mg, or K may compete uptake of one of the others as recorded by Bergmann (1992). In many lowland rice areas in the region that experience episodic flooding, it has been observed that about two weeks after flood occurrence, the leaves of the rice crops turn dark green, while those at the lower level become yellowish, spotted and brownish and with stunted growth, and poor root development which could be most likely due to K deficiency (Mabayag and Sobrevilla 2012). It is presumed that N and S deficiencies indicated by MOET test, and Ca and Mg toxicities found in soil laboratory analyses aggravate K deficiency due to the flooding event. Until now, the real causes of these abnormalities in crop growth are not yet clear since there is no sufficient data to pinpoint the real and specific cause. No documentation and characterization study have been conducted yet to determine the impact of episodic flooding on nutrient dynamics, availability and uptake in irrigated lowland rice soils in the station.

Thus, the study was conducted to evaluate the impacts of episodic flooding and fertilizer management on nutrient dynamics and uptake of major nutrients in irrigated lowlands of Agusan del Norte. Specifically, it aimed to (1) investigate the effects of episodic flooding on the soil chemical properties, dynamics and levels of N, P, K, Ca and Mg in the soil; and (2) examine the variation in N, P, K, Ca and Mg uptake as influenced by nutrient management at various growth stages.

MATERIALS AND METHODS

Field study. A field experiment was conducted at Philippine Rice Research Institute – Agusan Experiment Station (125°34.951' E 09°03.935'N) in Barangay Basilisa, municipality of Remedios T. Romualdez, Agusan del Norte province, Philippines for two cropping seasons from June 2017 to March 2018. One cropping during wet season (WS) or relatively drier season was conducted on June to October 2017 (2017 WS) and one cropping for very wet season (VWS) was conducted from December 2017 to March 2018 (2018 VWS).

Site description. The experimental area is a very flat (0 – 1 % slope) alluvial fan which is elevated at 14 masl. The soils were developed from the shale-sandstone, either old or new alluvium, and limestone as parent materials (Fernandez and Clar de Jesus 1980). Recent soil survey conducted identified the soils as Butuan series which developed from the older alluvial terraces (Collado and Obico 2007). The Caraga region, situated in the northern part Mindanao, has Type II climatic condition. It is characterized as having no distinct dry season with very pronounced rainfall during the months of November to April and wet during the rest of the months. Total rainfall peaked in the month of November and remained continuously high in December and January ranging from 120 to 280 mm wherein episodic floods occurred at least twice during this period. Lowest total rainfall or relatively drier months were observed in the months of March to April (45 – 70 mm) and August to September (85 – 90 mm).

Treatments. Four fertilizer treatments were laid out in randomized complete block design and replicated four times (Gomez and Gomez, 1984). The following treatments were imposed in each bunded plot measured at 5 x 5 m (25 m^2):

T1 – No fertilizer (Control);
T2 – 76-30-60 kg NPK ha^{-1} (2 splits, K) for 2017WS; 53-30-60 kg NPK ha^{-1} (2 splits, K) for 2018 VWS (Recommended NPK fertilizer rate for irrigated rice in the area) N applied based on Leaf Color Chart (LCC) reading, P was applied at 14 days after transplanting (DAT), K applied in 2 splits (50% at 14 DAT; 50% at 5 days before panicle initiation);
T3 – 76-30-60 kg NPK ha^{-1} (3 splits, K) for 2017WS; 53-30-60 kg NPK ha^{-1} (3 splits, K) for 2018 VWS
N applied based on LCC reading, P was applied at 14 DAT, K applied in 3 splits (50% at 14 DAT, 25% at 5 days before panicle initiation, and 25% applied at early flowering stage);
T4 – 53-7-37 kg NPK ha^{-1} (NPK fertilizer applied based on the documented farmers' best practice in the municipality wherein N and K fertilizers were applied in two equal splits (50% at 20 DAT, and 50% at panicle initiation stage or 35 DAT), and all P was applied at 20 DAT).

Cultural management practices. All cultural management practices and key checks recommended in the PalayCheck® System (PhilRice and FAO 2007) were strictly followed except for fertilizer management as earlier detailed. High quality seeds of a commonly planted in the area and early maturing variety - PSB Rc82 (Peñaranda) was planted for two cropping seasons.

Soil characteristics. Composite soil samples were collected before planting (initial), during active tillering, panicle initiation, flowering, and at physiological maturity stage of the crop using PVC pipe with 4" diameter and 10" long, and analyzed at Region 13 Soils Laboratory and University of the Philippines – Agricultural Systems Institute, Analytical Soils Laboratory. For the initial soil samples, soil analysis for pH was prepared in 1:1 soil to water ratio and measured with a glass electrode, organic matter was determined using Walkley and Black method, total N was analyzed using Kjeldahl method, available P was measured using the Olsen P method. The exchangeable K, Ca, and Mg were extracted by 1N ammonium acetate (NH_4OAc) and determined using a flame photometer (K) and EDTA titration for Ca and Mg. The available Zn and Cu were extracted with DTPA extracting solution and determined using the atomic absorption spectrophotometer (AAS). For soil samples taken during active tillering, panicle initiation, flowering, and at physiological maturity stage, only N, P, K Ca and Mg were analyzed following the same methods mentioned above.

Plant tissue concentration and uptake. Plant tissue samples were collected in four hills per plot during active tillering, panicle initiation, flowering, and at physiological maturity stage of the crop. Samples were oven-dried at 60 - 70°C for two to three days, weighed and grinded. Plant tissues were treated with nitric and sulfuric acid, and dry ashing was done in the furnace at 500ºC for 4-8 hours. The total N of the plant tissue both the grains and rice straw samples were determined using Kjeldahl method. The total P was determined through the Vanadomolybdate method and measured in spectrophotometer at 460 nm. The total K was determined using a flame photometer (Model No. 410, Sherwood) while Ca and Mg were measured using an atomic absorption spectrophotometer (Model No. 400, Perkin Elmer) (Perkin-Elmer 1996).

Nitrogen, P, K, Ca and Mg uptake in straws or grains (kg ha^{-1}) were computed using the formula:

$$\frac{\text{Nutrient conc in grain or straw (\%) x dry matter of grain or straw (kg ha}^{-1}\text{)}}{100}$$

Data analysis and interpretation. All data gathered were subjected to ANOVA (Gomez and Gomez 1984) using Statistical Tool for Agricultural Research software developed by the International Rice Research Institute and treatment means were compared using LSD at 5 % level of significance.

RESULTS AND DISCUSSION

Soil characteristics. The experimental area had a clay loam soil texture with slightly acidic pH (6.60). The soil is considered fertile with very high organic matter content (3.7%) and medium total N content (0.35%). Exchangeable K is high for irrigated rice at 0.44 $cmol_c\ kg^{-1}$ and available Olsen phosphorus is very high for acid soils with 25 mg kg^{-1}. Both Ca and Mg are very high at 37.97 and 37.79 $cmol_c\ kg^{-1}$, respectively. Micronutrients such as Cu and Zn are below average and very low, at 3.66 and 0.48 mg kg^{-1}, respectively (Table 1).

Table 1. Particle size distribution and chemical characteristics of the soil in the experimental area before planting

Soil Properties	Butuan Soil Series	Critical Level/ Range*
Particle size distribution		
% sand	22.1	
% silt	49.4	
% clay	28.2	
Texture	Clay loam	
pH	6.6	5.5-6.5
Organic matter content (%)	3.7	2.0-3.0
Total Nitrogen (%)	0.35	0.1-0.15
Available Olsen P (mg kg^{-1})	25	5.0 (acid soils) >25.0 (calcareous soils)
Exch. K ($cmol_c\ kg^{-1}$ soil)	0.44	0.20 $cmol_c\ kg^{-1}$
Calcium ($cmol_c\ kg^{-1}$ soil)	37.97	< 1 $cmol_c\ kg^{-1}$
Magnesium ($cmol_c\ kg^{-1}$ soil)	37.79	< 1 $cmol_c\ kg^{-1}$
Zinc (mg kg^{-1})	0.48	0.6 – 0.8 mg kg^{-1}
Copper (mg kg^{-1})	3.66	0.2 – 0.3 mg kg^{-1}

* *Source: Dobermann, A. and T. Fairhurst. 2000. Rice Nutrient Disorders and Nutrient Management. 1st Ed. International Rice Research Institute, Los Baños, Laguna, Philippines. 191 pp.*

Mg content in the soil was 13 times higher than the normal level of 1 $cmol_c\ kg^{-1}$. The excess Mg level derived from ultrabasic rocks of Mt. Hilong-hilong resulted in a Ca:Mg ratio of 1:1. The normal Ca:Mg ratio in the soil is between 3 – 4:1 (Dobermann and Fairhurst 2000). Calcium concentration in the soil was 37 times higher than the normal level of 1 $cmol_c\ kg^{-1}$ soil. The combined high levels of Ca and Mg in the irrigated lowland soils in Agusan del Norte resulted in wide (Ca + Mg):K ratio of 176:1. The ideal soil should be one with an exchangeable cation distribution of 65% Ca^{2+}, 10% Mg^{2+}, 5% K^{+}, and 20% H^{+} (13:2:1 Ca^{2+}:Mg^{2+}:K^{+} ratio; 6.5:1 Ca^{2+}:Mg^{2+} ratio) (Bear and Prince 1945). A ratio greater than 100 will result in stronger K adsorption to cation exchange sites and reduce the concentration of K in the soil solution (Dobermann and Fairhurst 2000). Moreover, the abundance of soil Ca and Mg may compete uptake of K and other cations in the exchange sites. Thus, this unbalanced cation ratio is believed to be the one of the major causes of soil nutrient problem in Agusan del Norte.

The soils grown with irrigated rice in the north east and mid-east part of Agusan del Norte province developed from the shale-sandstone, either old or new alluvium, and limestone as parent materials (Fernandez and Clar de Jesus 1980). The high concentration of Ca and Mg in Butuan soil series is inherent in soils derived from ultrabasic and/or ultramafic rocks. This condition is further aggravated by the continuous deposition of these cations carried by the floodwaters every flooding events. The pH of flood water slightly increased to 8.10 which could be attributed to the presence of calcium, magnesium and bicarbonate in the irrigation water. If this trend will continue with each flooding event, the accumulation of sediments could further increase the water pH, making many nutrients less available.

Soil nutrient dynamics. The soil NPK dynamics recorded at various soil conditions and growth stages of rice are summarized in Table 2.

Table 2. Nitrogen, P and K dynamics in the soil as influenced by NPK fertilizer application at various growth stages of rice for two cropping seasons

Fertilizer Management	Nitrogen (%)		Phosphorus (mg kg^{-1})		Potassium (cmol$_c$ kg^{-1} soil)	
	2017 WS	2018 VWS	2017 WS	2018 VWS	2017 WS	2018 VWS
Active Tillering	***ns***	***ns***	***ns***	***ns***	*	**
T$_1$: Control	0.36	0.38	26	26	0.46ab	0.30a
T$_2$: 76-30-60 kg NPK ha^{-1} (2 splits, K)	0.33	0.34	26	34	0.49a	0.14b
T$_3$: 76-30-60 kg NPK ha^{-1} (3 splits, K)	0.35	0.33	24	27	0.34bc	0.13b
T$_4$: 53-7-37 kg NPK ha^{-1}	0.34	0.33	23	30	0.26c	0.12b
Mean	**0.35**	**0.35**	**25**	**29**	**0.39**	**0.17**
Panicle Initiation	***ns***	***ns***	***ns***	***ns***	**	**
T$_1$: Control	0.34	0.34	29	22	0.23b	0.33b
T$_2$: 76-30-60 kg N$^{\pm}$PK ha^{-1} (2 splits, K)	0.34	0.34	29	23	0.21b	0.41a
T$_3$: 76-30-60 kg N$^{\pm}$PK ha^{-1} (3 splits, K)	0.34	0.34	30	23	0.30a	0.40a
T$_4$: 53-7-37 kg NPK ha^{-1}	0.35	0.33	29	23	0.32a	0.39a
Mean	**0.34**	**0.34**	**29**	**23**	**0.27**	**0.38**
Flowering	***ns***	**	***ns***	***ns***	***ns***	***ns***
T$_1$: Control	0.30	0.33b	28	21	0.14	0.32
T$_2$: 76-30-60 kg N$^{\pm}$PK ha^{-1} (2 splits, K)	0.35	0.35a	29	25	0.14	0.40
T$_3$: 76-30-60 kg N$^{\pm}$PK ha^{-1} (3 splits, K)	0.35	0.35a	27	22	0.13	0.35
T$_4$: 53-7-37 kg NPK ha^{-1}	0.34	0.34a	26	20	0.12	0.35
Mean	**0.33**	**0.34**	**27**	**22**	**0.13**	**0.35**
Physiological Maturity	***ns***	**	***ns***	***ns***	***ns***	***ns***
T$_1$: Control	0.30	0.34b	28	22	0.12	0.28
T$_2$: 76-30-60 kg N$^{\pm}$PK ha^{-1} (2 splits, K)	0.33	0.33c	30	25	0.14	0.35
T$_3$: 76-30-60 kg N$^{\pm}$PK ha^{-1} (3 splits, K)	0.33	0.36a	29	21	0.14	0.29
T$_4$: 53-7-37 kg NPK ha^{-1}	0.32	0.36a	27	21	0.11	0.29
Mean	**0.30**	**0.35**	**29**	**22**	**0.13**	**0.30**

* In a column, means followed by the same letter are not significantly different at 5% level of significance by LSD.

$^{\pm}$ LCC-based N rate applied in T$_2$ and T$_3$ plots during 2018 VWS was 53 kg N ha-^{1} only

Total nitrogen. Nitrogen dynamics in the soil recorded at various growth stages during 2017 WS (no episodic flooding) was not affected by fertilizer management. However, during the 2018 VWS, the combined effects of episodic flooding and fertilizer management were significant particularly during flowering and physiological maturity stage of rice. Nitrogen content in the soil ranging from 0.30 to 0.36 % was considered above the critical level for irrigated rice at 0.10 - 0.15% set by Dobermann and Fairhurst (2000). In unfertilized plots (T1), N level markedly decreased from 0.36 to 0.30% and from 0.38 to 0.34% during 2017 WS and 2018 VWS, respectively. The decrease observed in unfertilized plots was more rapid and continuous during 2017 WS (0.30%) which was relatively drier season compared to the 2018 VWS (0.35%).

The combined effects of episodic flooding and fertilizer management were significant at flowering and physiological maturity stage of rice in 2018 VWS. The soil N concentration was significantly higher in plots applied with LCC-based N (T3: 53 kg ha^{-1} plus 3 splits of K) and in farmers best practice plots (T4: 53 kg N ha^{-1} and 37 kg K_2O ha^{-1}). On the other hand, increasing the rate of N fertilizer application up to 76 kg N ha^{-1} (T2 and T3) applied based on LCC reading did not improve the level of soil N compared to the unfertilized plot (T1) throughout the 2017 WS. Although the observed soil N level during 2018 VWS was higher and the trend was decreasing towards crop maturity, but the recorded change was more or less steady compared to the previous cropping (2017 WS). This trend is generally observed in rice crops because N is equally important in the grain formation, grain filling, and protein synthesis at reproductive stage (Dobermann and Fairhurst 2000), thus ensuring N availability for plant uptake using LCC is vital.

In general, results indicated that both the indigenous N supply in the soil and the applied N were utilized by the plants to support the nutrient needs for plant growth and development. In untreated plots, since there was no other fertilizer supplied to the soil, the rapid decrease in soil N was expected as rice crop needs to take up at least 15-20 kg N to produce one ton of grain per hectare (Dobermann and Fairhurst 2000). It was observed that N level in the unfertilized plots could already support at least 4.6 t ha^{-1} grain yield both in wet and very wet cropping seasons. The results revealed that the indigenous N supply in the soils of Agusan del Norte is still very high, ranging from 65 to 90 kg ha^{-1}.

Available Olsen phosphorus. Generally, the dynamics of P in the soil was not affected by episodic flooding events and different P fertilizer rates applied (Table 2). Soil P recorded at various crop growth stages during the 2017 WS showed an increasing trend starting at panicle initiation to physiological maturity stage. Although P containing fertilizer was applied at 15 DAT or at early tillering stage, soil P concentration remained at 25 mg kg^{-1}. This trend is expected since P is needed by the crop at early stage to extend and strengthen the root anchorage into the soil system so that it could take up more nutrients to produce more tillers. On the contrary, soil P showed a decreasing trend during 2018 VWS. The P concentration in the soil continuously declined from the initial value of 25 mg kg^{-1} observed after fallow period or before planting to 22 mg kg^{-1} at flowering to physiological maturity stage. The decreasing trend observed in 2018 VWS where solar radiation and temperature were low was consistent with the observations of Dobermann and Fairhurst (2000). They observed that P is mobile in the plant and promotes tillering, root development, early flowering and ripening especially where the temperature is low. Furthermore, the results revealed that P fertilizer application did not influence P concentration in the soil even when applied at 30 kg ha^{-1} (T2 and T3). This is because inherent P content of irrigated lowland soils of Agusan del Norte is already high. Rice grain yield in unfertilized plot (T1) was 4.6 t ha^{-1}, which implies that the crop was able to take up at least 9 to 14 kg of P, which is lower than the available P in the soil. Even when P was not applied, the P level in the soil was high at 28 and 22 mg kg^{-1} during 2017 WS and 2018 VWS, respectively. Therefore, P fertilizer application could only be applied as maintenance fertilizer only to avoid nutrient mining in the soil.

Exchangeable potassium. Among the macronutrients, K is the most dynamic in the soil system and was significantly influenced by the fertilizer management and episodic flooding occurrence specifically during active tillering to panicle initiation stage (Table 2). During 2017 WS, highest K of 0.49 $cmol_c$ kg^{-1} (tillering stage) was obtained in plots applied with 60 kg K_2O ha^{-1} added in two splits (T2) but the level significantly decreased to 0.21 $cmol_c$ kg^{-1} at panicle initiation stage. For the 2018 VWS, it was noted that at active tillering stage, high level of soil K at 0.30 $cmol_c$ kg^{-1} was obtained from the unfertilized plots (T1) compared in the soils applied with K_2O fertilizer (15 to 30 kg K_2O ha^{-1} per split) (T2 and T3). The application of K-containing fertilizer at early tillering stage or at 15 DAT wherein flooding episodes occurred temporarily decreased the availability of K in the soil. The recorded decrease of 40 - 47 % was obtained causing the reduction drops below the critical level of < 0.20 $cmol_c$ kg^{-1}. It was markedly observed that K fertilizer added at 15 DAT negatively affects the K concentration level in the soil, ranging from 0.12 to 0.14 $cmol_c$ kg^{-1} only. The results revealed that episodic flooding events impacted the soil K level during flooding events from fallow period up to the tillering stage possibly due to the imbalanced levels of other nutrients deposited during flooding as well as the sediments, particularly Ca and Mg which could inhibit K availability.

Potassium is the most affected macronutrient required by plants when soil is subjected to episodic flooding. The medium to high exchangeable K inherent in the soil can drop to critical levels during flooding but could rise to optimum level after the flooding episodes. Between the two cropping seasons, soil K dynamics was more stable in 2018 VWS when episodic floods occurred as compared to 2017 WS which was a relatively drier season. The soil K concentration during 2017 WS markedly decreased during flowering to crop maturity stage ranging from 0.12 to 0.14 $cmol_c$ kg^{-1} which is already below the critical limit for rice at 0.20 $cmol_c$ kg^{-1} (Dobermann and Fairhurst 2000). The significant K declined in the soil could be due to high absorption of K from transplanting and continued till the dough stage and in some cases, up to maturity as observed in the previous researches (Ishizuka and Tanaka 1952; Mohanty and Patnaik 1974). The results also suggested that at flowering stage K is most needed by the rice plant and this is the critical stage of the crop where K should be managed properly. Among the major macronutrients, K is the most depleted nutrient in the soil since rice can take up K in luxury consumption. This could be the reason why there is a very low soil K balance for the next cropping or 2018 VWS. However, high soil K balance ranging from 0.28 to 0.40 $cmol_c$ kg^{-1} after harvest of the second crop (2018 VWS) regardless of rate and time of application. This could further be improved during fallow period when rice straws are recycled and incorporated back into the soil particularly when there is no episodic flooding event.

In general, episodic flooding occurring as early as during fallow period until maximum tillering stage of rice in the area, inhibits the availability of K. Supposedly, K is expected to increase as rice straws, stubbles and other organic materials decompose and undergo mineralization during fallow period. Although a slight increase was observed from 0.13 to 0.17 $cmol_c$ kg^{-1} soil, it was still below the critical limit (20 $cmol_c$ kg^{-1}). This could be the reason why severe K deficiency symptom was observed around 2-3 weeks after episodic flooding or during tillering stage of rice in affected fields (Nemeño and Paculba 2012). Like N, rice plants need at least 15 – 20 kg K to yield one t ha^{-1}. The results also revealed that inherent K status in the soil is very high ranging from 65 to 90 kg ha^{-1}. Thus, K fertilizer application is needed only to maintain the K balance in the soil and avoid K mining.

Exchangeable calcium and magnesium. Results of laboratory analysis during 2018 VWS showed that Ca and Mg concentration in Agusan soils (Butuan clay loam) are very high (Table 3).

At panicle initiation or after the flooding events, exchangeable Ca ranged from 25.68 to 28.14 $cmol_c$ kg^{-1}, and exchangeable Mg ranged from 21.30 to 24.30 $cmol_c$ kg^{-1}. High exchangeable Mg in the soil resulted in imbalanced Ca:Mg ratios of 1.1:1 and 1.2:1 at panicle initiation and at flowering stage, respectively. The ratio of Ca, Mg and K (Ca+Mg:K, K:Mg, Ca:Mg and Ca:K) in the soil is the most important because in case of excess concentration of one element, the uptake of the other elements is inhibited. The ideal ratio of Ca:Mg in the soil should be 3-4:1 for normal plant growth and the correct ratio of K, Ca and Mg in the soil is important because excessive concentrations of either element can affect negatively plant growth (Dobermann and Fairhurst 2000). Thus, Ca and Mg ratio in the soil should be improved and kept at the ideal ratio by increasing available Mg through fertilizer management or integrated crop management.

At physiological maturity stage, application of 60 kg K_2O ha^{-1} fertilizer (T3) applied in three splits decreased significantly Mg concentration in the soil with 15.33 $cmol_c$ kg^{-1} compared with the control (21.42 $cmol_c$ kg^{-1}). In contrast, this application resulted in increased Ca level in the soil. Moreover, the ratio of Ca:Mg increased ranging from 1.4:1 to 1.8:1 when K fertilizers were applied (T2 – T4) in two to three splits compared to 1.1:1 in unfertilized plots (T1). The increased Ca level observed in the soil could be attributed to the inhibition of Mg with K application. K^+ competes with Mg^{2+} in the apoplast binding sites, and possibly competes for transporters (Grauer and Horst 1992). Some Mg transporters may also transport other cations like K. As a consequence, a high plant available K concentration in the soil/rhizosphere blocks these unspecific Mg transporters for Mg uptake.

Table 3. Ca and Mg concentration (cmolc kg^{-1} soil) and ratio in the soil at various growth stages of rice as influenced by NPK fertilizer application in 2018 VWS

Fertilizer Application	Calcium	Magnesium	Mg:K Ratio	Ca:Mg Ratio	(Ca+Mg):K Ratio
	($cmol_c$ kg^{-1} soil)				
Panicle Initiation	**ns**	**ns**			
T1: Control	27.34	22.5	68 :1	1.2:1	151 :1
T2: 76-30-60 kg NPK ha^{-1} (2 splits, K)	27.14	24.3	59 :1	1.1:1	125 :1
T3: 76-30-60 kg NPK ha^{-1} (3 splits, K)	25.89	22.64	57 :1	1.1:1	121 :1
T4: 53-7-37 kg NPK ha^{-1}	25.68	22.91	59 :1	1.1:1	125 :1
Mean	*26.5*	*23.1*	*61 :1*	*1.1:1*	*131 :1*
Flowering	**ns**	**ns**			
T1: Control	28.09	21.38	67 :1	1.3:1	155 :1
T2: 76-30-60 kg NPK ha^{-1} (2 splits, K)	28.14	22.48	56 :1	1.3:1	127 :1
T3: 76-30-60 kg NPK ha^{-1} (3 splits, K)	27.98	23.08	66 :1	1.2:1	146 :1
T4: 53-7-37 kg NPK ha^{-1}	27.07	23.68	68 :1	1.1:1	145 :1
Mean	*27.8*	*22.7*	*65 :1*	*1.2:1*	*144 :1*
Physiological Maturity	**	*			
T1: Control	24.20b	21.42a	77 :1	1.1:1	163 :1
T2: 76-30-60 kg NPK ha^{-1} (2 splits, K)	24.88b	17.65ab	50 :1	1.4:1	122 :1
T3: 76-30-60 kg NPK ha^{-1} (3 splits, K)	27.48a	15.33b	53 :1	1.8:1	148 :1
T4: 53-7-37 kg NPK ha^{-1}	26.80a	18.23ab	63 :1	1.5:1	155 :1
Mean	*25.84*	*18.16*	*61 :1*	*1.4:1*	*147 :1*

* In a column, means followed by the same letter are not significantly different at 5% level of significance by LSD.

Crop Nutrient Uptake

Nitrogen uptake. The effect of fertilizer management on the total N uptake of rice plant was significant at the active tillering and flowering stage during 2017 WS. But in 2018 VWS, the combined effects of episodic flooding and fertilizer management statistically differed from panicle initiation to physiological maturity stage of rice (Fig. 1).

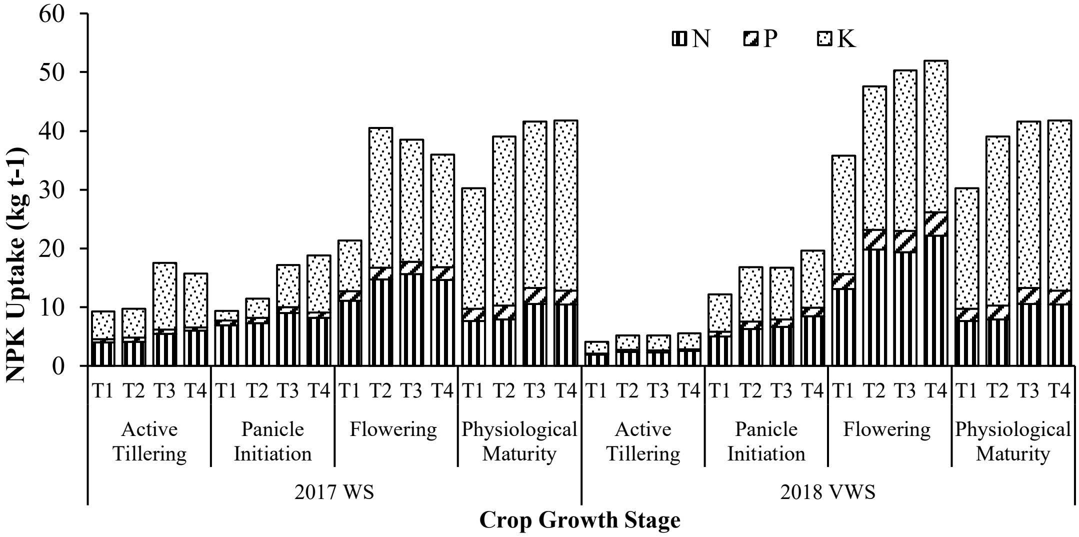

Fig. 1. Total NPK uptake (kg t-1) of rice at various growth stages as influenced by NPK fertilizer application for two cropping seasons.

The N uptake of plants applied with LCC-based N fertilizer (T2 and T3) and based on farmers best practice (T4) showed an increasing trend. In 2017 WS, the application of N ranging from 53 (T4) to 76 kg N ha^{-1} (T2 and T3) resulted in higher N uptake at active tillering stage at 5.44 and 5.99 kg t^{-1} yield compared to controlled plants (T1) with 4.02 kg t^{-1} only. Moreover, at the flowering stage where N requirement is higher, the effect of applied N was statistically higher compared to controlled plants. The uptake significantly increased at 29% in T2, 36 % in T3 and 32% in T4 when additional N fertilizer was applied. In 2018 VWS, the occurrence of episodic flooding was observed to affect the N uptake during tillering stage of rice in controlled plots. Nitrogen uptake obtained at active tillering stage was very low at 1.90 kg t^{-1}. Low N uptake was attributed to the low biomass production during the early to active tillering stage of rice due to flooding episodes. Although, N uptake at panicle initiation, flowering and physiological maturity stage increased at 4.98 kg t^{-1}, 9.56 kg t^{-1} and 13.11 kg t^{-1}, respectively, but it is significantly lower compared to treated plots. This is considered critical since the average N uptake in straw is 7 kg t^{-1} (Dobermann and Fairhurst 2000). Nitrogen is important at early stage since it promotes rapid growth (i.e. increased plant height and number of tillers) and increased leaf size. Moreover, it is also needed at reproductive stage to increase spikelet number per panicle, percentage of filled spikelet in each panicle and grain protein content (Dobermann and Fairhurst 2000).

Overall, N is an important nutrient that could affect all parameters contributing to yield, thus, N application of 23 kg ha^{-1} at early panicle initiation stage (T4) and early flowering stage (T2 & T3) allowed the plant to take up more N. These applications significantly enhanced the average N uptake of rice at flowering (15.09 kg t^{-1}) and physiological maturity stage (20.43 kg t^{-1}) compared to unfertilized plots (9.56 and 13.11 kg t^{-1}, respectively). Moreover, N uptake of rice was higher during 2017 WS when N rate applied at 76 kg N ha^{-1} compared to 2018 VWS. The difference observed could be attributed to lower LCC-based N fertilizer rate applied at 53 kg N ha^{-1} (T2 & T3) in 2018 VWS. Higher N uptake in plots applied with 53 kg N ha^{-1} (T4) based on farmers' best practice implied that plants were able to optimize the applied N during this growth stage wherein total rainfall decreased and solar radiation slightly increased favoring the physiological activity of the crop. According to Fageria et al. (2006), solar radiation is one of the most important factors of improving crop productivity owing to its direct affects in plant growth through the rate of photosynthesis. At early stage of the crop, photosynthesis products are primarily used in building plant tissues. As the crop matures, these chemical products of photosynthesis are translocated to sites of utilization and are incorporated into plant parts of economic interest i.e., grain in cereal crops. N fertilizer application at 53 kg ha^{-1} (T4) is already sufficient rate that could enhance N uptake for both cropping seasons. The total N taken up by the plants in soil was high at 75 kg N ha^{-1} and 60 kg N ha^{-1} for 2017 WS and 2018 VWS, respectively. Increasing N rate or application based on LCC reading was comparable to farmers' best practice (T4) but it is not economically sound. Thus, lower N rate is more practical and economical particularly in areas where indigenous soil N is high and climatic condition limits the photosynthetic activity in plants.

Phosphorus uptake. The P uptake of rice was significantly affected by episodic flooding and fertilizer management. Like N, P uptake of rice was reduced during flooding due to reduced biomass produced by the plant in soil subjected to flooding or when the soil is highly reduced. In 2017 WS, the effect of applied P was significant during flowering stage only with values ranging from 2.01 to 2.23 kg P t^{-1} yield. In 2018 VWS, effect of P application significantly different from tillering to harvesting. Phosphorus uptake reduced to at least 0.30 kg t^{-1} during 2018 VWS compared during 2017 WS with 0.62 kg t^{-1}.

This could be one of the reasons of reduced tillering when the soil is subjected to episodic flooding. The observed trend is important since P is particularly needed by the plant during early tillering stage to promote root development and tillering. It is also needed by the plant during reproductive stage for early flowering and ripening of rice (Dobermann and Fairhurst 2000). Thus, high P availability for high P uptake is needed during these critical stages of rice. Overall, the P uptake was consistently high in plots applied with 7 kg P_2O_5 ha^{-1} fertilizer rate (T4), which is comparable to those with 30 kg P_2O_5 ha^{-1} (T2 and T3). The results proved that inherent P status in the soil is high.

Potassium uptake. Among the macronutrients, K was the most affected nutrient when the soil was subjected to flooding episodes. It was observed that rice response to different K fertilizer management was significant during 2017 WS from active tiller to physiological maturity stage of the crop. At active tillering stage, highest K uptake was recorded in plants applied with 60 kg K_2O ha^{-1} (T3) and 37 kg K_2O ha^{-1} (T4) with 11.40 and 9.16 kg t^{-1}, respectively. It was also noted that in T2 the amount of K taken up by rice plants during flowering (11.50 kg t^{-1}) and physiological maturity stage (23.76 kg t^{-1}) was comparable. In 2018 VWS, the episodic flooding events affected the K uptake of plants from tillering until flowering stage. Although, the uptake markedly increased at the physiological maturity stage, this might have been too late to improve the yield–promoting parameters. The combined effects of fertilizer management and episodic flooding on rice K uptake was evident in the early stage wherein a lower amount of K uptake was recorded compared with the previous cropping. During this stage also, the crop was exposed to a series of flooding events causing soil K concentration to drop at below the critical level of 0.05 to 0.20 $cmol_c$ kg^{-1} soil. This could be the result of high Ca and Mg carried by the irrigation and floodwaters deposited in the soil, causing imbalanced Ca:Mg:K ratio.

The application of 60 kg K_2O ha^{-1} in two (T2) and three (T3) splits and 37 kg K_2O ha^{-1} applied in two splits (T4) further increased K uptake in both cropping seasons but K uptake recorded in unfertilized plots was also high. In general, K uptake of rice increased as the crop approached to physiological maturity stage. Since K does not have pronounced effect on tillering, K in rice is needed during reproductive to flowering stage to increase the number of spikelet per panicle, percentage of filled grains and 1000-grain weight (Dobermann and Fairhurst 2000). In fact, K uptake of rice during physiological maturity was doubled from the absorbed K at flowering stage for both cropping seasons.

The inherent K supply in the soil is high which is equivalent to 70 kg K per 4.6 t ha^{-1} grain yield in 2017 WS and 90 kg K per 4.6 t ha^{-1} grain yield during 2018 VWS. Thus, application of 53 – 7 – 37 kg N P_2O_5 K_2O ha^{-1} (T4) or even lower was found to be the appropriate and practical fertilizer rate under Agusan del Norte soil and climatic condition. This can increase the availability of soil NPK and enhance NPK uptake which can improve crop growth and productivity. The inherent fertility of Butuan soil is high; applying NPK fertilizer beyond this rate could further enhance grain yield but it is not an economical and sustainable practice. In addition, increasing K fertilizer application in soils high in Ca and Mg content could aggravate nutrient imbalance particularly Mg due to its antagonistic effects.

Synergistic and antagonistic effects of potassium. The effects of K to Ca and Mg obtained at various growth stages of rice and in grains are presented in Figure 2. The synergistic effects of K with Ca and the antagonistic effects of K on Mg were observed in the study.

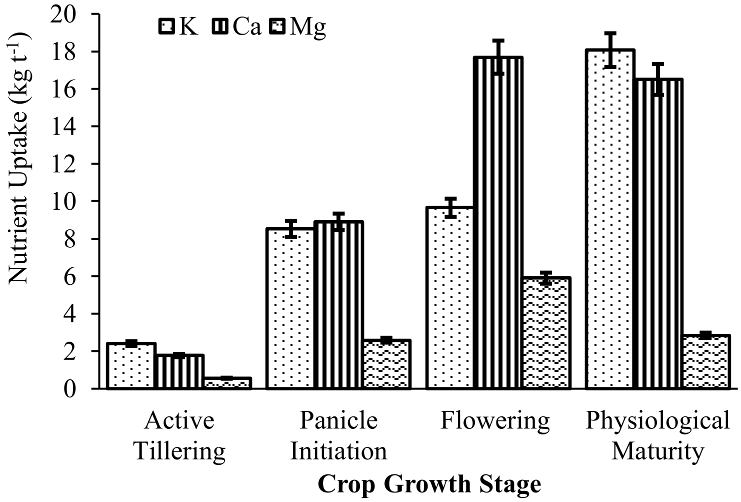

Fig. 2. Potassium, Ca and Mg uptake of rice at various growth stages as affected by different fertilizer management during 2018 VWS.

As K uptake increased, Ca uptake also increased from the active tillering to flowering stage of the crop, but at the maturity stage, K uptake significantly increased. In the 2018 VWS, the application of 53 kg N – 30 kg P_2O_5 and 60 kg K_2O ha^{-1} (K applied in 3 splits or T3) was found to further enhanced the uptake of Ca and is comparable to 53 kg N – 7 kg P_2O_5 and 37 kg K_2O ha^{-1} (T4). The average amount of Ca taken up during panicle initiation was 8.9 kg t^{-1} the straw yield; at the flowering stage, it was highest at 17.69 kg t^{-1} straw yield and during physiological maturity at 16.50 kg t^{-1} straw yield. These values actually exceeded 2 – 3 times higher than the normal range of 3 – 6 kg Ca t^{-1} grain yield as observed by Dobermann and Fairhurst (2000). The results suggest that as long as Ca is available in the soil solution, rice could take it up as this was observed in the amount of Ca taken up by the plants in both fertilized and unfertilized plots.

In contrast, high K and Ca uptake negatively affected Mg uptake of rice. Potassium is known to be an antagonist of Mg absorption in plants which is very evident in the observed Mg concentration in rice plant tissue collected in the study site. Magnesium content both in rice straws and grains ranged at 0.05 to 0.06 % at all growth stages (Table 4), far below the critical limit for deficiency in rice which is of <0.13% and <0.10% during tillering to panicle initiation and maturity stage, respectively (Dobermann and Fairhurst 2000). On the other hand, high Mg concentrations in the soil solution did not inhibit K uptake even at low external concentrations. The soil K solution found in unfertilized plots ranged from 0.30 to 0.46 cmolc kg^{-1}, higher or even double than the critical level set for rice (0.05 to 0.20 cmolc kg^{-1}). In the case of a higher Mg concentration in the soil solution, generally K uptake is not disturbed. Typically, the amount of K in the soil solution is much lower than Mg concentration; therefore, plants have been developed specific K-transport systems in the root cells to ensure sufficient K uptake when its concentration in the soil solution is critically low (Horie et al. 2011).

Despite high Mg concentration in the soil, plants were not able to utilize Mg possibly due to wide exchangeable Mg:K and Ca:Mg ratios. Mg uptake will be reduced if the exchangeable Mg:K ratio is greater than 1:1 while Ca:Mg ratio would be greater than 3 – 4:1 (Dobermann and Fairhurst 2000). The recorded Mg:K ratio ranged from 50:1 up to 77:1 while Ca:Mg ratio ranged from 1.1:1 up to 1.8:1 (Table 3). It is, in fact, possible that wide exchangeable Mg:K and very low exchangeable Ca:Mg ratios found in Butuan soils inhibits Mg uptake despite the very high soil Mg content recorded. The total Mg uptake of rice showed a very interesting trend since the amount of Mg taken up by the plants at the early tillering to panicle intiation stage across fertilizer management treatments was very low at 0.20 and 2.62 kg Mg t^{-1} grain yield. This is far below the average crop removal of 3.5 kg Mg t^{-1} grain yield (Dobermann and Fairhurst 2000) indicating that Mg is the major problem in the plant system. Although the application of NPK fertilizers increased significantly Mg uptake by the plants during flowering to physiological maturity stage, this was very low compared to Ca. Ca was preferred by the plant over Mg, making the Ca:Mg ratio in the plant higher at 3-4:1 than the normal level of 2:1. The enhanced Mg uptake of the plant with the application of NPK fertilizers at different rates and stages was an indicator that Mg was deficient in the soil system despite the observed high concentrations. Under Agusan soil conditions, the competition between Ca and K to Mg in the exchange site prevails, particularly when it is present in high concentrations.

Table 4. Potassium, Ca and Mg content and ratio in rice plant tissue at various growth stages as affected by different fertilizer management during 2018 VWS.

Fertilizer Management	Potassium (%)	Calcium (%)	Magnesium (%)	Ca:Mg Ratio	Mg:K Ratio
Active tillering	2.68 (ns)	0.19 (ns)	0.06 (ns)	3.1:1	45:1
Panicle initiation	1.82 *	0.19 (ns)	0.06 (ns)	3.4:1	30:1
Flowering	2.41 (ns)	0.18 **	0.06 (ns)	3.0:1	40:1
Physiological maturity					
Straws	1.82 (ns)	0.32 (ns)	0.05 *	5.8:1	36:1
Grains	0.30 (ns)	0.08 *	0.04 (ns)	2.0:1	8:1

Mg deficiency is the major cause of the yellowing and chlorosis of the older leaves, and shorter or undeveloped root system rice as observed after the soil was subjected to flooding episodes (Fig. 3). Mg deficiency results in shorter roots, smaller shoots, and necrotic spots on leaves owing mainly to abnormal physiological processes reflected in impaired carbon metabolism and decline in chlorophyll and carbon fixation (Hermans et al. 2010). As a rule, amounts of assimilate transported to roots significantly decreased, thus the first symptoms to appear is the root system reduction that would negatively affects the water and nutrient uptake. Under Mg deficiencies root growth decreased markedly, leading to an increase in shoot to root dry weight ratios in plants (Bose et al. 2013). Next visible symptom is the reduction of growth of the aerial parts of plants resulting in pale-colored interveinal chlorosis on older leaves and later on in younger leaves. In severe cases, chlorosis progresses to yellowing and finally necrosis in older leaves which could lead to reduced number of spikelet and reduced 1,000-grain weight (Dobermann and Fairhurst 2000).

Magnesium deficiency mimics K deficiency symptoms. The same type has been observed for K but not P (Cakmak 2008 and Hermans 2005), this could be due to the high mobility of Mg under Mg starvation; thus, Mg deficiency symptoms typically appear on older leaves of the plant just like K (Dobermann and Fairhurst 2000). The diagnosis of the previous nutrient deficiency symptoms observed in the area was associated mainly with K because Mg deficiency rarely occurs in irrigated lowland soils.

Fig. 3. Comparison of healthy plant (center) and Mg deficient plants (left and right side) showing yellow orange interveinal chlorosis appeared in older leaves of stunted plants observed after flooding episodes in the irrigated lowland rice of PhilRice Agusan experimental fields.

CONCLUSION

Among the macro nutrients, K was the most dynamic in the irrigated lowland rice and when soils were subjected to episodic flooding. The high levels of indigenous K supply in the soil plus the high K fertilizer application and the synergistic effects of K and Ca are the major cause of Mg deficiency despite high Mg concentration in the soil. Discovering K-induced Mg deficiency in irrigated lowland rice soil of Agusan del Norte is the breakthrough of this study, thus further in-depth research work on soil nutrient dynamics and interactions of K, Ca and Mg as well as the management of these major cations particularly when the soil is subjected to this kind of flooding and exposed to this kind of climatic condition is needed since this problem is expected to worsen as more intense rainfall and frequent flooding are being experienced due to climate change.

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EFFECTS OF FARMER-ENTREPRENEURIAL COMPETENCIES ON THE LEVEL OF PRODUCTION AND TECHNICAL EFFICIENCY OF RICE FARMS IN LAGUNA, PHILIPPINES

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ABSTRACT

This study analyzed the effects of personal entrepreneurial competencies (PECs) on production and technical efficiency of rice farms in Laguna, Philippines. Forty farmers were randomly sampled and interviewed from May to July 2016. Descriptive, stochastic frontier production function, and regression analyses were performed. Majority (63%) of farmer-respondents were male, with average age of 54 years, average farming experience of 27 years, and average farm size of 2 ha. Majority (83%) was married with average household size of 5 and 65 percent were leaseholders. Results revealed that half of the respondents were weak opportunity seekers and had weak commitment to work contract, 43 percent were weakly persistent, and 32 percent had strong persistence competency. Only area cultivated significantly affected output during dry season, but area cultivated, labor, N-fertilizer, and seeds were significant factors of output in wet season. Farms were technically efficient during dry season but technically inefficient (technical efficiency of only 69.70%) during wet season. Generalized Linear Model of the binomial family with logit link showed that the dummies for "strong" level of competency for opportunity seeking, persistence, demand for quality and efficiency, risk-taking, information-seeking, systematic planning and monitoring, and self-confidence competencies were positive determinants of technical efficiency of farmer-respondents.

Keywords: entrepreneurship, personal entrepreneurial competencies, technical efficiency, generalized linear model with logit link

INTRODUCTION

Rice, the most important staple crop of Filipinos, continues to play a vital role in Philippine political economy, accounting for around 21% of Gross Value Added in agriculture (BAS, 2015), 3.5 percent of Gross Domestic Product (Intal, Jr. and Garcia, 2005), and employing 2.5 million households. These households are broken down into 2.1 million farmers, 110,000 workers for post-farm activities and 320,000 for additional activities (Gonzales, 2013 as cited by FAO, n.d.). The demand for this crop in the country crosses all social classes, with a high percentage of rural households depending upon the various stages of rice production as livelihood. However, their rice productivity is too low which leads to low income. The country's rice productivity in 2014 was 4.02 while China, Vietnam, and Indonesia yielded 6.81, 5.76, and 4.73 metric tons per hectare, respectively (USDA, n.d. as cited by IRRI, 2015). According to a study by Reyes, et. al., (2012), poverty incidence in 2009 among agricultural households (57%) is thrice that of the non-agricultural (17%). The share of *palay* (rice with husk) growers in the number of poor is the largest at 30 percent as compared to corn growing (17%), fishing (15%), and coconut growing (14%), while the headcount poverty rate among *palay* farmers is lower at 42 percent. Rice farmers in the country are traditional, in general. Traditional farmers are rational but risk-averse (reluctant to take risks) (Norton, et al. 2014). These farmers usually focus only on the availability of their production inputs like seed, fertilizer, pesticide among others, reducing opportunity for them to become competent entrepreneurs. Farmers usually miss out on prospects to farm as entrepreneurs due to their priorities such as their production tasks with some producing exclusively for home consumption (McElwee 2005).

Maintaining the robustness of economic and social status is one of the difficult tasks faced by rural communities, many of which are experiencing zero to low growth and development. Thus, rural community leaders foresee entrepreneurship as a solution as it creates new business enterprises with strong potential for increasing local economic activity. Government and private investors are interested in entrepreneurs, anticipating in them the element of growth that leads to innovation, success, job-creation and economic growth. Many small-scale farmers and extension organizations understand that there is little future for farmers unless they become more entrepreneurial in the way they run their farms.

An entrepreneur as “an idea man and a man of action who possesses the ability to inspire others, and who does not accept the boundaries of structured situations (Schumpeter 1949). He is a catalyst of change, instrumental in discovering new opportunities, which makes for the uniqueness of the entrepreneurial function”. Schumpeter (n.d.), as cited by Hall (2010), pinpointed entrepreneurship as the key creative force, talking in terms of a continuous process of disruption; doing something different for benefits; and creative destruction of the old to bring the new. It means being responsible for the marshalling of ideas, resources, people, processes, institutions and policy to affect new outcomes. Entrepreneurship is “the use of private initiatives to transform a simple business concept into a viable new enterprise. It could also involve diversifying an existing enterprise and encouraging it to grow.” (Kahan 2013)

It is important that entrepreneurs react with the environment proactively to minimize the negative effects of challenging business environments. Entrepreneurial competency has a critical role in taking such proactive approaches with the environment. Therefore, the role of an entrepreneur’s competency is a highly critical factor in achieving excellence in performance to ensure sustainable growth and success of a venture amidst a competitive business environment. The importance of entrepreneurial competency has increased during the past few decades due to the strategic role played by the human factor, particularly the entrepreneur of a business enterprise (Kochadai 2011). On the contrary, entrepreneurship is a new situation for many farmers (Bergevoet et al. 2005). There is still doubt if farmers have the capabilities for the entrepreneurial behavior needed, as they play an important role of being the sole labor force on the farm. Their responsibility is to combine the functions of the entrepreneur, manager, and craftsman in such a way that enables them to be successful. Success stories are likewise fueled by efficiency in doing business, be it a production, marketing, or purely service business. When it comes to production, the more frequent concern is technical efficiency. Technical efficiency refers to how productive a business can be given minimum resources necessary to do the job.

Meanwhile, it should be noted that the concept of entrepreneurship is not common to every culture or society. The fear of failure can also be a barrier (McElwee 2005). Traditional farmers usually do not want changes in their farming routines (Kahan 2013). Changes are considered as problems instead of opportunities, while entrepreneurial farmers usually use their confidence and their creativity to maximize and develop their ideas toward the attainment of goals. Entrepreneurship is not largely practiced or even promoted in rural areas and has been given relatively little emphasis in either agricultural or business literature. Empirical research on rural entrepreneurship is relatively scarce and this concept remains largely unknown, and even scarcer are the ones relating it to technical efficiency. A study therefore, on the effects of entrepreneurial competencies on the output and technical efficiency of rice farmers is vital. The study sought to determine the effects of entrepreneurial competencies on the output and technical efficiency of rice farms in Laguna, Philippines, a highly industrializing province but still rice-based.

RESEARCH METHODOLOGY

A total of 40 rice farmers from the remaining rice-based communities in the province of Laguna in the Philippines were randomly chosen and personally interviewed using a pretested interview schedule from May to July 2016. The lists of rice farmers were taken from their respective Municipal Agriculture Office (MAO). The interview schedule included questions on Personal Entrepreneurial Competencies (PEC), as developed by the UP Institute of Small-Scale Industries (UP-ISSI) and adopted from the Management Systems International (MSI) and McBer and Company. PEC questionnaire used 55 items to measure 10 PECs with different indicator questions. These PECs include opportunity seeking, persistence, committed to work contract, demand for quality/efficiency, risk-taking, goal-setting, information seeking, systematic planning and monitoring, persuasion and networking, and self-confidence (Diaz et al. 1997 as cited by Depositario, et al. 2011). PEC scores were interpreted using the following: 19 and above as strong; 16-18 as moderate; and 15 and below as weak.

STATA 10 by StataCorp was used to obtain the maximum likelihood estimates (MLE) of the production function parameters and frontier production functions (the technically feasible input-output relationship). In estimating the technical efficiency, the following stochastic production frontier function was used:

$$q_j = f(z_{ij}, \beta) + (v_j - u_j) \qquad \textit{Equation (1)}$$

where: q_j = quantity of output (mt/ha) of the jth farmer
z_{ij} = vector of capital inputs
β = vector of production coefficients to be estimated
v_j = random variability in the production that cannot be influenced by of the farmer
u_j = deviation from maximum potential output attributable to technical inefficiency

Generally, there are two models under the Stochastic Frontier Production that can be used in determining technical efficiency, the Cobb Douglas and the Transcendental Logarithmic (Translog) production frontier but the Cobb-Douglas model was used to analyze the input-output relationship in this study as indicated in the following equation:

$$lnq_j = \beta_0 + \sum_{i=0}^{5} \beta_i lnz_{ij} + (v_j - u_j) \qquad \textit{Equation (2)}$$

where: q_j = quantity of output (mt/ha) of the jth farmer
z_1 = area cultivated (ha)
z_2 = labor (mandays)
z_3 = nitrogen (kg)
z_4 = crop protection cost[2] (PhP)
z_5 = seeds (kg)
v_j = random error
u_j = error due to technical inefficiency

The generalized linear model for technical efficiency as affected by the ten PECs was expressed as:

$$\ell_n(\beta) = TE_j \cdot \log\left[G\left(\beta_{0n} + (\beta_{1n} \cdot PEC_{M_j}^{(n)}) + (\beta_{2n} \cdot PEC_{S_j}^{(n)})\right)\right] + (1 - TE_j) \cdot \log\left[1 - G\left(\beta_{0n} + (\beta_{1n} \cdot PEC_{M_j}^{(n)}) + (\beta_{2n} \cdot PEC_{S_j}^{(n)})\right)\right]$$

where:
TE_j = technical efficiency of jth farmer
G (·) = a known function satisfying 0 < G (z) < 1 for all Z ϵ $\mathbb{R}$

This ensures that the predicted values of y lie in the interval (0, 1).

$PEC_{M_j}^{(1)}$= Moderate opportunity seeking dummy of jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(1)}$= Strong opportunity seeking dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(2)}$= Moderate persistence dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(2)}$= Strong persistence dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(3)}$= Moderate commitment to work contract dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(3)}$= Strong commitment to work contract dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(4)}$= Moderate demand for quality and efficiency dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(4)}$= Strong demand for quality and efficiency dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(5)}$= Moderate risk-taking dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(5)}$= Strong risk-taking dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(6)}$= Moderate goal-setting dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(6)}$= Strong goal-setting dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(7)}$= Moderate information seeking dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(7)}$= Strong information seeking dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(8)}$= Moderate systematic planning and monitoring dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(8)}$= Strong systematic planning and monitoring dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(9)}$= Moderate persuasion and networking dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(9)}$= Strong persuasion and networking dummy jth farmer
(1 = strong level and 0 = otherwise)

$PEC_{M_j}^{(10)}$= Moderate self-confidence dummy jth farmer
(1 = moderate level and 0 = otherwise)

$PEC_{S_j}^{(10)}$= Strong self-confidence dummy jth farmer
(1 = strong level and 0 = otherwise)

$b_i s$ are represented by the regression coefficients of the explanatory variables.

RESULTS AND DISCUSSION

Description of respondents. Majority (63%) of farmer-respondents were male, with average age of 54 years (34-76 years), average farming experience of 27 years (3-56 years), and average farm size of 2.71 ha which is quite higher than the country's average size of 1.14 ha (Tolentino 2015). Majority (83%) is married with average household size of five. Most of the respondents (33%) graduated tertiary level (e.g. dentist, doctor, and seaman) but still they prefer rice farming since their parents were also farmers from whom they inherited their existing rice farm. On the other hand, more than half of them (65%) were leaseholders only while 73 percent availed credit and had 15 training programs and seminars attended, on the average.

Personal entrepreneurial competencies (PECs) of rice farmers. In terms of personal entrepreneurial competencies, Table 1 shows that exactly half of the respondents were weak opportunity seekers. They do not reuse waste products from their harvests like rice straw and rice husks which can help in increasing profit, these were just burned. These were considered as a burden and not an opportunity to be innovative and resourceful.

Table 1. Distribution by personal entrepreneurial competency level, 40 rice farmer-respondents, Laguna, Philippines, 2015

Farmer Entrepreneurial Competency Level	Percent	Farmer Entrepreneurial Competency Level	Percent
Opportunity Seeking		*Goal Setting*	
Weak	50	Weak	40
Moderate	15	Moderate	35
Strong	35	Strong	25
Persistence		*Information Seeking*	
Weak	43	Weak	33
Moderate	25	Moderate	18
Strong	32	Strong	50
Commitment to work contract		*Systematic Planning and Monitoring*	
Weak	53	Weak	43
Moderate	23	Moderate	25
Strong	25	Strong	33
Demand for Quality/Efficiency		*Persuasion and Networking*	
Weak	45	Weak	58
Moderate	30	Moderate	13
Strong	25	Strong	30
Risk Taking		*Self-confidence*	
Weak	55	Weak	45
Moderate	18	Moderate	20
Strong	28	Strong	35

Forty-three percent of the respondents were weakly persistent and only 32 percent had strong persistence competency. Similarly, half of them had weak commitment to work contract. That is, they do not give time and effort and do not have enough courage to seek ways to maximize their profit. Many of these farmers just depended on their caretakers in managing their farms as they only visited their farms during the planting and harvesting seasons and seldom on the vegetative stage. Farmer-owners usually contributed only capital (without prior knowledge regarding what needs to be bought) and land while almost all labor is exerted by the caretakers and hired laborers. This is perhaps the result of the fact that the highest proportion of the farmer-owners (45%) had weak demand for quality and efficiency.

Having a large number dependent on their caretakers means that there is a possibility that they can be short-changed by the latter. In addition, since hired laborers and caretakers are wage-takers achieving the best quality of yield might not be a priority since they get paid whether the harvest is of high quality or not. Moreover, they tended to just imitate whatever a neighboring farm is doing without considering if it is applicable to their own farm. Such actions can lead to low yields which will lead to low profit, and sometimes, to incur some losses for the farm.

Risk seeking is rarely the case among farmers (Quilloy 2015). This is supported by the results of this study with findings that a higher proportion (55%) of the respondents have weak risk-taking competency (risk-averse). Risk averse pertains to someone who does not like the possibility for an undesirable event to occur. They are also, generally (40%) weak goal-setters. This might have been their response to the climatic conditions in the area which bring flooding, intense rain, or drought resulting to significant production losses. It should be noted that the Philippines is in the western rim of the Pacific, an area which is prone to extreme weather disturbances such as typhoons. On average, 8 or 9 tropical storms make landfall in the Philippines each year, with another 10 entering Philippine waters (Brown 2013). The eastern and southern portions of Laguna have no distinct seasons but experience distributed rainfall throughout the year. The study areas, however are among the flood-prone municipalities in the province due mainly to the increased water level of the Laguna Lake, overflowing of rivers, degraded watersheds, or due to urban runoff resulting from unsound developments in the area (Ardales et al. 2015). Even if rice is unique in that it can thrive in wet conditions where other crops fail, uncontrolled flooding is still a problem, because rice plants cannot survive if submerged in water for long periods of time (IRRI, n.d.).

On the other hand, half of the respondents were strong information seekers as supported by the fact that on the average, in 2015, they attended 15 training programs and seminars. Some of these were rice production training courses on *PalayCheck System*, farm machinery operation and safety, organic fertilizer production and utilization, soil analysis, techniques in fighting rice diseases caused by viruses, and technologies such as rice-mushroom and Carrageenan Plant Growth Promoter (PGP). *PalayCheck System* is a rice integrated crop management system for transplanted irrigated lowland rice farming. It integrates and balances relevant technology and crop management options with farmers' learning to improve productivity and profitability in an environment-friendly manner (Llanto et al. 2005).

Others also attended seminars about farm record keeping, effective water management, and basic microfinance while still others attended the "Radyo Program sa UPLB". Seminars attended other than rice farming include: garlic production and raising of sow, cattle, and goat. This information can help the farmers gain more knowledge and expand their farm business.

Forty-three percent (17) of the respondents had weak level of competency for systematic planning and monitoring. More than half (58%) of them had weak persuasion and networking competencies. This implies that the respondents are not good at establishing effective partnerships and relationships. For instance, they confessed that they do not know where to sell their produce at a higher price and do not have the motivation to influence their co-farmers about the knowledge and techniques that they have. Similarly, almost half (45%) of them had weak self-confidence. This can be linked with their low demand for quality and efficiency. There were however, a number (35%) who had strong self-confidence and moderately self-confident (20%).

Production and yield. The Philippines has two seasons for rice: wet and dry seasons. Wet-season rice crop in the north lasts from June to November and the dry-season crop from January to May-June. This is the season in Laguna. In the south it is the reverse: wet-season crops last from October-November to March-April and dry-season crops from May-June to November (FAO 2004). Table 2 shows that on the average, farmers produced 17.10 mt of *palay* during the dry season and a little lower during the wet season (14.35 mt). The good weather condition during summer months could have contributed to this difference. The greater radiation during ripening in dry season can contribute to the higher grain yield because of the greater biomass accumulation from flowering to physiological maturity during this period than in wet season. Higher grain yield in dry season could also partly be the result of greater spikelet production efficiency per unit biomass at flowering (Yang et al. 2008)

Table 2. Distribution by production and by season, 40 rice farmer-respondents, Laguna, Philippines, 2015

Production (mt)	Average		Dry Season		Wet Season	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
≤ 5	8	20	7	18	12	30
5.01 to 10	16	40	16	40	13	33
10.01 to 15	5	13	6	15	5	13
15.01 to 20	4	10	2	5	4	10
> 20	7	18	9	23	6	15
Total	40	100	40	100	40	100
Average	15.73		17.10		14.35	

In terms of yield, on the average, farmer-respondents had 5.54 mt per hectare (Table 3) which is much higher than the national average yield of 3.9 and 3.87 mt per hectare in 2015 and 2016, respectively (Countrystat PSA as cited by IRRI 2016).

Table 3. Distribution by yield (mt/ha) and by season, 40 rice farmer-respondents, Laguna, Philippines, 2015

Yield (mt/ha)	Average		Dry Season		Wet Season	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
≤ 4	7	18	9	23	13	33
4.01 to 6	16	40	12	30	16	40
6.01 to 8	16	40	11	28	10	25
> 8	1	3	8	20	1	3
Total	40	100	40	100	40	100
Average	5.54		6.07		5.01	

Input Utilization. Table 4 shows the average inputs used in rice production during dry season. Roughly 3 hectares of land were cultivated for rice by each farmer-respondent during dry season. Total amount of labor varied depending on tools and equipment used, land area planted to rice, and number of laborers. In this study, an average of about 345 man-days (one man-day is equivalent to eight hours of work) were allocated for the different activities in producing rice. The farmer-respondents used approximately 375 kg of nitrogen fertilizer, spent PhP12,596 for crop protection, and utilized 167 kg of seeds. For the wet season, the farmer-respondents cultivated same farm size as the dry season. However, they allocated slightly higher amount of labor (346 man-days) (Table 5). This is because *"hulip"* or plant replacement is commonly done in wet season when rice parcels are frequently flooded. In addition, the farmer-respondents used only 280 kg of nitrogen fertilizer in wet season, much lower than that of the dry season because during this time, rainwater is abundant. Rainwater contains nitrogen which can be readily absorbed by the rice plants. Crop protection cost and quantity of seeds utilized during wet season were almost the same with that of the dry season averaging PhP12,541 and 167 kg, respectively.

Table 4. Summary of descriptive statistics for inputs used, 40 rice farmer-respondents, Laguna, Philippines, dry season, 2015

Input	Mean	Standard Deviation	Maximum	Minimum
Area cultivated (ha)	2.71	2.82	12.00	0.70
Labor (man-day)	344.28	530.37	2670.00	63.13
N Fertilizer (kg)	374.93	435.13	2034.00	70.50
Cost of Crop protection (Php)	12,596.00	13,831.82	55,250.00	280.00
Seeds (kg)	166.76	203.99	960.00	15.00

Table 5. Summary of descriptive statistics for average inputs used, 40 rice farmer-respondents, Laguna, Philippines, wet season, 2015

Input	Mean	Minimum	Maximum	Standard Deviation
Area cultivated (ha)	2.71	0.70	12.00	2.82
Labor (man-day)	346.03	68.13	2,670.00	530.49
N Fertilizer (kg)	279.67	60.00	2,034.00	393.94
Crop protection's cost (Php)	12,541.38	280.00	55,250.00	13,890.23
Seeds (kg)	167.21	15.00	960.00	203.70

Production Function. There were five variables considered in estimating the production function: area cultivated, labor, N fertilizer, crop protection costs, and seeds. Crop protection cost was omitted due to presence of collinearity. It was revealed that only area cultivated significantly affected the output at 95 percent significance level (Table 6). Area cultivated had a positive coefficient which implies that every 10 percent increase in the land area, *cet. par.*, would result to 8.29 percent increase in rice production. As expected, increasing land utilization would increase rice production. The sum of all regression coefficients (significant and insignificant) is equated to production elasticity. With the sum of 1.04, in dry season, the stochastic frontier production function depicted increasing returns to scale suggesting that increasing the amount of all inputs by 1 percent will increase the output by 1.04 percent, holding other factors constant.

Table 6. Maximum likelihood estimates of the parameters of the stochastic frontier production function, 40 rice farmer-respondents, Laguna, Philippines, dry season, 2015

Variable	Coefficient	Standard Error	Z-Value	P-Value
Constant	0.553	1.231	0.45	0.653
z_1 Area cultivated (ha)	0.829**	0.240	3.45	0.001
z_2 Labor (man-days)	-0.009	0.132	-0.07	0.944
z_3 N-Fertilizer (kg)	0.340	0.213	1.60	0.110
z_5 Seeds (kg)	-0.117	0.078	-1.49	0.135
Returns to scale	1.042			
Log likelihood	-17.520			

** significant at 5% probability level

On the other hand, for wet season, it was revealed that at 1 percent level of probability, every 10 percent increase in the area cultivated, *cet. par.*, would result in 9.15 percent increase in the total volume of rice produced. Similarly, the amount of nitrogen fertilizer is a positive determinant of rice production at 1 percent level of probability. This means that a 10 percent increase in the amount of nitrogen fertilizer, *cet. par.*, would result to 5.69 percent increase in rice production (Table 7). Nitrogen promotes rapid plant growth and improves grain yield and quality through higher tillering, leaf area development, grain formation, grain filling, and protein synthesis. It is highly mobile within the plant and soil (Rice Knowledge Bank, n.d.).

Table 7. Maximum likelihood estimates of the parameters of the stochastic frontier production function, 40 rice farmer-respondents, Laguna, Philippines, wet season, 2015.

	Variable	Coefficient	Standard Error	z-Value	P-Value
	Constant	1.731	0.067	25.97	0.000
z_1	Area cultivated (ha)	0.915***	0.108	8.51	0.000
z_2	Labor (man-days)	-0.359***	0.114	-3.14	0.002
z_3	N-Fertilizer (kg)	0.569***	0.040	14.27	0.000
z_5	Seeds (kg)	-0.166***	0.054	-3.10	0.002
Returns to scale		0.959			
Log likelihood		-6.124			

***significant at 1% probability level

However, labor, while significant at 1 percent level of probability, had a negative sign. This indicates that a 10 percent increase in labor, *cet. par.,* would result to 3.59 percent decrease in rice production. This has implication in the labor efficiency of workers and can also be linked to the fact that there were many farmers who depended only on their caretakers for farm operations. Since hired laborers and caretakers are wage-takers, they do not have enough incentive to improve the quality of their work, adversely affecting yield.

Quantity of seeds was also significant but with a negative relationship to production at 1 percent level of probability. Coefficient implies that a 10 percent increase in the quantity of seeds, *cet. par.*, would result to a 1.66 percent decrease in rice production. This could be attributed to improper transplanting of seedlings which lead to their overuse. Farmers believe that increasing the quantity of seeds would increase production thus, tended to transplant bunches of seedlings with the aim of increasing the yield. However, according to the Rice Knowledge Bank of IRRI (n.d.), transplanting requires less seed but much more labor compared to direct seeding. A lot of farmer-respondents did the straight-row method of transplanting. In this method, only two to three seedlings of 15–21 days, wet-bed or dry-bed, grown seedlings should be transplanted at 20 x 20 cm spacing. During this stage, hired laborers have the tendency to speed up their work (since it is on *pakyawan* or contract labor), therefore, the number of seedlings to be transplanted is generally neglected by them. They transplant four or more seedlings which can affect the production of rice negatively as the recommended spacing was not followed.

Unlike in the dry season, during wet season, the stochastic frontier production function with the sum of regression coefficients amounting 0.959, was found to depict decreasing returns to scale. This suggests that increasing the amount of all inputs by 10 percent will increase the output by 9.6 percent, holding other factors constant.

Technical efficiency level. Technical efficiency is the deviation of the average production function from the frontier production function. It is the ratio of the actual production and potential production for a given set of inputs and technology (Quilloy 2015). Only wet season was considered since it is during this season that the farmer-respondents experienced low production level and therefore, necessitates further analysis for improvement. Rice production was found to be 30.30 percent technically inefficient during wet season since the weighted mean technical efficiency was 69.70 percent and only four farms were found technically efficient. The most number of farms (18% each) were 50 to 59 and 90 to 99 percent technically efficient. One farmer got technical efficiency level ranging from 10 to 19 percent, the lowest recorded in this study (Table 8).

Table 8. Distribution by technical efficiency level, 40 rice farmer-respondents, Philippines, wet season, 2015

Technical Efficiency (%)	Percent	Technical Efficiency (%)	Percent
10 to 19	3	60 to 69	13
20 to 29	0	70 to 79	13
30 to 39	10	80 to 89	13
40 to 49	5	90 to 99	18
50 to 59	18	100	10
Minimum		17.90	
Maximum		100	
Mean		69.70	

Effects of entrepreneurial competencies on technical efficiency. Again, in view of the fact that during dry season, the farms were technically efficient, thus less variability, it was deemed more critical to consider the wet season parameters in determining the effects of entrepreneurial competencies on technical efficiency. This is to better understand what needs to be done for future improvement of the area's rice industry. The General Linear Model (GLM)of the binomial family with the logit link was used for this purpose. Results revealed that opportunity-seeking, demand for quality and efficiency, information-seeking, persistence, risk-taking, systematic planning and monitoring, and self-confidence were significant factors of technical efficiency (Table 9). The dummy variables for "strong" in opportunity seeking, demand for quality and efficiency, and information-seeking competencies are significant determinants of technical efficiency at 10 percent probability levels. These figures suggest that if the abilities/attitudes of the farmers can be improved for them to become strong in these competencies, the technical efficiency of their rice farms can be increased by 0.25, 0.25, 0.29, respectively, holding other things constant. In addition, the dummy variables for "strong" in persistence, risk-taking, systematic planning and monitoring, and self-confidence competencies are significant at 5 percent level of probability and had positive signs. Similarly, values obtained implies that by cultivating these competencies from weak to strong, technical efficiency of the rice farms can be increased by 0.31, 0.27, 0.27, and 0.30, *respectively,* holding other things constant.

Table 9. Effects of PECs on technical efficiencies using GLM with logit link, 40 rice farmer-respondents, Laguna, Philippines, wet season, 2015

Variable		DY/DX	Standard Error	Z-Value	P-Value
Opportunity seeking					
$PEC_{M_j}^{(1)}$	Moderate dummy	0.070	0.178	0.40	0.691
$PEC_{S_j}^{(1)}$	Strong dummy	0.250*	0.137	1.83	0.067
Predicted mean			0.715		

Variable		DY/DX	Standard Error	Z-Value	P-Value
Demand for quality and efficiency					
$PEC_{M_j}^{(2)}$	Moderate dummy	0.206	0.135	1.53	0.127
$PEC_{S_j}^{(2)}$	Strong dummy	0.252*	0.130	1.94	0.053
Predicted mean			0.716		
Information-seeking					
$PEC_{M_j}^{(3)}$	Moderate dummy	0.111	0.164	0.68	0.498
$PEC_{S_j}^{(3)}$	Strong dummy	0.289*	0.150	1.92	0.055
Predicted mean		0.715			
Persistence					
$PEC_{M_j}^{(4)}$	Moderate dummy	0.095	0.146	0.65	0.517
$PEC_{S_j}^{(4)}$	Strong dummy	0.310**	0.129	2.41	0.016
Predicted mean			0.726		
Risk-taking					
$PEC_{M_j}^{(5)}$	Moderate dummy	0.132	0.153	0.86	0.388
$PEC_{S_j}^{(5)}$	Strong dummy	0.273**	0.129	2.12	0.034
Predicted mean		0.720			
Systematic planning and monitoring					
$PEC_{M_j}^{(6)}$	Moderate dummy	0.143	0.144	0.99	0.321
$PEC_{S_j}^{(6)}$	Strong dummy	0.270**	0.134	2.01	0.044
Predicted mean		0.716			
Self-confidence					
$PEC_{M_j}^{(7)}$	Moderate dummy	0.085	0.156	0.55	0.586
$PEC_{S_j}^{(7)}$	Strong dummy	0.296**	0.132	2.24	0.025
Predicted mean		0.723			

***, **, and * denote significance at 1%, 5%, and 10% probability levels, respectively.

CONCLUSIONS AND RECOMMENDATIONS

Generally, the farmer-respondents have weak opportunity seeking, persistence, commitment to work contract, demand for quality/efficiency, risk taking, goal setting, and systematic planning and monitoring competencies but they have strong information seeking competency. Rice production was technically efficient during the dry season but inefficient during wet season. In view of these conclusions and other research findings, the following are recommended:

Continued provision of more and new information on rice farming. Aside from seminars, carefully planned tours may also help farmers gain new knowledge and see markets first-hand, visit input suppliers and buyers, and make contacts. Farmers' visits to other farms allow exchange of experiences which will improve their competencies for enhanced rice farming technical efficiency. Those who have wrong misconceptions about proper rice farming practices, which contribute to low yield, could learn from those performing best practices.

Farm Business School should be made available and accessible to more farmers. Participation in training courses requires considerable motivation on the part of a farmer to consider attending a formal training course. Courses take up valuable time and farmers need encouragement and incentives to participate. Farm Business School (FBS) is a curriculum-based approach to extension aimed at building farmers' entrepreneurial capacity (Kahan 2013). Learning takes place in the context of the participants' farming businesses through schools set up at community level. It helps farmers learn how to make their farming enterprises and operations profitable and-responsive to market demands.

Improving the entrepreneurial competencies of rice farmers. One of the immediate solutions to remedy the weak entrepreneurial competencies of the farmers is equipping the rice extension workers with knowledge on how to improve these competencies. Extension workers bridge the gap between the technocrats and the farmers because most of them are technically-trained but they too lack formal training on entrepreneurship. Their role is crucial in assisting and getting farmers to reflect on their business performance and help them implement their learning,

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IMPROVING IRRIGATION WATER EFFICIENCY IN PADDY AGRICULTURE THROUGH A BETTER WATER PRICING POLICY IN THE JATILUHUR IRRIGATION AREA, WEST JAVA, INDONESIA

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ABSTRACT

Water shortage is a long standing problem in Java and its condition is getting worse over time. The problem is not simply due to deterioration of natural resource, but also because demand for water steadily increases. This study is an attempt to use water charge policy to improve water use efficiency and inter-sector allocation which the government has apparently ignored by implementing a dual water charge policy. By this policy the government provides irrigation water to paddy agriculture with almost no water fee, while supply of water to industry and other urban sectors is apparently charged with expensive fee. This study was conducted in the Jatiluhur irrigation area of West Java to investigate the possibility of increasing irrigation water fee (ISF) for rice farming. The methods used are Residual Imputation Approach (RIA), Contingent Valuation Method (CVM) and regression analysis. The research was conducted in the cultivation seasons of 2016/2017, from October 2016 to September 2017 with a total sample of 471 farmers. The cropping season was divided into two, namely wet season and dry season. This study confirmed that it is possible to improve irrigation service fee (ISF) in this region. The current fee paid by paddy farmers is only about three percent of the economic contribution of irrigation water to paddy production value. Because paddy farming is economically profitable, it does make sense to raise ISF. However, local farmers who are mostly poor could reject this proposal because of its adverse impact on their family income whose size is relative small. Anticipating this problem, the government should implement a policy to compensate such income reduction.

Keywords: irrigation water service fee, willingness to pay, water use, residual imputation approach

INTRODUCTION

Rice is the most important staple food for Indonesia and the government has strongly committed to meet its rice demands from domestic production. Such a strong commitment for pursuing rice self-sufficiency was the government's agenda since five decades ago. In 1984, in the era of President Soeharto, a rice self-sufficiency was attained for the first time since the independence from Dutch colonial in 1945 (Hobohm 1987). However this great achievement was not sustained. Over the last two decades, Indonesia has pursued rice self-sufficiency. Java island is a single major source of rice, contributing more than 50% of the national production. Achieving and maintaining rice-self sufficiency means raising domestic production to meet its ever growing domestic demands, due to high population growth. The average annual population growth for 2010-2016 in West Java Province, Java Island, and Indonesia are 1.54%, 1.25% and 1.36%, respectively (BPS 2017). Such a high population growth requires Indonesia to increase rice production of about 0.5 million ton per annum if it does not want to import rice from overseas market. However, this is not easy to realize. Apart from a continual decline in area for rice production notably in Java, another major problem is water irrigation. While its supply declines due to environmental degradation, demands for water increase not only from agriculture, but also notably the industrial sector.

Java faces a worsening water scarcity problem with intense competition for water use among economy and public sectors (Syaukat and Fox 2004). Currently Java has the highest irrigation water demand of 1,838.28 m^3/sec compared to other islands, where Sumatra Island at 1,726.79 m^3/sec and Sulawesi Island at 644.41 m^3/sec (Soekmono 2014). In considering the seriousness of water problem in Java, Hatmoko, a prominent water irrigation researcher, recommended the government implement a policy for gradual shift of agriculture from this island into outer islands of the country[1]. When resource scarcity prevails, efficiency in its use becomes a necessity. Meanwhile economic theory dictates that scarcity commands a positive price for use of a scarce resource. The scarcer its supply the higher the price to be paid for its use so that its user is motivated to use it more efficiently. However, this conservation logic is not applied in dealing with the water scarcity in Java. In fact, Syaukat et al. (2014) claimed there is no price for water irrigation in the whole of Indonesia. Water charge is simply land area i.e., per hectare basis, not volumetric. In this way, dual price strategy is applied whereby expensive water fee is applied to municipal and industry use, while very cheap water tariff is applied for agriculture. This water pricing strategy will not promote efficiency in using irrigation water since it does not treat users equally (Johansson 2000; Sumaryanto 2006; Syaukat and Siwi 2009).

The current condition of increasing competition for water use makes it desirable to improve water fee for agriculture in Java. In pursuing this ultimate goal, the study will investigate four research questions. First, how much is economic value (economic rent) of irrigation water in paddy production? Second, has the water charge paid by paddy farmers exceeded the economic rent of irrigation water in paddy production? Third, is there any room for raising irrigation water charge? Fourth, how much is willingness to pay of the farmers for water irrigation and what factors affecting it? Findings from this investigation will be synthesized to formulate some recommendations to improve irrigation water charge. The study was conducted in Jatiluhur Dam system of West Java Province. It is a multi-function dam whose function is not only to generate electricity, but also to provide fresh water for urban sectors (industries and households), and irrigation especially for paddy farming. The Jatiluhur dam system is very crucial for pursuing rice self sufficiency since its irrigation area covers five districts of West Java province which are major rice producing areas in Java.

Globally water supply has increasingly shifted from direct human use to agriculture because irrigated agricultural lands continually increase (Cai et al. 2003). At present, about 18% of the global agricultural land is irrigated land. In addition, more than two thirds (71%) of the irrigated land are located in developing countries, including Asia (Johansson 2000). Competitive water use between agriculture and urban sector (industry and urban households) is continuous. This competition has been at the cost of reduction of supply of water to agriculture to allow for increase of water supply for industry and urban households. As a consequence, the performance of irrigation systems in these countries is declining (Rosegrant and Ringler 2000).

Water from Jatiluhur dam system is mostly used for paddy agriculture. However, allocation of water from this system into the agriculture gradually declined (Katiandagho 2007; Hadipuro 2007; Slametto 2012). The relevant question is how to promote water use efficiency and conservation? Johansson (2000) argues that water pricing should be used as an instrument to promote water use efficiency and conservation. Underlying this argument, one can correctly claim all sectors, including

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[1] "Jawa Rentan Krisis Air" (Java is highly risky of water shortage) available at http://mediaIndonesia.com/news/read/41795/jawa-rentan-krisis-air/2016-04-22. Accessed at 21 January 2017.

agriculture, have to pay a "correct" price for water that it uses.

However, such a water payment rule does not apply for paddy agriculture in Indonesia, including in Java. There is no price for water irrigation in this country (Syaukat et al. 2014). Farmers do not pay volumetric tariff for irrigation water, but fixed fee per hectare of land. Allocation of water is merely based on cost recovery. Two water schemes are applied by the water utility, *Perum Jasa Tirta II*, by charging a volumetric tariff for raw water allocated to the industrial and municipal sectors, while for agriculture sector the utility charges no volumetric tariff, but fixed rate based on land area. This cost recovery pricing strategy is not supportive for promotion of water use efficiency since it treats users not equal. Efficiency in use of water will be realized only when (same) water price is applied to all users and it will also promote equality in allocation of water among users (Johansson 2000; Sumaryanto 2006; Syaukat and Siwi 2009). Meanwhile, the government needs to employ water pricing to encourage paddy to use irrigation water more efficiently (Sumaryanto 2006).

Water pricing uses various methods such as: volumetric pricing, output-input pricing, area pricing, tiered pricing, two-part tariff, and water market pricing (Tsur and Dinar 1997; Johansson 2000; Syaukat 2000), water pricing, non-volumetric water pricing, and water markets (Boswoth et al. 2002; Mole and Berkoff 2007) or area-based pricing, volumetric pricing, and market equilibrium pricing (Chifamba et al. 2013). Actually, all the pricings can be grouped into three categories because all methods, outside of volumetric water pricing and market pricing, can be categorized as non-volumetric pricing (Johansson 2000).

In Indonesia, volumetric water pricing is not only expensive, but also has constraints, because of numerous small irrigated land, inadequate tools and mechanisms to apply it. Not only is the cost of using non-volumetric pricing much cheaper, but also it is easier to manage since water charge can be determined based on output, area of water irrigation and price of farm land (Johansson et al. 2002). Another issue related to pricing of irrigation water is economic value that it generates for farmers as they will pay if its use results in economic value. There are three methods to measure economic value, namely: hedonic pricing (HP), residual imputation approach (RIA), and the alternative cost approach (ACA) (Young 1996). HP can be applied in a situation where market can provide data to estimate *willingness to pay* (WTP) of users or quality of environment. RIA is a method that measures productivity when water is treated as input. This measurement determines shadow price of unpriced input by residual imputation and under special conditions can be used to measure value of natural resource used in production of particular product (Ashfaq et al. 2005). RIA measures the economic contribution of water (water rent) in the production process (Heady 1952). In using RIA, incremental contribution of each input must be estimated. If prices of all inputs are identified, except irrigation water, residual value of production after deduction of contribution of all other inputs whose price is identified becomes the value of irrigation water.

Although water scarcity is increasingly pronounced, none of the discussed methods of water pricing is applied in Indonesia. Farmers on irrigated land do not pay for water, rather make a contribution, "iuran", or *Iuran Pengelolaan Irigasi* (IPI) or irrigation water service fee (ISF). It covers use of water and maintenance of water infrastructures. Although ISF is relatively small, a majority of farmers are not willing to pay. It is desirable to understand what factors determine willingness to pay (WTP) for irrigated water before designing water pricing policy.

RESEARCH METHODOLOGY

Location. The study was carried out in the Jatiluhur Irrigation Scheme located in West Java Province. This scheme obtains its water resource from the Jatiluhur dam system which is a multifunction dam system. Its water resource is used not only for irrigation, but also supplied for the generation of electricity and to industry and urban households. The Jatiluhur Irrigation Scheme involves the total irrigated farmland of 223,090 hectares divided into three main areas of irrigation, namely West Tarum irrigation area (44,475 hectares), North Tarum irrigation area (87,194 hectares) and East Tarum irrigation area (91,421 hectares). The West Tarum includes Karawang and Bekasi Districts, while the North Tarum covers Karawang District, and the East Tarum include Karawang, Subang, and Indramayu Districts. These large areas are one of major producers of rice in Java.

Respondents and sampling procedure. The main source of information used for this study is farmers who operated rice farm during the period October 2016 to September 2017. There are two rice cultivation seasons, wet season cultivation, or *musim tanam rending* and dry season cultivation, or *musim tanam gadu*. A simple proportional random sampling technique was used (Gaspersz 1991) to select a number of farmers who operated rice farm during the two cultivation seasons in the Jatiluhur Irrigation Scheme. The total number of respondents is 471 farmers consisting of 105 farmers of the West Tarum irrigation area, 171 farmers of the Nort Tarum irrigation area and 195 farmers of East Tarum irrigation area.

Method for estimating the economic value of water. RIA derivation requires two postulate principles. First, competitive balance requires that resource (input) prices equal the marginal value of the product (for each resource i, $P_i = VMP_i$). Producers are assumed to maximize profits. The second postulate requires that the total value of the product be divided up, so that each resource paid according to its marginal productivity and the total value of the product can be completely divided up by each contribution input (Heady 1952, Debertin 1986).

Based on the two postulates above, it can be illustrated that in an agricultural production process, to produce an agricultural product notated (Y) which is produced using four factors of production, namely: capital (K), labor (L), natural resources or other inputs such as land (R) and irrigation water (W), so that the production function can be written as follows:

$$Y = f(K, L, R, W) \quad (1)$$

Furthermore, it can write the second postulate with the assumption that the input market and output perfectly competition, the price is assumed to be fixed (given). Based on the second postulate above:

$$TVP_Y = (VMP_K\,Q_K) + (VMP_L\,Q_L) + (VMP_R\,Q_R) + (VMP_W\,Q_W) \quad (2)$$

where, TVP_Y is the total value of product Y, VMP_i is the value of marginal product of resource i (K, L, R and W), and Q is the quantity of resource (input) i. If factors and products are assumed to be in a perfectly competitive market, prices can be treated constant. The first postulate (which confirms that $VMP_i = P_i$) then (2) becomes:

$$TVP_Y - (P_K\,Q_K + P_L\,Q_L + P_R\,Q_R) = P_W\,Q_W \quad (3)$$

$P_W\,Q_W$ measures the economic contribution of irrigation water to TVP. It's known as "water rent". When the volume of irrigation water (Q_W) is known, the value of the water unit (P_W) can be measured, usually called "price of water". It is assumed that all variables (3) are known, except the price of water (P_W), so it can be solved to find out the P_w by determining the shadow price of the water as follows:

$$Pw^* = [TVP_Y - (P_K\,Q_K + P_L\,Q_L + P_R\,Q_R)] / Qw \quad (4)$$

Method for estimating the willingness to pay for water. Water irrigation is a quasi private good so that it is a non-marketable input. Therefore, market price for irrigated water does not exist. Instead, the Stated Preference Method (SP) can be used. Two approaches included in the SP approach are Contingent Valuation Method (CVM) and Choice Experiment (CE). CVM is a direct method of economic assessment through the question of willingness to pay someone, while CE is an indirect method of economic valuation (Fauzi and Anna 2005). CVM is used to estimate farmer WTP values calculated both individually and in total population. WTP estimation uses a formulation from Hanley and Spash (1993) which is modified with the following stages:

Stage 1, forming a hypothetical market. Consumer behavior will be measured in a hypothetical situation; ***Stage 2,*** obtaining bid value (bids) through surveys. Based on the value of this offer will get the WTP value of each respondent; ***Stage 3***, calculate the estimated average WTP (EWTP). Furthermore, the estimated average WTP is calculated by the formula as follows:

$$E(WTP) = \sum_{i=1}^{n} W_i P_{fi} \qquad (5)$$

Where E(WTP) is the average WTP estimate, Wi is the lower limit of the WTP Class i, P_{fi} class is the relative frequency of the class in question, n is the number of classes (intervals), i is the class (interval) of WTP (i = 1 , 2,3, ... n); ***Stage 4,*** determine the total WTP value (TWTP). The total WTP of farmers is estimated by using a formula:

$$T(WTP) = \sum_{i=1}^{n} \left[\frac{n_i}{N}\right] P \qquad (6)$$

Where, TWTP is the willingness of the farmer population to pay for irrigation services fee, WTPi is the willingness of the respondents (sample) to pay, n is the total area of sample land that is willing to pay for WTP, N is the total area of sample land, P is the total land area of the farmer population, and i is a sample; i = 1,2,3, ..., n; ***Stage 5,*** Evaluation of CVM, evaluating the CVM model can be seen from the level of reliability of the WTP function to find out whether the CVM carried out can provide a true description of the size of the farmer's research.

Econometric model of factors affecting the WTP value. Multiple linear regression model is used to determine the factors that affect the value WTP of farmers in improving irrigation services. Multiple Linear Regression analysis model with the estimation of Ordinary Least Square (OLS) as follows:

$$WTP_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \cdots + \beta_i X_i + E_i \qquad (7)$$

where: WTP_i is the middle value of the WTP to improve irrigation water services, X_1 = farm income (Rp/year), X_2 = farming experience (years), X_3 = number of household members (persons), X_4 = education (years), X_5 = age (years), X_6 = knowledge of irrigation services fee (dummy variable) that is not knowing IPI = 0 and knowing IPI = 1, X_7 = service of irrigation (dummy variable), service not good = 0 and good service = 1, X_8 = distance of location to the nearest water source (meters), and X_9 = participation of farmers in operation and maintenance (dummy variables) that is inactive = 0 and active = 1.

RESULTS AND DISCUSSION

Economic contribution of irrigation water. Technically, economic contribution of irrigarion water (water value or water rent) is simply a residual, meaning its amount is obtained after reduction of all cost elements, except water, from the total value product (total revenue), calculated on a per hectare base. The economic value of irrigation water on paddy production is quite significant (Table 1). As operators who use commercial inputs for the production of paddy, farmers are very much concerned on the extent of profit they obtain from their farming operation. It is the same as farm profits, assuming that there is no irrigation water fee. The water value is equivalent to 18.57% and 20.51% of the total value product (total revenue). Inasmuch as paddy farming operation lasts for about four months, paddy farming operation in the Jatiluhur irrigation area is very profitable, with a profit margin of about 4.5% per month.

Table 1. Estimation of irrigation water value for paddy production at wet and dry cultivation season of 2016/2017 in Jatiluhur irrigation area

Size of Farms (Ha)	Wet Season			Dry Season		
	Total Revenue	**Total Cost**	***Water Value (Rp/Ha)***	**Total Revenue**	**Total Cost**	***Water Value (Rp/Ha)***
< 0.5	24,069,545	19,602,279	4,467,327	26,678,858	21,441,295	5,237,563
0.50 ≤ L ≤ 1.0	24,766,206	20,174,718	4,591,489	27,579,078	21,899,659	5,679,419
> 1	26,380,404	21,443,888	4,936,517	29,403,734	23,048,422	6,355,313
Total	**24,974,575 (100.00)**	**20,335,668 (81.43%)**	**4,638,909 (18.57%)**	**27,827,651 (100.00%)**	**22,117,907 (79.49%)**	**5,709,744 (20.51%)**

Note : US$ 1.00 = Rp 14,000 (Indonesian rupiahs)

Water irrigation service fee. Water irrigation service fee (ISF) is not determined by the Jatiluhur water authority, but local officers, *ulu-ulu*, who manages water distribution at the tertiary water channel, and maintains it as well. The *ulu-ulu* is also a farmer and member of farmers' organization. The ISF represented a payment for water service received by the farmers. The average contribution collected by *ulu-ulu* (ISF) is 20 kg of husked rice or *gabah kering giling* (GKP). In this case, ISF can be in terms of regular rice or glutinuous rice which is more expensive. The weighted average prices of the husked rice received by the farmers are Rp 5,428 and Rp 5,638 per kg, respectively, in the wet and dry seasons. The average ISFs per hectare collected by *ulu-ulu* per season is slightly higher during the dry season compared to wet season (Table 2). This occurs because the weighted average price of the husked rice is higher in the dry season than that of the wet season. The average ISF could be classified into four categories. A large number of farmers (73.46%) pay the ISF on this category i.e., between Rp 102 to Rp 117 tousands/ha/season, and about 5.73% of farmers pay ISF in the fourth category (more than Rp 117 thousand/ha/season).

Table 2. The ranges and weighted average of ISF for 2016/2017 in Jatiluhur irrigation area

Ranges of ISF (Rp 1000 /Ha/CS)	Wet Season			Dry Season		
	ISF (Rp/Ha)	**n**	**%**	**ISF (Rp/Ha)**	**N**	**%**
72 < ISF ≤ 87	72,036	12	2.55	72,239	13	2.76
87 < ISF ≤ 102	93,642	86	18.26	97,250	85	18.05
102 < ISF ≤ 117	111,332	346	73.46	113,870	346	73.46
ISF > 117	137,083	27	5.73	138,810	27	5.73
Total	**108,558**	**471**	**100.00**	**112,654**	**471**	**100.00**

(%) percentage to that of the total respondents

The irrigation water charges are almost negligible compared to the water value (Table 3). This is not unique to the Jatiluhur irrigation system as it also occurs in other irrigation areas, Bogor Regency in West Java and Kudus Regency in Central Java (Syaukat et al. 2014).

Table 3. Relative value of ISF compared to the economic water value in Jatiluhur Irrigation Area, cultivation seasons of 2016/2017

Cultivation Season	Water Value (Rp/Ha)	Water fee (ISF) (Rp/Ha)	Relative Value of ISF Compared to Water Value (%)
Wet	4,638,909	108,558	2.34
Dry	5,709,744	112,654	1.97

Estimation of value of *willingness to pay* for irrigation water. As the farmers have actually made an irrigation service fee (*ISF)*, comparing the value of WTP and *ISF* will indicate as how much to raise the current water charge.

(1) Hyphothetical market. In this study, farmers were asked about the current condition of the irrigation canal, problems, and quality of service. Based on this, the farmers then asked their WTP when there is improvement regarding the quality of irrigation services into their fileds.

(2) Obtain a bid value. WTP values are obtained by offering respondents a number of choices. The starting points were the ISF value paid by the farmers (Rp/ha/season) (Table 2). The initial value of the bids is set at Rp 110,000 and Rp 113,000 per ha, respectively for the wet and dry season with an average increase of Rp 30,000. The increase in value is based on changes in the increase in ISF per season that occurred in Jatiluhur irrigation area, which is an average increase of 5 kg of husked rice per ha.

Among the 471 respondents, there were 321 farmers (68.15%) who were willing to pay and 150 were not willing to pay (31.85%). Analysis of WTP is focused on respondents who are willing to pay for irrigation water. The average land ownership of the farmers started as small as 0.10 ha and the largest 3.50 ha. Farmers who have large farms tend to respond willingly ("yes") to increase the bids. Farmers who have small land, have average bids value below the median bids value, while farmers who have large land, average bid value is above the median. The median of WTP is about Rp 470,000 per hectare and Rp 503,000 per hectare, respectively, for the wet and dry seasons, which are above the current ISF average.

(3) Estimate of average WTP. During the wet season, the largest percentage of the respondents are in class of Rp 442,000 to Rp 607,000, with the estimated average WTP at Rp 187,905 and Rp 179,735 per ha, respectively, for wet season and dry season (Table 4). The estimated total average WTP is about Rp 431,416 and Rp 466,581 per ha, respectively, for the wet and dry cultivations. Thus, in the dry season, the WTP of farmers tended to increase along with the increase in the value of bids. When the income of farmers increase, the WTP of farmers for irrigation water tends to increase too.

Table 4. Estimation of individual WTP in Jatiluhur Irrigation Area, 2016/2017.

	Interval Class of WTP (Rp/ha)/Seasons	Frequency (Person)	$EWTP_{Min}$ (Rp/ha)	$EWTP_{Max}$ (Rp/ha)	EWTP Average (Rp/ha)
Wet	110,000 – 275,000	72	24,673	61,682	43,178
	276,000 – 441,000	85	73,084	116,776	94,930
	442,000 – 607,000	115	158,349	217,461	187,905
	608,000 – 773,000	49	92,810	117,997	105,403
	Total	**321**	**348,916**	**513,916**	**431,416**
Dry	110,000 – 275,000	65	22,274	55,685	38,980
	276,000 – 441,000	64	55,028	87,925	71,477
	442,000 – 607,000	110	151,464	208,006	179,735
	608,000 – 773,000	82	155,315	197,464	176,389
	Total	**321**	**384,081**	**549,081**	**466,581**

(4) Estimate of total value of population WTP. The estimated total values of WTP are Rp 193,614,753 and Rp 207,243,802, respectively, for wet season and dry season (Table 5). The values of WTP are far above the current level of water charge (ISF) set for the famers in Jatiluhur irrigation area. These indicate that the potential consumer surplus of the farmers are available and can be used to improve irrigation water services.

Table 5. Estimation of the total WTP of the population in Jatiluhur Irrigation Area, 2016/2017.

Interval Class of WTP/Seasons	Frequency (persons)	Land areas of the samples (ha)	Land areas of the population (ha)	Total WTP (Rp/season)
Wet season				
110,000 – 275,000	72	17.68	35.72	6,875,697
276,000 – 441,000	85	31.14	62.91	22,553,374
442,000 – 607,000	115	77.28	156.11	81,881,965
608,000 – 773,000	49	59.00	119.19	82,303,717
Total	321	185.10	373.94	193,614,753
Dry season				
110,000 – 275,000	65	15.58	31.48	6,059,014
276,000 – 441,000	64	20.85	42.12	15,100,766
442,000 – 607,000	110	63.52	128.32	67,301,625
608,000 – 773,000	82	85.15	172.02	118,782,398
Total	321	185.10	373.94	207,243,802

Estimation *Bids Curve.* The farmers' total bid curve for irrigation water in Jatiluhur irrigation area based on the results of the WTP survey are presented in Figure 1 and Figure 2. The WTP curve could represent a demand curve because the cheaper the cost of irrigation water use, the more farmers are willing to pay and vice versa, the more expensive the use of irrigation water, the fewer farmers will be willing to pay. In these two figures, WTP for irrigation water in the wet season are lower than the dry season. Graphically, the demand curve of the WTP for irrigation water slightly shifts upwards for the dry season.

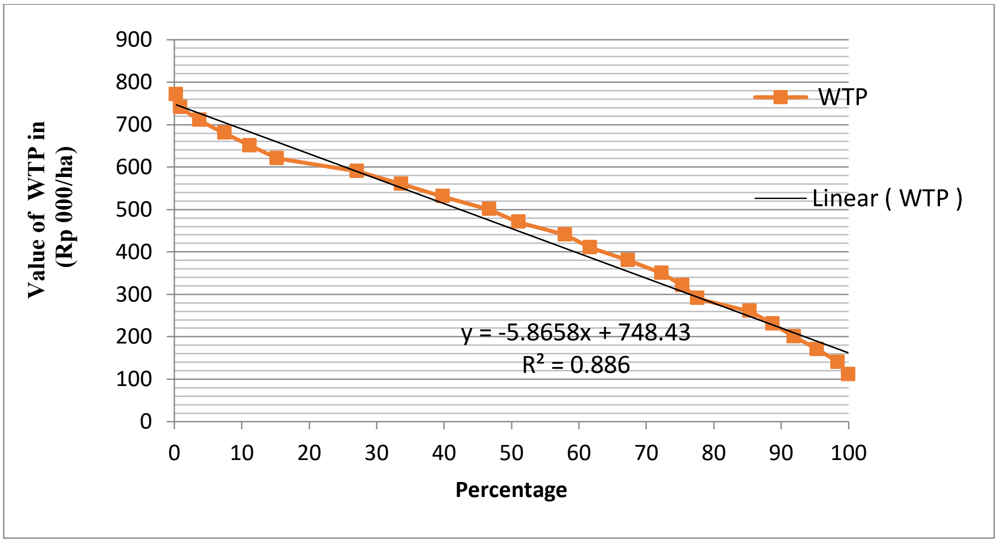

Fig. 1. Total farmers WTP in Jatiluhur Irrigation Area, Wet Season

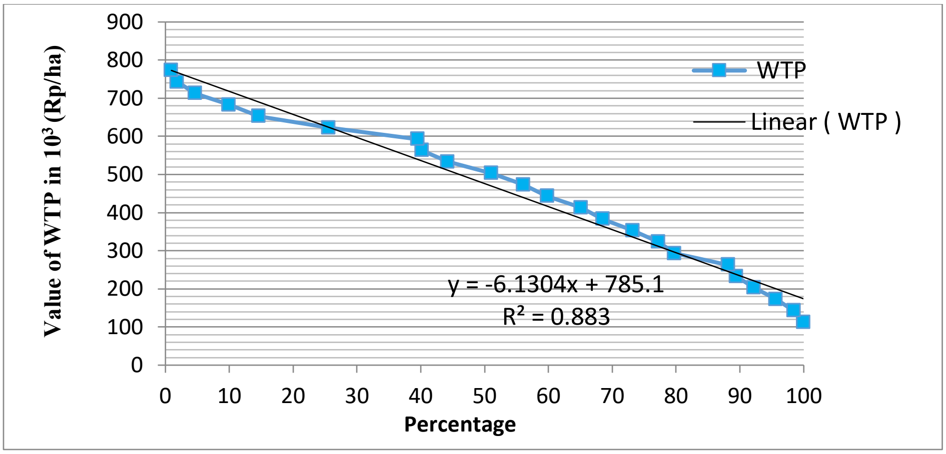

Fig. 2. Total farmers WTP in Jatiluhur Irrigation Area, Dry Season

Consumer Surplus. The consumer surplus is the difference between WTP and irrigation service fees (ISF) paid by the farmers. The calculation of consumer surplus value is estimated from the demand function of previously formed irrigation water WTP. Based on Table 2, on the average, the local farmers pay a ISF about Rp 108,558 and Rp 112,654 per ha, while the estimated average WTPs are Rp 431,416 and Rp 466,581 per ha, respectively, for the wet and dry seasons. Thus, the values of consumer surplus are Rp 322,858 and Rp 353,927 per ha, respectively, the wet and dry season (Table 6). These values indicate the benefits to the famers from consuming irrigation water in the paddy production. Thus, for the two seasons, there is a potential of extracting more water charge of as much as Rp 676,784 per ha. This value is a surplus received by the farmer, since the value of WTP is higher than the ISF paid by them. This value can be realized if there is an improvement the irrigation channel service can be implemented.

Table 6. Consumer surplus for irrigation water in Jatiluhur Irrigation Area, wet and dry cultivation season of 2016/2017.

Season	WTP Average (Rp/ha/season)	ISF Average (Rp/ha/season)	Consumer Surplus (Rp/ha/season)
Wet	431,416	108,558	322,858
Dry	466,581	112,654	353,927
Total Two Seasons	897,997	221,213	676,784

(5) Evaluation of CVM survey. The CVM survey conducted in the study is reliable with an R^2 greater than 0.15, so it can be used to predict factors that influence the estimated value of WTP and the model can be used properly (Table 7).

Factors affecting value of willingness to pay. An econometric model for analyzing factors affecting value of WTP of individual farmers is formulated. The estimates of this model as well as indicators of the model fittest are presented in Table 7. The model is fit as indicated by relatively high R-square (0.547), no multicolinierity (VIF < 5) and no autocorrelation (DW>DU). Only four out of nine independent variables have a significant effect on the value of WTP of individual farmers' WTP. Three factors (farmers' income X_1, farming experience X_2, and quality of irrigation service X_7) have a positive, while another one (outlet of irrigation X_8) has negative effect on value of WTP. Both famers' income and farming experience have a positive effect on famers' WTP so that the increase of farmers' income and the length of farming experience will increase the value of water charge that farmers are willing to pay. The quality of irrigation service also positively affects the farmers' WTP value. The better quality of irrigation service, the higher value of irrigation charge that farmers are willing to pay. This means that the farmers will be willing to pay a higher water charge for a better water irrigation service. The government needs to improve the current quality of water facilities and distribution if it wants to raise irrigation water charge. In contrast, distance of farm from main irrigation outlet (X_8) negatively affects the value of water charger. The farther the location the lesser is the value of the water charge that the farmers are willing to pay. This implies that water charge should be imposed differentially according to distance of the farm from the main distribution outlet.

Table 7. Factors affecting the value of farmers WTP in Jatiluhur Irrigation Area, Wet and Dry Seasons, 2016/2017.

Variables	Jatiluhur Irrigation Area		
	Coefisient	P-value	VIF
Constant	104561.14	0.000	
Farmer's Income (X_1),	0.0016675**	0.000	1.222
Farming Experience (X_2)	250.000**	0.001	1.355
Number of Household's members (X_3)	-1008.3595*	0.050	1.192
Length of Farmer's Formal Education (X_4)	295.88458	0.204	1.113
Age of Farmer (X_5)	-22.940565	0.782	1.274
Knowledge about *ISF* (X_6)	-1087.5269	0.404	1.004
Quality of Irrigation Service (X_7)	14270.538**	0.000	1.291
Distant of Farmland from Main Outlet of irrigation (X_8)	-3.007381**	0.006	1.179
Farmer's Involvement in Irrigation Management (X_9)	-583.25942	0.666	1.042

Annova F-hit =43.939*; $P < 0.005$
$R^2 = 0.560$; Adjusted $R^2 = 0.547$
Durbin Watson =1.879, DW > DU, 1.879 > 1.868 or 4-DW > DU, 2.121 > 1.868 : no autocorrelation

Notes : ** Significant with $\alpha = 1\%$, * Significant with $\alpha = 5\%$

CONCLUSION AND POLICY RECOMMENDATION

Economic contribution of irrigation water to the value of paddy farming production is quite large. However, the value of ISF that farmers actual pay is very small. There is a scope to increase ISF inasmuch as there is a large positive gap between the value of ISF that farmers are willing to pay and the actual ISF. Farmers'willingness to pay are affected by farmer's income, farmer's length of farming experience, quality of irrigation service and the distance of farms from the main distribution outlet.

Water shortage in Java is getting worse due to high population growth, industrialization and deforestation, among others. Improving this condition requires more effective measures such as raising the current ISF. The current charge is relatively very small compared to water irrigation contribution to value of paddy. From the perspective of profitability of paddy farming there seems no reason to reject the proposal for raising the current ISF. Paddy farming in Jatiluhur is very profitable so that it is possible to raise water charge without turning its operation to become a loss.

Although profitability of paddy farm is high, paddy farmers are generally poor since their land areas are quite small. The raise in water charge will reduce profit of the paddy farm which will affect adversely farmer income. However, such income reduction will not be a logical argument to reject the policy of raising irrigation water charge since it is desirable to motivate the paddy farmers to use irrigation water efficiently and to improve sectoral water allocation. This study has shown that the farmer's income affects positively the value of irrigation water charge that they are willing to pay. This implies that reduction of profit due to the raise of water charge will make them less willing to accept the new water charge policy. To anticipate this problem, the government should implement policies to improve income of rice farmers.

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CONSUMER EVALUATION OF NUTMEG PRODUCTS IN BOGOR REGENCY, INDONESIA

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ABSTRACT

Development of nutmeg (*Myristica fragrans* Houtt.) food and beverage home industry business in Bogor Regency has played an important role to the enhancement of the local economy and provides employment opportunities for women in neighboring areas. However, despite its existence as one of the local products, the current trend of nutmeg consumption seems to be decreasing due to the emergence of more fruit-based product varieties in the regency. This paper sought to clarify consumption trends of nutmeg food and beverage products in Bogor Regency and evaluate consumers' preferences in order to formulate measures to improve sales of nutmeg food and beverage products. A questionnaire survey was conducted in 2014 to 117 respondents in Bogor Regency, including 46 households and 71 university students. Despite the decreasing trend in nutmeg consumption, especially in young generation, there still seems to be potential of consuming and purchasing nutmeg products by people who come from outside Bogor Regency. In general, consumers attached importance to taste, appearance, and price in buying nutmeg products. Improving the packaging is vital for product development. Consumers who like to consume nutmeg will potentially continue to buy regardless of some degree of increase in the selling price without neglecting quality. In the future, offering samples of nutmeg products can be effective to let consumers know its actual taste, especially for those who have not consumed or bought nutmeg products.

Keywords: consumer survey, Price Sensitivity Models, Quantification Theory Type I

INTRODUCTION

Bogor Regency is one of the major producing areas of nutmeg in Indonesia. The nutmeg industry of the regency has expanded from producing raw materials only to processing several nutmeg products (Juwita and Tsuchida 2017). Unlike most nutmeg producing areas in eastern Indonesia popularly known for processing nutmeg spices, the regency is famous for the development of nutmeg food and beverage products (e.g. nutmeg sweets and nutmeg syrup). These products are sold in many places around the regency, such as local markets, bus terminals, train stations and tourism areas. Locals have recognized nutmeg sweets as one of their traditional foods. Development of nutmeg food and beverage industry has played an important role in the local economy. Not only nutmeg fruit farmers, nutmeg food and beverage home industry businesses also provide employment opportunities for women in neighboring areas. Moreover, besides its food culture and economic value, Lestari et al. (2012) proved that nutmeg also has health benefits, such as potential for anti-diabetic treatment. However, despite its functions and values, consumption of nutmeg food and beverage in Bogor Regency seems to be decreasing in the recent years. With the variety of more attractive food and beverages available (e.g. taro brownies, pumpkin short cakes, baked sweet potatoes, and many fruit-based beverages), consumers, especially the young people, tend to choose other options over nutmeg products. Furthermore, the number of nutmeg food and beverage producers have decreased by half in the past five years. Nevertheless, although there have been studies conducted to understand about market and purchasing behavior of other agricultural products in Bogor Regency, such as goat milk (Santoso et al. 2012) and organic vegetables (Slamet et al. 2016), as well as study on consumer behavior towards agricultural products with Geographical Indication (GI) in Indonesia (Dewi et al. 2017), there has been no research that specifically focused on the consumption trends for nutmeg food and beverage products. Thus, this study aimed to clarify the consumption trends for nutmeg food and beverage products and to evaluate consumers' preferences in order to formulate measures to improve sales of nutmeg food and beverage products in Bogor Regency.

METHODOLOGY

Survey area. Bogor Regency in West Java Province is located around 60 km from Jakarta. As one of the closest regencies to the national capital, Bogor Regency plays an important role as satellite city to the capital (Nas 1986). Surrounded by mountainous areas, Bogor Regency has not only become the residential area for working people in Jakarta but has also been one of the main tourism areas for the local community. With its suitable environment and convenient access to the capital, development of nutmeg processing industry in Bogor Regency has been rapidly expanded in the past ten years with variety of nutmeg products known as one of main local commodities.

Data collection. This study used two types of respondents namely, households and students. Household-respondents lived in three locations of residential areas, specifically: (1) the center of Bogor City; (2) border areas between Bogor City and regency; and (3) outer areas of the regency. Household-respondents were selected through snowball sampling method. First, the three residential areas were chosen to represent different types of living environments in Bogor Regency. Second, consumers in each residential area were randomly visited according to introduction from local authorities. Third, the survey was mainly conducted in one block of neighborhood in each area, depending on the available time of the respondents. Specifically, household-respondents were targeted to husbands or wives who were assumed to make buying decisions in the family. However, due to place and time constraints, food tasting was not conducted to household-respondents. Therefore, only respondents who have knowledge about nutmeg products in Bogor Regency were selected. Meanwhile, student-respondents were selected from those who study in IPB University, a public university with students coming from different areas across the country. Student-respondents were randomly met in the university's food court and were requested to participate in the food tasting. Three types of nutmeg food and beverage products (fresh sweets, dried sweets, and syrup) that were bought from local stores in Bogor Regency were prepared in small-sized serving. Students who had available time were asked to enter the classroom nearby the food court and participate in the survey as respondents.

The consumer survey was conducted from the 15 August to 19 September 2014 in Bogor Regency. Data from a total of 117 respondents, consisting of 46 households and 71 university students were collected. The questionnaire consisted of 22 multiple choice and open-ended questions which mainly focused on four aspects of nutmeg products, such as product, price, place and promotion (McCarthy's 4P). Specifically, the questionnaire had three main sections: (1) details of survey respondents (sex, age, hometown, and current residency); (2) trend in purchasing and consuming nutmeg products (buying place, provision of products information, and frequency and amount of purchase); and (3) consumers' preferences for nutmeg products (taste, price, and product appearance).

Data analysis

Tests of Statistical Significance. Averages or ratios were calculated in order to grasp the characteristics of consumers' behaviors. *T-Test* and *Chi-square Test* were used to estimate the significance for the differences between the analysis results. In terms of the price preference, related data were analyzed using Price Sensitivity Models and Quantification Theory Type I.

Van Westendorp Price Sensitivity Models. To analyze consumer preferences for price (IDR/kg) of nutmeg products, respondents were asked to answer the following questions based on Van Westendorp (VW) Price Sensitivity Models. The VW Price Sensitivity Models is a set of survey questions that are used to work out how to set prices for products. It is specifically focused on finding an acceptable price as a quality indicator. VW approach is based on the assumption that reasonable prices exist for consumers in every category and for each perceived level of quality within a category. Data elicited in the VW approach answers the following four indirect questions to calibrate price from different perspectives (Price A to D).

Price A: At what price would you begin to consider the product is getting expensive, but you still would consider purchasing it?

Price B: At what price would you consider the product to be too expensive to purchase it?

Price C: At what price would you consider the product to be priced low – the best buy for the money?

Price D: At what price would you consider the product is so cheap that you would doubt its quality?

Thus, for each of the four price questions, the cumulative frequencies are plotted against the current price on the same graph. The intersection of Price A curve with Price D curve according to VW is called the point of "marginal cheapness". The intersection point of Price B curve with Price C curve is called "marginal expensiveness". The range between these two points shows the area of the price acceptable for most consumers. The intersection of the Price A and the Price C curves also correspond to the "indifference price" point, where there are an equal number of respondents for both these questions. The intersection of the Price B and Price D curves defines the point of "optimal pricing" (Lipovetsky et al. 2011; Ceylana et al. 2014).

Quantification Theory Type I. To clarify the potential determinants of the price levels showed by consumers in the Price Sensitivity Models, Quantification Type I Analysis is utilized according to Hayashi's First-Fourth Methods of Quantification Theory. Hayashi's Quantification Type I is a method to predict the quantitative external criterion or criterion variable on the basis of the information concerning the qualitative attributes of each subject and to analyze the influence of each attribute to the criterion variable (Tanaka 1979).

The following were considered related to the price level (Price A): (1) taste evaluation score, (2) purchasing experience, (3) consuming experience, (4) age, and (5) sex. Hence, the correlation between the external criterion (Y) of Price A and five of the qualitative factors was estimated using Hayashi's Quantification Theory Type I as follows: $Y=a_0+\Sigma b_i \cdot X_i$

Where Y: price A at which consumers begin to think the product is getting expensive

X: dummy variables

$X_1 - X_5$: taste evaluation score (very bad, bad, average, good, and very good)

$X_6 - X_7$: purchasing experience (no and yes)

$X_8 - X_9$: consuming experience (no and yes)

$X_{10} - X_{11}$: age (age 20-39 and age 40-69)

$X_{12} - X_{13}$: sex (male and female)

a_0: constant term

b_i: category score

The category score (b_i) and constant term (a_0) were calculated by the same method used to calculate coefficients in multiple linear regression analysis using dummy variables. The category which exhibits the largest score from among the factors causes the external criterion to be larger, and therefore, it can be assumed that the category with the largest score is the most potential determinants of the price levels (Price A) (Matsumura 2004).

Profile of respondents. Table 1 shows the profile of survey respondents. In this survey, number of female respondents are observed to be slightly dominating both groups of respondents. The interview to household-respondents also confirmed that female members of the family were the ones who usually purchase nutmeg products in the market. The ages of household-respondents varied from 20 to 69 years old with an average of around 40 years old. On the other hand, all student-respondents were in their 20s.

Table 1. Profile of survey respondents (Unit: %)

	Household-respondents (H) (n = 46)	**Student-respondents (S) (n = 71)**
Gender		
Male	45.7	46.5
Female	54.3	53.5
Age (years)		
20~29	30.5	100
30~39	13.0	-
40~49	15.2	-
50~59	26.1	-
60~69	15.2	-
Estimated Average	42.8	-
Hometown		
Bogor Regency (Including Bogor City)	71.7	26.8
Outside Bogor Regency	28.3	73.2

Source: Consumer survey in 2014

In terms of hometown, 71.7% of household-respondents (hereafter, H-respondents) originated from regency. Meanwhile, 73.2% of student-respondents (hereafter, S-respondents) came from outside the regency. Although 28.3% of the H-respondents came from outside the regency, most of them have lived in Bogor for some years which are generally longer than those of the S-respondents from outside the regency.

H-respondents were divided into two groups (H1-respondents: people under 40 years old, H2-respondents: people aged 40 years old and above), and S-respondents were divided into two groups (S1-respondents: people from the regency, S2-respondents: people from outside the regency), in order to analyze consumption trends of nutmeg products and preferences by varying age and difference in hometown.

For S-respondents, the classification was based on difference in hometown. It is because all respondents are in the same group of age. Meanwhile, group classification for H-respondents was based on ratios of respondents in terms of group of age (Table 1). Classification by age is chosen instead of difference in hometown, because H-respondents who are from outside Bogor Regency have resided longer in Bogor Regency compared to those of S-respondents. Hence, by dividing ratios of H-respondents into two big groups, the total ratios of H1-respondents are 43.5%, while H2-respondents are 56.5%. Although the exact average age of respondents is unclarified because respondents were only asked to choose their age group instead of stating their actual age (estimated average age was 42.8 years old), the in-depth interview showed different perspectives between those who are under or above 40 years old. Thus, the H-respondents were divided into two groups with 40 years old as the border line.

PURCHASING BEHAVIOR OF NUTMEG PRODUCTS' CONSUMERS

Table 2 shows the experience of consuming nutmeg products by group. In the H-respondents, ratios of consuming nutmeg products of H2-respondents were significantly higher than those of H1-respondents. In the case of S-respondents, more than 70% of S1-respondents had experience of consuming nutmeg fresh and dried sweets products, while only 40.4% and 65.4% of S2-respondents have consumed the same, respectively. People who are originally from and residing in the regency have significantly consumed more nutmeg products compared to those who come from outside the regency. Furthermore, it is also clarified in the in-depth interview to H-respondents that those who have been residing in Bogor Regency for longer period have more information about nutmeg products as they frequently encounter nutmeg products in their daily lives (e.g. in stores at the bus terminal, train station, or traditional market). Although they have not been purchasing by themselves, some of them had the chance of consuming nutmeg products while visiting friends, neighbors or relatives in the regency. However, the interview also clarified that the difference of ratios of consuming nutmeg products between H1-respondents and H2-respondents have been affected by the shift of nutmeg products' consumption trend in the regency. Not only the number of nutmeg producers was said to be decreasing, nutmeg products are currently acknowledged as traditional products of Bogor regency while in the same time there are also many other varieties of food and beverages products that are more attractive for younger consumers.

Table 2. Percentage of people who have consumed nutmeg products by group (Unit: %)

Type of Nutmeg Products	Household-respondents (H)			Student-respondents (S)		
	H1 Age 20-39 (n = 20)	**H2 Age 40-69** (n = 26)	**Total H** (n = 46)	**S1 Bogor** (n=19)	**S2 Outside Bogor** (n=52)	**Total S** (n = 71)
Fresh Sweets	85.0	96.2	91.3[e]	78.9[c]	40.4[d]	50.7[f]
Dried Sweets	55.0	76.9	67.4	73.7	65.4	67.6
Syrup	15.0[a]	46.2[b]	32.6[e]	5.3	9.6	8.5[f]

Source: Consumer survey in 2014

Notes: 1) a and b in the same row denote ratios of H1 and H2 are significantly different at 5% level.
2) c and d in the same row denote ratios of S1 and S2 are significantly different at 1% level.
3) e and f in the same row denote ratios of Total H and Total S are significantly different at 1% level.
4) Results of test of significance for the differences were estimated using chi^2-test.

To clarify the conditions of consumers' actual purchasing of nutmeg products, only respondents who have ever purchased nutmeg products were asked about their purchasing behavior, such as purchasing place and provision of information related to nutmeg products.

Place of purchasing nutmeg products. Many kinds of nutmeg products are sold in many places around the regency, including stores inside local markets or nearby bus terminals, and tourism areas (Table 3). Thus, more than 45% of H-respondents purchased nutmeg products at the local market that they frequently visited and commonly perceived to offer nutmeg products at a cheaper price. Moreover, it is also noticed that around 30% of H-respondents purchased nutmeg products directly from producers. Some of them mentioned that they became regular customers of specific producers after purchasing from them for several years.

Table 3. Place of purchasing nutmeg products (Unit: %).

Place of Purchase	Household-respondents (H)			Student-respondents (S)		
	H1 Age 20-39 (n = 18)	H2 Age 40-69 (n = 24)	Total H [a] (n = 42)	S1 Bogor (n = 11)	S2 Outside Bogor (n = 23)	Total S [b] (n = 34)
Local Market	50.0	45.8	47.6	36.3	21.8	26.5
Bus Terminal	-	4.2	2.4	9.1	4.3	5.9
Souvenirs Store	22.2	16.6	19.0	36.4	60.9	52.9
Tourism Area	-	4.2	2.4	9.1	8.7	8.8
Producer	27.8	29.2	28.6	9.1	4.3	5.9

Source: Consumer survey in 2014 (only respondents who have purchased nutmeg products until 2014)

Notes: 1) a and b denote purchasing place patterns of Total H and Total S are significantly different at 1% level.

2) Results of test of significance for the differences were estimated using chi^2-test.

On the other hand, S-respondents showed different patterns in terms of purchasing place. S-respondents purchased nutmeg products at souvenir stores or local markets, where 60.9% of S2-respondents purchased at souvenir stores. Compared to stores inside the local market, souvenir stores are usually located near bus terminal or train station where consumers from outside the regency can easily visit. Meanwhile, 36.4% and 36.3% of S1-respondents purchased nutmeg products at souvenir stores and local market, respectively.

Source of information on nutmeg products. Promotion of the nutmeg products plays an important role in spreading the information and expanding the sales of the products. Table 4 shows the source of information on nutmeg products. A total of 47.6% of H-respondents knew about nutmeg products from their families/relatives, while 40.5% of them received information from their friends. These can be attributed to the long tradition of producing and consuming nutmeg products in the regency. Meanwhile, 63.6% of S1-respondents answered that they received information from their own family or relatives. Most of them purchased at the same place where their family usually buy. On the other hand, 39.2% of S2-respondents had information about stores from their friends. They usually asked their friends who are from the regency for recommended stores. About 7.1% of H-respondents and 20.6% of S-respondents received information from pamphlet/flyer. Although other sources of information (e.g. pamphlets and flyers) were identified, there seemed to be a need to develop innovative ways to promote and increase nutmeg consumption.

Table 4. Source of information on nutmeg products (Unit: %).

Source of Information	Household-respondents (H)			Student-respondents (S)		
	H1 Age 20-39 (n = 18)	H2 Age 40-69 (n = 24)	Total H (n = 42)	S1 Bogor (n = 11)	S2 Outside Bogor (n = 23)	Total S (n = 34)
Pamphlet / Flyer	11.1	4.2	7.1	18.2	21.7	20.6
Friends	38.9	41.6	40.5	18.2	39.2	32.4
Family /Relatives	44.4	50.0	47.6	63.6	34.8	44.1
Others	5.6	4.2	4.8	-	4.3	2.9

Source: Consumer survey in 2014 (only respondents who have purchased nutmeg products until 2014)

Annual purchasing frequency and quantity of nutmeg products. Overall, H-respondents have significantly purchased much more nutmeg products than S-respondents (Table 5). H2-respondents buy more frequently, specifically 1.3 times and 1.8 times per year more than H1-respondents for fresh and dried sweets, respectively. Meanwhile, S-respondents tend to buy fewer nutmeg products. On the average, S-respondents purchase nutmeg products once a year and there is no significant difference between those of S1-respondents and S2-respondents. However, the mean purchasing quantity of S1-respondents for dried sweets was 1.9 times more than S2-respondents. These findings are found to be related with the in-depth interview conducted to H-respondents. As mentioned previously, H2-respondents tend to have consumed more nutmeg products than H1-respondents (Table 2). Thus, confirming the decreasing trend of nutmeg products in terms of purchasing frequency by the younger consumers (H1, S1, and S2 respondents).

Table 5. Annual frequency (F) and quantity (Q) of purchased nutmeg products.

Type of Nutmeg Products	Household-respondents (H)						Student-respondents (S)					
	H1 Age 20-39		H2 Age 40-69		Total H		S1 Bogor		S2 Outside Bogor		Total S	
	F	Q	F	Q	F	Q	F	Q	F	Q	F	Q
Fresh Sweets												
n	14	14	17	17	31	31	4	4	5	5	9	9
mean	3.9	1,950	5.1	2,426	4.6[a]	2,221[c]	1.0	750	1.0	750	1.0[b]	750[d]
S.D.	5.9	1,903	4.3	1,976	5.0	1,926	0.0	289	0.0	707	0.0	530
Dried Sweets												
n	8	8	9	9	17	17	5	5	6	6	11	11
mean	2.6	1,500	4.6	1,444	3.6[a]	1,471	1.4	1,050	1.2	542	1.3[b]	773
S.D.	1.3	1,126	4.4	1,391	3.4	1,234	0.9	570	0.4	485	0.6	564

Source: Consumer survey in 2014 (only respondents who have purchased nutmeg products until 2014)

Notes: 1) F = Frequency (Unit: times/year); Q = Quantity (Unit: gr/time)

2) a and b in the same row denote means of frequency (F) of Total H and Total S are significantly different at 5% level.

3) c and d in the same row denote means of quantity (Q) of Total H and Total S are significantly different at 5% level.

4) Results of test of significance for the differences were estimated using t-test.

IMPORTANT FACTORS AFFECTING CONSUMERS PURCHASING BEHAVIOR

In order to expand consumption of nutmeg products, there is a need to discuss important factors to be considered and improvements to be done for future development of nutmeg products. Table 6 shows that both H-respondents and S-respondents mentioned taste, product appearance and price as the major factors, conveying that these three factors should be initially assessed and improved to suit the quality requirements of consumers for nutmeg products.

Table 6. Factors considered important in purchasing nutmeg products (Unit: %)

Items	Household-respondents (H)			Student-respondents (S)		
	H1 Age 20-39 (n = 20)	H2 Age 40-69 (n = 26)	Total H (n = 46)	S1 Bogor (n = 19)	S2 Outside Bogor (n = 52)	Total S (n = 71)
Taste	80.0	57.7	67.4	52.6	67.3	63.4
Product Appearance	10.0	26.9	19.6	31.6	17.3	21.1
Quantity	-	-	-	-	-	-
Packaging	-	3.9	2.2	-	3.9	2.8
Labeling	5.0	-	2.2	-	-	-
Price	-	7.7	4.3	15.8	9.6	11.3
Others	5.0	3.8	4.3	-	1.9	1.4

Source: Consumer survey in 2014

Taste. Table 7 shows the evaluation results of the taste of nutmeg products based on 5-point Likert Scale (1 very bad taste, 3 average taste, and 5 very delicious). In case of the S-respondents, nutmeg fresh sweets, dried sweets and syrup were provided as samples because not all respondents have consumed nutmeg products. S-respondents were asked to give a score to each of nutmeg products after food tasting. However, since the food tasting was not conducted for H-respondents due to limitation of tasting place, scores were taken from H-respondents who have actual experience tasting nutmeg products but none of them have purchased and/or consumed nutmeg syrup.

Table 7. Taste evaluation score of nutmeg products

Type of Nutmeg Products	Household-respondents (H)			Student-respondents (S)		
	H1 Age 20-39	H2 Age 40-69	Total H	S1 Bogor	S2 Outside Bogor	Total S
Fresh Sweets						
n	18	24	42	19	51	70
Mean	4.44	4.38	4.40[a]	3.42	3.18	3.24[b]
S.D.	0.70	0.71	0.70	1.12	1.05	1.07
Dried Sweets						
n	14	19	33	19	52	71
Mean	3.43	3.68	3.58	3.63	3.25	3.35
S.D.	1.22	1.11	1.15	1.12	1.01	1.04
Syrup						
n	-	-	-	19	50	69
Mean	-	-	-	2.95[a]	4.12[b]	3.80
S.D.	-	-	-	1.27	0.69	1.02

Source: Consumer survey in 2014

Notes: 1) There are 1 to 2 respondents who did not give scores for all products.
2) a and b in the same row denote means are significantly different at 5% level.
3) Results of test of significance for the differences were estimated using t-test.

Price. Figures 1 and 2 show the accepted price curves based on prices A to D and percentage of accumulative respondents based on the VW Price Sensitivity Models. It should also be noted that this analysis only focused on H-respondents due to the large amount of nutmeg sweets purchased and their capacity to appropriately evaluate price of nutmeg sweets. Moreover, in the questionnaire, the current price of each product was provided to give information to respondents who had not purchased any nutmeg product (e.g. 27,000 IDR/kg for fresh sweets and 25,000 IDR/kg for dried sweets). Thus, the following questions is set to graph the accepted price curves.

Price A: At what price would you begin to consider the product (1 kg of nutmeg sweets) is getting expensive, but you still would consider purchasing it?

Price B: At what price would you consider 1 kg of nutmeg sweets to be too expensive to purchase it?

Price C: At what price would you consider 1 kg of nutmeg sweets to be priced low – the best buy for the money?

Price D: At what price would you consider 1 kg of nutmeg sweets is so cheap that you would doubt its quality?

There is a clear difference between H1-respondents and H2-respondents. H2-respondents are willing to pay higher for nutmeg sweets compared to H1-respondents. "Indifference Price" point (the point of intersection of the curve Price A and Price C) of nutmeg fresh and dried sweets for H1-respondents were about 25,000 and 20,000 IDR/kg, respectively. Meanwhile, those of H2-respondents were about 27,000 IDR/kg for both products. Moreover, the above accepted price curve (especially curve of price A) means that there are some consumers who are willing to continue to purchase nutmeg products regardless of the increase in selling price. Thus, Hayashi's Quantification Theory Type I analysis clarified the potential determinants of the price levels showed by consumers who are willing to continue to buy nutmeg sweets.

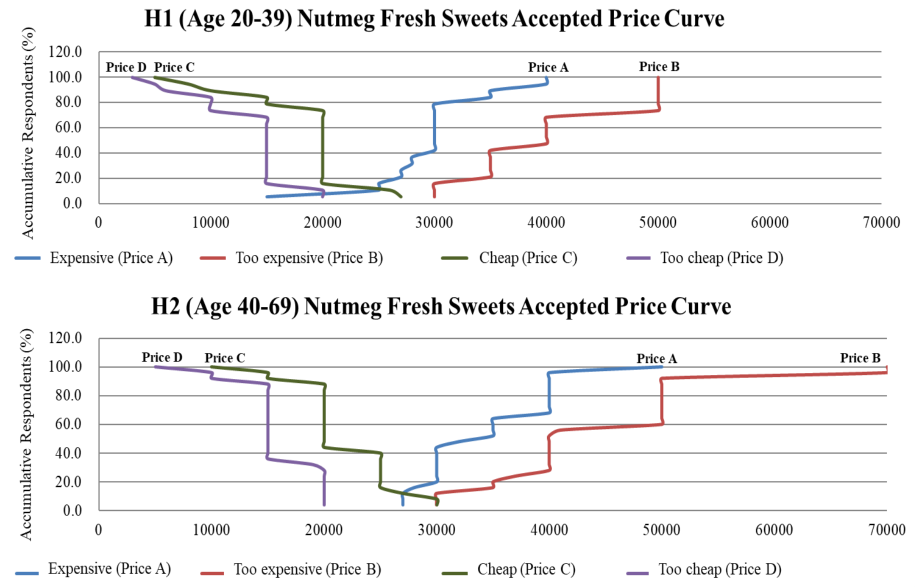

Fig. 1. Nutmeg fresh sweets accepted price curve of H-respondents

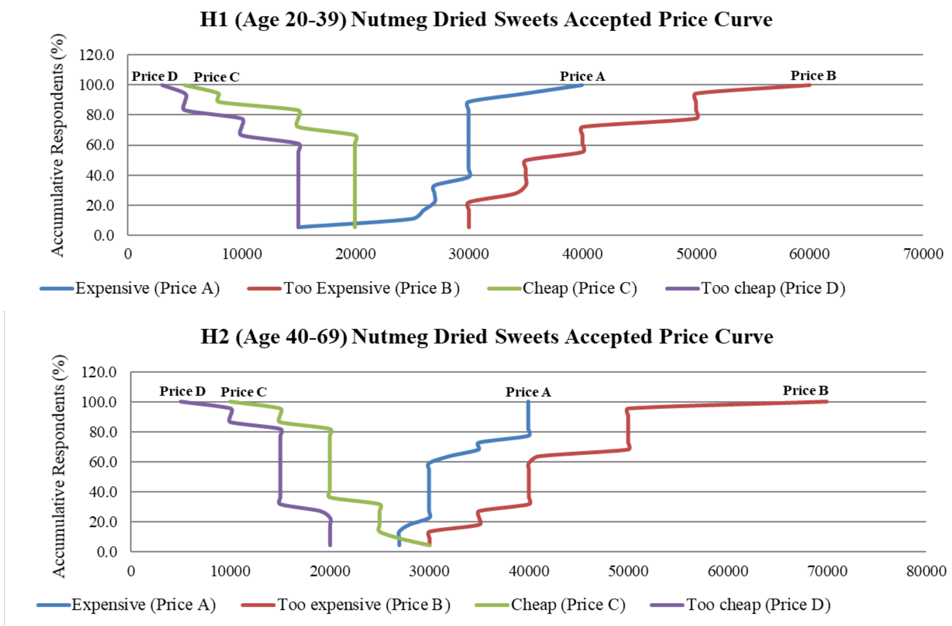

Fig. 2. Nutmeg dried sweets accepted price curve of H-respondents

Factors such as taste evaluation score, purchasing experience, consuming experience, age, and sex influence the accepted nutmeg price of fresh sweets and dried sweets, respectively (Tables 8 and 9).

Table 8. Factors affecting accepted price of nutmeg fresh sweets in H-respondents.

Item	Category	n (n=42)	Category Score (b_i) (Unit: 1,000 IDR)
Taste Evaluation Score	1 point (X_1)	1	-20.06
	2 points (X_2)	-	-
	3 points (X_3)	6	-4.65
	4 points (X_4)	15	-0.91
	5 points (X_5)	20	3.08
Purchasing Experience	No (X_6)	7	5.32
	Yes (X_7)	35	-1.06
Consuming Experience	No (X_8)	2	-0.16
	Yes (X_9)	40	0.01
Age	Age 20-39 (X_{10})	19	-2.87
	Age 40-69 (X_{11})	23	2.37
Sex	Male (X_{12})	17	0.24
	Female (X_{13})	25	-0.17
$R^2=0.4424$			

Table 9. Factors affecting accepted price of nutmeg dried sweets in H-respondents.

Item	Category	n (n=37)	Category Score (b_i) (Unit: 1,000 IDR)
Taste Evaluation Score	1 point (X_1)	1	-13.53
	2 points (X_2)	6	-0.43
	3 points (X_3)	9	-0.28
	4 points (X_4)	13	0.16
	5 points (X_5)	8	2.06
Purchasing Experience	No (X_6)	11	3.00
	Yes (X_7)	26	-1.27
Consuming Experience	No (X_8)	6	-2.58
	Yes (X_9)	31	0.50
Age	Age 20-39 (X_{10})	18	-1.99
	Age 40-69 (X_{11})	19	1.88
Sex	Male (X_{12})	17	0.12
	Female (X_{13})	20	-0.11
$R^2=0.4279$			

The taste evaluation score which represents whether consumers like or dislike the products is the biggest factor in deciding the price accepted by consumers, conveying that customers who like to consume nutmeg products will potentially continue to purchase regardless the increase of the price provided the products is of suitable quality. The purchasing and consuming experiences also affect accepted price. In terms of consuming experience, respondents who had consumed nutmeg sweets before tending to continue to purchase the products even if its price becomes a little higher, which consistently conveys same trend with taste evaluation score. Meanwhile, respondents who have no purchasing experience tend to show positive response toward the increase in price, which is contrary to prior expectation. They seem to tend to evaluate the price higher due to lack of actual price information. Moreover, as depicted on Figures 1 and 2, category score of age in Table 8 and 9 also confirmed that H2-respondents are willing to pay higher for nutmeg sweets compared to H1-respondents. On the other hand, the influence of sex on accepted price is small.

Product appearance. Most nutmeg products are being displayed in stores and sold in simple packaging. The fresh sweets products are displayed in glass bins, then weighed and packed in plastic bag when customers buy according to their orders. Meanwhile, dried sweets are packed 250 grams each in plastic bags without proper labelling (e.g. no information on ingredients and product). It should be noted that most of nutmeg products sold in the local markets or small souvenirs stores nearby bus terminals or tourism areas have no brand. Currently there are only one or two brands of nutmeg products in the regency that properly pack and put label on their products, hence these products are usually sold in supermarket or big souvenirs stores with relatively higher price. On the other hand, as the most recently developed product, the packaging of nutmeg syrup seems to be much better than others. Nutmeg syrup is sold in either plastic or glass bottle of difference sizes, i.e. 500 ml or 1 liter depending on the processor. The bottle is properly sealed and labeled with ingredients and product information. Most syrup processors have also created products' brand for better marketing.

Furthermore, this study identified the following measures are necessary to improve products appearance: 1) improving package seal, 2) providing label with product information, and 3) changing packaging color (Table 10). Improving packaging of nutmeg products can increase consumers' trust on quality of the products. Especially, by providing label about product's ingredients on the package, consumers can have more knowledge on how the product is made and what kind of benefits it has. Hence, good packaging can potentially attract more consumers to buy nutmeg products.

Table 10. Necessary improvement on nutmeg products appearance (Unit: %)

Items	Household-respondents (H)			Student-respondents (S)		
	H1 Age 20-39 (n = 19)	H2 Age 40-69 (n = 26)	Total H (n = 45)	S1 Bogor (n = 19)	S2 Outside Bogor (n = 52)	Total S (n = 71)
Improve package seal	47.4	38.5	42.2	42.1	48.1	46.5
Provide label of product information	52.6	57.7	55.6	36.8	36.5	36.6
Change packaging color	-	-	-	15.8	7.7	9.9
Package in small glass bin / bottle	-	-	-	5.3	5.8	5.6
Others	-	3.8	2.2	-	1.9	1.4

Source: Consumer survey in 2014

Note: 1) There is 1 respondent who did not give score for all products.

CONCLUSION AND RECOMMENDATION

This paper has clarified the consumption trends and preferences of households and students for nutmeg food and beverage products (i.e. nutmeg fresh sweets, nutmeg dried sweets, and nutmeg syrup) in Bogor Regency. In general, the differences in consumer age and hometown affected purchasing behavior of nutmeg products. The older consumers who are originally from and residing in the regency have purchased more nutmeg products compared to younger consumers. On the other hand, despite the decreasing trend of nutmeg consumption in the regency, there is also possibility of consuming and purchasing nutmeg products by people who come from outside Bogor Regency.

Both student-respondents and household-respondents emphasized the importance of taste, products appearance, and price when they purchase the nutmeg products. Hence, it is important to improve the products based on the needs and preferences of target consumers. The following measures can be considered for product improvements: 1) providing products with a little less sugar for aged people who are paying attention on taking too much sweets; 2) developing new products such as nutmeg syrup which can meet the preference of younger generation; 3) labeling of ingredients and expiration date; and 4) packaging that looks delicious and hygienic. Though these measures may increase the production cost of nutmeg products, consumers who have understood the benefits of nutmeg may purchase regardless of slight price increase.

In addition, for further market expansion, offering food tasting when selling nutmeg products can be an effective way to increase consumer awareness, especially for those who are coming from outside the regency and have no experience in consuming or buying nutmeg products.

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PROPAGATION TECHNIQUES FOR RAPID ESTABLISHMENT AND PRODUCTION OF COCOYAM (*Xanthosoma sagittifolium* (L.) Schott)

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ABSTRACT

Corm, cormel and corm setts of cocoyam (*Xanthosoma sagittifolium* L. Schott) were tested to determine the most practical and efficient propagation technique for its multiplication. The study for evaluating corm and cormel used whole corm, top half, bottom half, and cormel. Corms and its parts showed that all planting materials have comparable sprouting percentage at 8 weeks after planting (WAP) except for cormel which had significantly lower sprouting. Whole corm and top half of corm produced significantly longer corm and higher corm yield than other treatments. The study for sett used small sett with 15 and 30 cm petiole, big sett with 15 and 30 cm petiole and small sett with intact shoots. The result showed that all treatments gave comparable percent survival at 4 WAP except for small corms with intact shoots. Big sett with 30 cm petiole showed higher plant height, stem girth, petiole length, and number of leaves than other treatments. Small setts with 15 and 30 cm petiole and big sett with 30 cm petioles have comparable corm length, girth and yield. All treatments except for those with small setts with intact shoots have comparable number and length of cormel. Cormel yield from small sett with 15 cm petiole is comparable with big sett with 30 cm petiole.

Keywords: Takudo, Gabing San Fernando, cocoyam, *tannia*, propagation techniques, rapid multiplication

INTRODUCTION

Cocoyam *(Xanthosoma sagittifolium)* (L.) Schott is locally known in the Philippines *as Gabing San Fernando, Galiang, Takudo,* and *Butig*. It is a perennial crop belonging to the family *Araceae* (Aroid), and has a corm where the cormels are attached. Corm is the pseudo stem of the plant while sett is the top portion of the main plant including about 5 mm of corm and the leaves cut off about 20-30 cm above the base, but leaving the newly formed leaf at the center of the plant (Kay 1987) (Fig. 1). Cormels are the parts that grow from the corm. Several large leaves sprout from the main stem and the leaves are sagittate and erect with long, ribbed petioles (Bermejo and de Leon 1994; Pardales1997). They are grown for their edible corms or cormels which are used as food (boiled as snack food), yam substitute in yam jam (*Halayang ube*), and additional vegetables for meat or fish sour broth (*sinigang).* The young leaves of cocoyam are also used sometimes as vegetable similar to spinach (Bermejo and De Leon 1994). Ohaemenyi (1993) reported that cocoyam corms can be cooked and used to some extent in the diets of growing pigs.

Xanthosoma sagittifolium grows in hot and humid areas of the world and is cultivated extensively throughout West Africa (Onwueme 1982). It is also common anywhere on the dryland environment of the Philippines. In the past, it, was mainly cultivated and consumed by the less privileged small scale farmers. A study conducted by the Farming Systems and Soil Resources Institute (FSSRI) and the Institute of Animal Science (IAS) in Dolores, Quezon used corms of cocoyam as substitute for corn in swine feeds (Villancio et al. 2001). For Philippine farmers, the cormels are marketed for human consumption while the main corms (*sakwa*) are used as planting material and as feeds (Villancio et al. 2001; Bulatao et al. 2010).

The use of cocoyam as a raw material for brewing is reported by Onwuka and Eneh 1996. It is a staple crop in parts of Ghana, Nigeria, Japan, and Hawaii. In South Pacific Island countries, edible aroids, principally taro (*Colocasia esculenta L. Schott*), form a high proportion of the root crops. However, in the Caribbean and West Africa, tannia (*X. sagittifolium*) dominates (Owuso –Darko et al. 2014). Cocoyam is now gaining more importance due to the superiority of their corms and cormels in terms of energy, proteins and mineral elements (Mwenye 2009). Cocoyam cormel ranks second to sweet potato in terms of nutritive value and digestibility, having a nutritional value comparable to potato, containing 15 - 39% of carbohydrates, 2-3% of protein and 70-77% of water (Bermejo and Leon 1994).

In spite of its growing importance, the production of cocoyam has been stagnant for many years owing mainly to low productivity (Schafer 1999), the limited availability of traditional planting material (corm cuttings), as well as viral and fungal infections (Xu et. al. 1995; Mbouobda, et. al. 2007). Planting material acquisition is a big challenge especially for commercial or large scale production due to the inherent low multiplication ratio of the corms (Owusu-Darko 2014). The production technologies for cocoyam for large scale production are not yet well established in the Philippines and are greatly based on small-scale production. There is a need to develop the component technologies for large scale planting to get the potential benefits from this crop. Thus, this study was conducted to determine the most practical and effective propagation technique using different plant parts of cocoyam as planting materials that will give early establishment and higher yield.

MATERIALS AND METHODS

Two separate trials (Trial A and B) were conducted from August 2015 to April 2016 to determine the best propagation technique to rapidly multiply cocoyam planting materials using the following: corm and its parts, cormel and setts (Fig. 1).

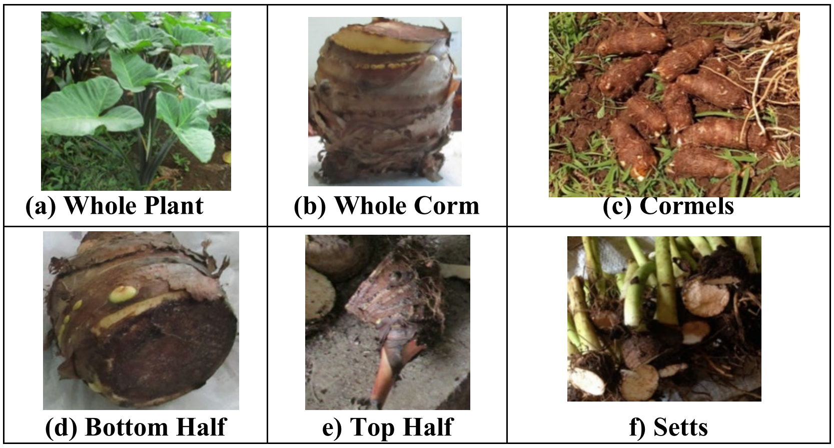

Fig. 1. Cocoyam (*Xanthosoma sagittifolium)* plant showing the whole plant and the different parts used as planting materials, (a) whole plant, (b) whole corm, (c) cormels, (d) bottom half corm, (e) top half corm and (f) setts.

The planting materials were cleaned, sorted according to sizes of corm's and sett's girths. They were then cut into sizes according to the proposed treatments (Fig. 1). The planting materials were treated with fungicide (Mancozeb 80WP) to prevent corm and sett rot which may affect the sprouting and development of the cocoyam plants.

Corm parts and cormel as planting material. For the trial using corm and cormel, four (4) treatments; b) whole corm, c) whole cormel, d) bottom half corm, and e) top half corm (Fig. 1) were laid in Randomized Complete Block Design with 4 replications. This experiment was established at the Agricultural Systems Institute (ASI) screen house using the 16 concrete enclosed, volcanic soil-filled plots of 4m x 4m. Cocoyam was planted at a distance of 50cm x 50cm apart.

Different types of setts as planting material. Similarly, for the trial involving setts, 5 treatments; a) small sett with 15 cm petiole, b) small sett with 30 cm petiole, c) big sett with 15 cm petiole, d) big sett with 30 cm petiole, and e) small sett with intact shoots, were arranged in a Randomized Complete Block Design with 4 replications. The corm size of the small sett was 29-32 mm girth while big sett was 42-59 mm. This was established at Block C8 of the Central Experiment Station of the University of the Philippines Los Banos. Plot size was 10 m x 5 m and 50 planting materials were planted in each plot at a distance of 1 m x 1 m. The total experimental area was 1,560 m^2 including the 2 m alley way between treatments and replicates.

The plants were fertilized at the rate of 30-30-30 kg NPK/ha using complete fertilizer (14-14-14) as basal application and urea (46-0-0) as side dress at 3 and 6 months after planting. Weeds were controlled regularly through using grass cutter and hand weeding. Insect pests were controlled by spraying bio-con agent, Nuclear Polyhedrosis Virus (NPV) to control cutworm, which were observed during the early establishment of the plants. For both trials, data collection started after planting (4 WAP) until harvest (28 WAP). The experimental area was irrigated as needed using perforain irrigation system.

a) big sett with 15 cm petiole

b) big sett with 30 cm petiole

c) small sett with 15 cm petiole

d) small sett with 30 cm petiole

e) small sett with intact shoots

Fig. 2. Sett planting material treatments, (a) big sett with 15cm petiole, (b) big set with 30cm petiole, (c) small sett with 15cm petiole, (d) small sett with 30 cm petiole, (e) small sett with intact shoots.

Data were collected from 10 sample plants per replicate per treatment for the following: a) number of plants that have sprouts b) plant height, c) petiole length, and d) girth size. The following yield and yield parameters were also gathered: number of cormels per plant, cormel yield per plant (g), cormel length and girth (cm), corm yield per plant (g), and corm length and width (cm). Observations on the sprouting started when the shoots became evident, i.e. around 0.5 -1.0 inch above the ground. The number of plants that have sprouts was counted every week until 9 WAP. The collected data were statistically analyzed for significance using ANOVA and comparison of means.

RESULTS AND DISCUSSION

Corm parts and cormel as planting material. Sprouting of propagules started 3 WAP which is close to the findings of Osundare (2010) where corm, cormel and split corm of cocoyam emerged in 2 to 3 WAP. Whole corm gave a 100% sprouting after the 8 weeks of observation. All treatments showed statistically similar sprouting percentage at 5WAP (Table 1). The percent sprouting of cormel was statistically comparable with the whole corm and top half corm on the 5 WAP but statistically lower than the former treatments starting 6 up to 8 WAP and never attained 100% sprouting even on the 8 WAP. No noticeable sprouting was observed on the 9-10 WAP in all treatments. The result is consistent with the findings of Tsedalu et al. (2014) who found out that corms achieved 50% emergence earlier than cormels. The delay in the sprouting of bottom half corms and cormel at 3 WAP to 5 WAP could be due to the dormancy of cut corms. Wilson (1984) attributed the delay in sprouting to the dormancy period of aroids from cutting portions of corm or cormels of approximately 5 weeks. The results showed that it is better to use whole corm, top half and bottom half of corm as planting material compared to cormels. This is especially critical when planting materials are scarce where the whole corm could be divided into two parts (top and bottom) without affecting its sprouting percentage.

Table 1. Weekly sprouting percentage of corm, cormels and corm setts as planting materials.

Treatment	Percentage sprouting in weeks after planting (WAP)					
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
Whole corm	86.0^{a}	90.5^{a}	94.0^{a}	97.5^{a}	99.5^{a}	100.0^{a}
Top half corm	74.0^{a}	81.0^{ab}	90.0^{a}	94.5^{a}	99.5^{a}	99.5^{a}
Bottom half corm	30.0^{b}	56.0^{b}	75.0^{a}	86.0^{ab}	95.5^{ab}	99.0^{a}
Cormel	55.5^{ab}	64.0^{ab}	68.0^{a}	69.0^{b}	78.0^{b}	80.0^{b}

Whole corm and top half of corm had significantly higher plant height and petiole length than bottom half of corm and cormel from 12 WAP to 24 WAP (Fig. 3 and 4). Petiole girth of whole corm is significantly higher than top half, bottom half and cormel at 12 WAP (Fig. 5). At 16 WAP and 20 WAP, whole corm, and top half corm had significantly higher petiole girth than bottom half of corm and cormel at 16 WAP and 20 WAP. Whole corm, top half of corm and cormel had significantly higher number of leaves compared to bottom half of corm from 12 WAP to 20 WAP (Fig. 6). On the 24 WAP and 28 WAP, number of leaves of whole corm is significantly higher compared to the other 3 treatments.

These results could be attributed to the age of the corm parts. Primary corm of cocoyam is the main stem of the plant and the secondary 'corms' are its branches (Enyi 1967). The age of the planting sett where the main stems are cut to produce setts will depend on its position on the corm, the top being the youngest and those from the bottom the oldest. Also found out in their study on *Xanthosoma mafafa* that better growth and yield performance of cormels than that of the corm and split corm can be attributed to the new and fast growing root system produced from the stolons of the planted cormels (Osundare and Fajinmi 2013). Cormels were active in utilizing available soil nutrients compared to the old roots of corms with worn out buds and split corm. When transferred to the field, the latter two uses more period to rejuvenate and establish its old root system. A study conducted by Lebot (2008) stated that taro and cocoyam can be grown from suckers split longitudinally in halves or quarters with their attached pieces of corms but would result in a reduced leaf area per plant.

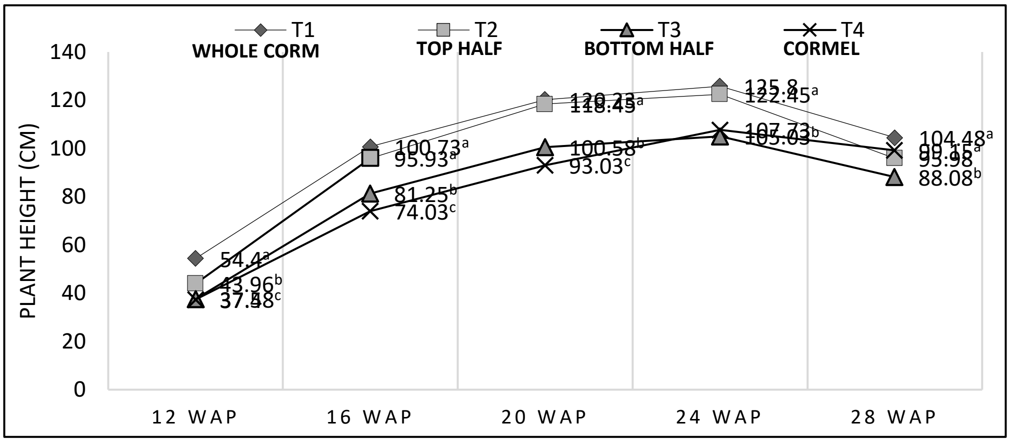

Fig. 3. Plant height of cocoyam using corm parts and cormel as planting materials from 12 WAP to 28WAP.

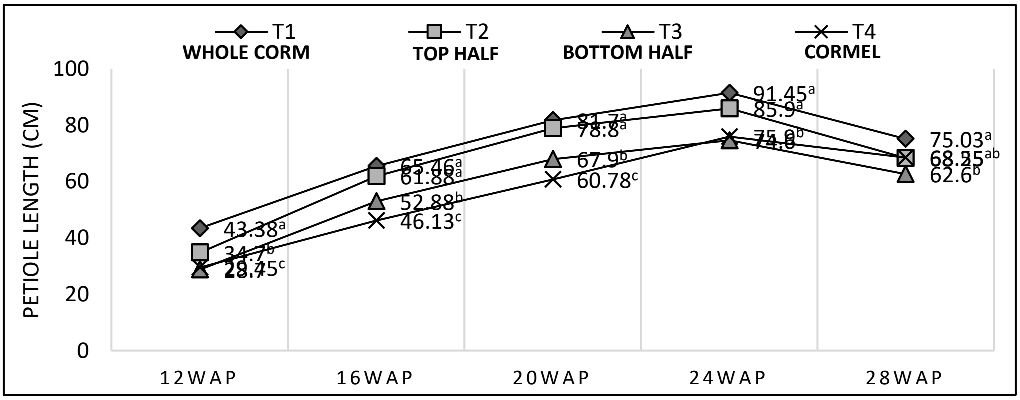

Fig. 4. Petiole length of cocoyam using corm parts and cormel as planting materials from 12 WAP to 28WAP.

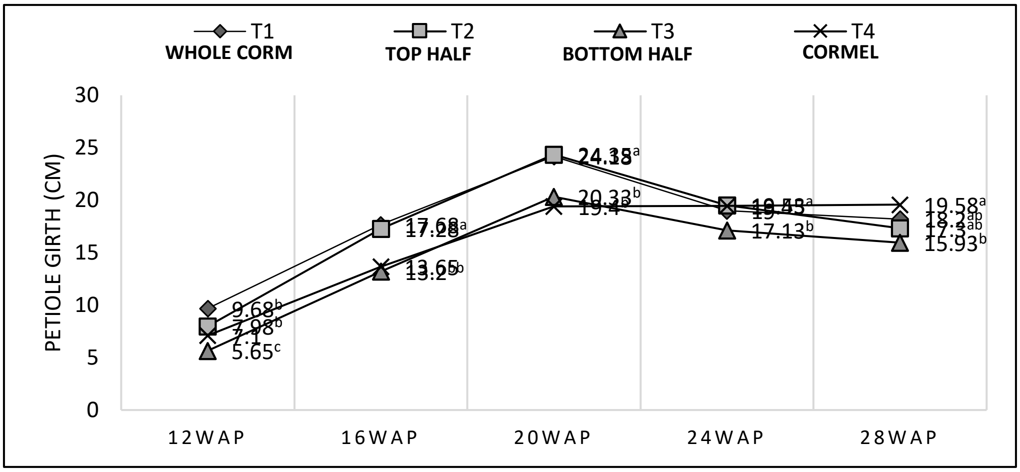

Fig. 5. Petiole girth of cocoyam using corm parts and cormel as planting materials from 12 WAP to 28WAP.

The early establishment of the plants demonstrated by the use of whole corm and top half corm have full advantage over the other treatments on the initial plant growth in terms of plant height, plant girth, and petiole length at the start of the growing period while the plants became less advantageous on these parameters at maturity.

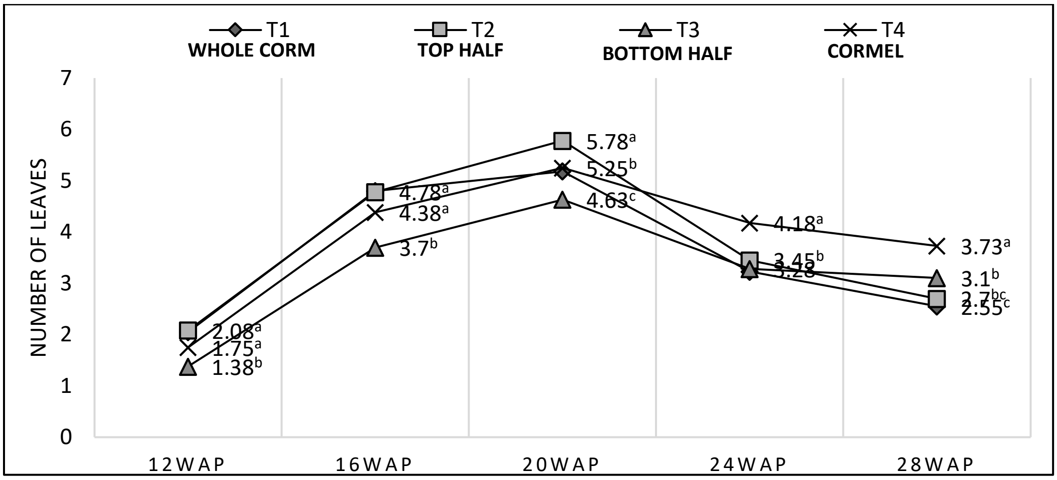

Fig. 6. Number of leaves using corm parts and cormel as planting materials from 12 WAP to 28WAP.

Yield of corms and cormel as planting material. Yield and yield parameters of cocoyam planted using whole corm, top half and bottom half of corm and cormel are presented in Table 2. Using whole corm and top half of corm produced significantly longer corm than bottom half of corm and cormel. Corm weight is significantly higher when using whole corm than bottom half of corm. Corm weight of whole corm as planting material is comparable to using top half of corm. No significant difference in corm girth was observed using different types of planting materials. No significant difference was also observed in the cormels produced and the corresponding parameters, e.g. cormel number, length, width and weight using different types of planting materials (Table 2).

Table 2. Yield (number of corms and cormels harvested) and yield parameters of cocoyam using whole corm, split corms and cormel.

Treatment	**Corm Length** (cm)	**Corm girth** (cm)	**Corm yield** (g/plant)	**Number of cormel per plant**	**Cormel length** (cm)	**Cormel girth** (cm)	**Cormel yield** (g/plant)
Whole corm	15.71^{a}	22.58^{a}	442.88^{a}	3.85^{a}	5.80^{a}	10.60^{a}	170.11^{a}
Top half	13.93^{a}	23.75^{a}	393.00^{ab}	3.58^{a}	6.71^{a}	11.33^{a}	190.95^{a}
Bottom half	11.63^{b}	22.30^{a}	237.25^{c}	4.45^{a}	6.56^{a}	12.06^{a}	240.45^{a}
Cormel	12.03^{b}	28.43^{a}	321.50^{bc}	4.35^{a}	6.00^{a}	11.00^{a}	196.18^{a}

In a field experiment using corm as planting material, produced plants have higher mean height, leaf number, shoot number, leaf area, corm weight and corm diameter per plant as well as higher total and marketable yield (Tsedalu et al. 2014). It is consistent with the results of study conducted by Edossa et al. (1995) as cited by Ivancic and Lebot (2000) who found that using corm produced higher mean corm weight per plant than cormel. Their results also showed that the use of corm as planting material markedly increased total corm yield per unit area than using cut corm and cormel. This can be ascribed to a greater number of buds per given area compared to split corm (Ivancic and Lebot 2000). Central corms give greater yields than the cormels which are also sometimes used especially when planting materials are scarce (Bermejo and Leon 1994). In another study in taro conducted by Gonzales et al. (1992), the use of big cormels (30-39 g) as planting material produced higher corm and cormel yields compared to using smaller cormels. Bigger cormels have more reserved nutrient (bigger sink) for growth and development. This indicates that the size of the corm and cormels affect yield of the cocoyam.

Establishment performance of different setts as planting material. All treatments gave a high percent sprouting of the propagules on the 4 WAP except for small sett with intact shoots (Table 3). Percent survival using small sett with 15 and 30 cm petiole are significantly higher compared to small sett with intact shoots. Small sett with 15 to 30 cm petiole showed greater sprouting percentage than other treatments and are statistically significant compared to all treatments. The size of the corm may be one factor for higher sprouting percentage. High sprouting percentage of the youngest sections of the corm was attributed to both greater bud number per given area and to the short period of their dormancy (Enyi 1967). Better establishment in the field was achieved by using setts from the oldest section of the corm, probably because they were less vulnerable to decomposition by soil micro-organisms. Setts from the oldest sections of the corm produced plants with the greatest leaf blade area, total dry weight and dry weight of various organs and it is recommended that planting setts should be obtained from the less succulent section of the corm.

Table 3. Percent survival of cocoyam plants using different corm sett planting materials at 4 WAP.

Treatment	Percentage of surviving cocoyam (%)
Small sett with 15cm petiole	97.50[a]
Small sett with 30cm petiole	100.00[a]
Big sett with 15cm petiole	87.50[ab]
Big sett with 30cm petiole	95.00[ab]
Small sett with shoots intact	80.00[b]

Although the small sett with 30 cm petiole achieved a better head start in its plant height, petiole length and girth at 8 WAP up to 16 WAP, the big sett with 30 cm petiole had higher plant height and girth size at 16-18 WAP up to 20 WAP (Figures 7, 8 and 9). The use of small sett with 30 cm petiole obtained significantly higher plant height and petiole length during the first 8-16 WAP compared with other treatments. Petiole girth is significantly lower for treatments with intact shoots from 8 WAP up to 28 WAP (Figure 9). The poor performance of sett with intact shoots may be due to transplanting shock. With already photosynthetically active shoots, the plant may not have adjusted to the nutrient and acclimatization demand for its sustained growth. The loss of root tips and root hairs due to root pruning at transplanting disturbs the roots affecting the root and shoot ratio. This induces a “recovery phase” during which shoot growth is suppressed until the previous root and shoot ratio is restored (Kerbiriou et al. 2013). In this experiment, the setts are cut with only 5-10cm of the corm retained although protruding young buds are still visible. The results suggest that the size of the corm as well as the length of the petioles are important in the production of cocoyam.

Yield performance of different setts as planting material. Yield and yield parameters using different sett sizes and petiole lengths are presented in Table 4. Using small setts with 15 cm petiole as planting material produced significantly higher corm length, corm girth and corm weight than using big setts with 15 cm petiole and small sett with intact shoots. Corm length, corm girth and corm weight using small setts with 15 cm petiole is comparable to using small setts with 30 cm petiole and big setts with 30 cm petiole. Significantly higher number of cormels were harvested, with longer sized cormel and higher corm girth were produced using small sett at 15 cm petiole and big sett at 30 cm petiole contrary to small sett with intact shoots. Cormel weight was significantly higher using big sett with 30cm petiole as compared to all other treatments. However, small sett with 15cm petiole ranked second highest in yield. This was corroborated by the study conducted by Gebre, et al. (2015) where increase in corm yield per hectare was attributed to bigger corm size as having more food reserve that lead to early canopy closure, maximum leaf area and leaf area index which help for the production of bigger weight of corms and cormels. In this experiment however, big corm gave higher yield only with longer petiole but not with shorter petiole. Another study by Ameyaw et al. (1994) also reported that larger sett size produced heavier tuber weight per hectare than the smaller sett size for yam, also a rootcrop. The results suggest that the size of the corm as well as the length of petioles are important in the propagation of yam. In this study, it is recommended that planting material to be used for cocoyam should have petiole length and corm girth of at least 15 to 30cm and 30.6 to 50.5mm, respectively.

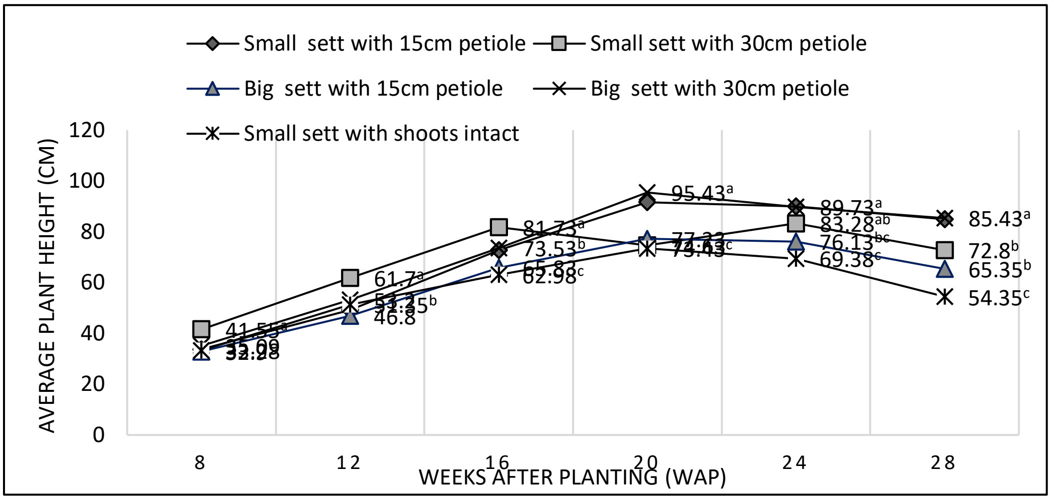

Fig. 7. Plant height of different sett sizes and petiole lengths as planting materials from 8 WAP to 28 WAP.

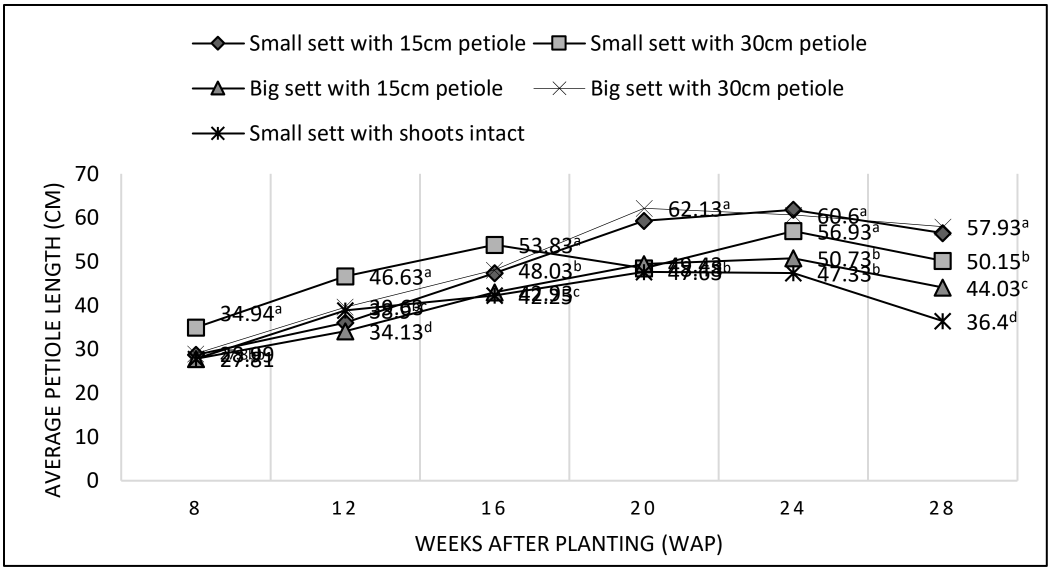

Fig. 8. Petiole length of different sett sizes and petiole lengths as planting materials from 8 WAP to 28 WAP.

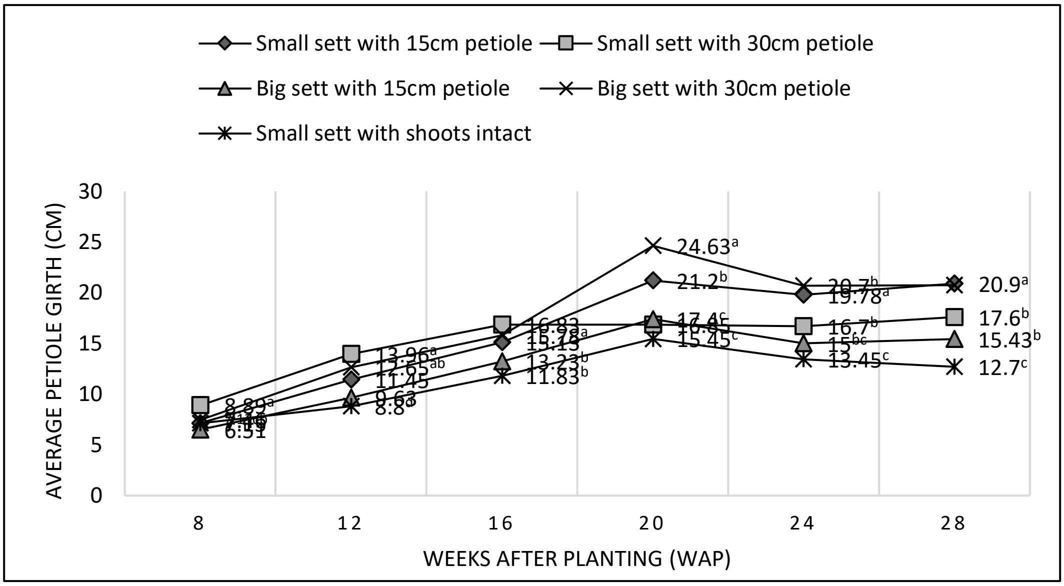

Fig. 9. Petiole girth of different sett sizes and petiole lengths as planting materials from 8 WAP to 28 WAP.

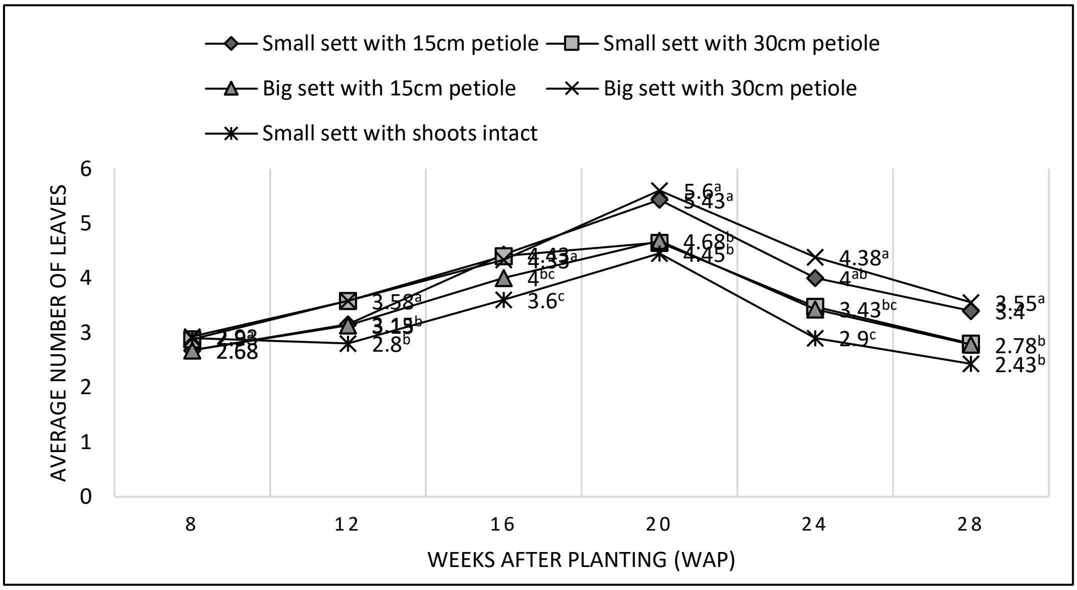

Fig. 10. Number of leaves using different setts sizes and petiole lengths as planting materials from 8 WAP to 28 WAP.

Table 4. Yield (corm and cormel) and yield parameters of cocoyam using different sett size and petiole length.

Treatment	**Corm length** (cm)	**Corm girth** (cm)	**Corm yield** (g/plant)	**Number of cormel per plant**	**Cormel length** (cm)	**Cormel girth** (cm)	**Cormel yield** (g/plant)
Small sett, 15cm petiole	11.00^{a}	25.00^{a}	366.75^{a}	7.45^{a}	5.75^{a}	11.48^{a}	333.85^{ab}
Small sett, 30 cm petiole	10.70^{ab}	23.00^{ab}	318.13^{a}	5.68^{ab}	5.30^{ab}	9.06^{abc}	249.00^{b}
Big sett, 15 cm petiole	9.18^{bc}	20.51^{bc}	198.75^{c}	5.20^{ab}	5.10^{ab}	8.68^{bc}	225.73^{b}
Big sett, 30 cm petiole	10.64^{ab}	23.13^{ab}	316.00^{ab}	6.63^{a}	6.67^{a}	10.16^{ab}	454.40^{a}
Small setts with intact shoots	8.63^{c}	19.48^{c}	200.25^{bc}	4.00^{b}	3.57^{b}	6.44^{c}	179.20^{b}

CONCLUSION AND RECOMMENDATION

For rapid establishment of GSF, corm or sett could be used. Whole corm is the most effective as it will sprout early and gives the highest sprouting percentage. However, for practicality, both top half corm and bottom half corm can also be used. Although they will sprout later than the whole corm, they are able to catch up with the whole corm in the latter stages of crop growth without significant differences in other crop parameters from the whole corm except corm yield. The use of cormel is less effective as it has low percent sprouting and may result in high quantities of non-marketable cormels. Use of cormel is also less practical because this is the part highly marketed for food in the Philippines. It is recommended that the cocoyam planting material to be used should at least have a 15 to 30cm petiole length and the corm size should be within a girth size of 30.6 to 50.5mm. The use of sett as planting material is also effective regardless of the size of the sett and length of petiole. However, retaining the shoots in the sett would reduce the percent sprouting of the planting materials.

For corm production, whole corm and top half of corm are the best planting materials as these produced longer corm and higher corm yield as well as sprouted earlier with higher sprouting percentage. For cormel production, all these types of planting materials can be used. Cormel, which is the more economically important part of cocoyam can be marketed while corm (whole corm, top and bottom half of corm) can be used as planting materials.

Multi-location trial using bigger plot sizes is being recommended for further verification of the results of this study. Nutrient management for this crop is also recommended for large-scale production. Value addition like feeds for animals other than pigs and use of cocoyam flour in food products can be explored.

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EFFICACY AND RESIDUAL ACTIVITY OF *Lecanicillium kalimantanense* and *Helicoverpa armigera* Nucleopolyhedrovirus (*Hear*NPV) AGAINST CORN EARWORM *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) UNDER FIELD CONDITIONS

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ABSTRACT

Helicoverpa armigera is one of two most important pests attacking corn in Indonesia, Virus *Hear*NPV and *Lecanicillium kalimantanense* are insect pathogens that can be used for pest management. This research sought to test the efficacy of *Hear*NPV and *L. kalimantanense* applied singly or mixed against *H. armigera* under field conditions. This study was conducted from January to April 2017, with the field phase using randomized block design consisting of three treatments and control, with four replicates, in the IPB Cikabayan experimental garden. Laboratory studies were conducted in the Insect Pathology laboratory, Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural Institute (IPB). The treatments consisted of viral suspension of *Hear*NPV, conidial suspension of *L. kalimantanense,* mixture of viral and conidial suspension. The corn silk were sprayed using a hand sprayer with entomopathogen suspension after artificial infestation of young larvae at 45 days after planting. Cob damage and larval population were observed and the pathogen was reisolated from corn and soil. All treatments effectively lowered the larval population. Cob damage were reduced by 50% following treatment by fungal suspension whereas cob damage after treatment with viral and mixture of (viral + conidial suspension) were 17.5 % and 22.5 % respectively. No viable conidia could be isolated from corn silk, whereas 13 CFU (colony forming units) was obtained from soil. Polyhedra of *Hear*NPV could be detected from both corn silk and soil 15 days post treatment. Additive effects on mixed applications did not occur in viruses, when compared to the *Hear*NPV application, mixed application was not recommended because it decreased HearNPV virus activity.

Key words: cob damage, entomopathogens, number of larvae, residue, sweet corn.

INTRODUCTION

Corn earworm or *Helicoverpa armigera* (Hubner) is one of two most important pest of sweet corn in West Java Province, along Asiatic corn borer, *Ostrinia furnacalis* Guen. (Lepidoptera: Crambidae). Losses due to the corn earworm is often significant. This polyphagous insect attacks cotton, beans, sorghum, sunflower, soybeans, peanuts, and tomato (Tay et al. 2013). Decrease in yield due to borer attack in the island of Sulawesi reached 51.9 - 53.4% (Karim et al. 2013). The average cob damage in East Java province reached 21.5% (Sarwono et al. 2003). Chemical control is preferably avoided on food crops to minimize the risk of poisoning. In Indonesia, sweet corn is consumed soon after harvest, either as plain food or mixed with vegetable. Application of chemical pesticides might entail negative impacts to beneficial organisms such as honey bees, parasitoid *Trichogramma* sp. and earwigs. Insecticides like pr ofenofos, endosulfan, and cyfluthrin have negative effect on the natural enemies of *H. armigera* such as *Paederus* sp. (Coleoptera: Staphylinidae), *Camphyloma* sp. (Hemiptera: Miridae), *Chrysopa* sp. (Neuroptera: Chrysopidae), and spider (Araneae: Araneidae) (Nurindah and Subitakto *in* Laba (2010). The use of entomopathogenic microorganisms that are very specific are expected to control the pest population while being environmentally safe for beneficial arthropods.

Entomopathogens evaluated against *H. armigera* include *Beauveria bassiana, Metarhizium anisopliae, Nomuraea rileyi* and *Hear*NPV (Qayyum et al. 2015). *Hear*NPV was more effective against *H. armigera* than mixed application (*Hear*NPV and *Lecanicillium* sp.) in the laboratory, the value of LT_{50} in *Hear*NPV application against *H. armigera* larvae was 2.03 days, while mixed applications (*Lecanicillium* sp. and *Hear*NPV) took 3.23 days (Ginting et al. 2018). *Lecanicillium* sp. PTN01 was able to inhibit *H. armigera* egg hatching by 13.75%, and the first instar larval survival 98.75% in the laboratory. Virulence test showed the highest *H. armigera* larval mortality of 41.25%, at 10^7 conidia/mL density. The DNA sequence analysis of ITS 1 and ITS 4 primers showed that *Lecanicillium* sp. PTN01 was similar to fungus species *L. kalimantanense* strain BTCC F23 with 94% homology (Ginting et al. 2019). *Lecanicillium kalimantanense* strain BTCC F23 was isolated from exoskeleton of (Staphylinoidea: Coleteopera) in *Asplenium nidus* which grows in tropical rainforests, in East Kalimantan (Sukarno et al. 2009).

L. lecanii is able to infect eggs of soybean bug *Riptortus linearis* (F.) (Hemiptera: Alydidae) (Prayogo 2004). Corn cob stalk borers (*Helicoverpa armigera*) can be controlled by using the fungus *Beauveria bassiana* (Ritu *et al*., 2012), and *L. lecanii* for corn stalk borers *(Ostrinia furnacalis)* (Agustin 2014). NPV isolated from a cotton field was effective against *H. armigera* (Diyasti 2016). The fungus *Lecanicillium* and NPV are hypothesized to be effective against corn earworm larvae. Because the mode of actions exhibited by the two entomopathogen are not similar, *contact poison* for fungus and *per oral* for NPV, it is not intended to study deeply the effect of joint action between two entomopathogen. This research sought to measure the efficacy of *Hear*NPV and *L. kalimantanense* applied separately and as a mixture against *H. armigera* under field conditions.

MATERIALS AND METHOD

Corn cultivation. Sweet corn variety Talenta was planted in polybags (25 cm diameter and 50 cm height) in order to minimize contamination by other microorganisms from the environment to the soil, on January 7, 2017. Soil and cow manure mixture (2 part of soil and 1 part of manure) was used as growing media. One seed was placed at a depth 3 cm in the soil and fertilizer was applied according to the manual of corn cultivation (System Information Management Development Rural, 2000). All polybags were laid out in the experimental field of the University Farm at Cikabayan (Bogor), Faculty of Agriculture, Bogor Agricultural University. The distance between polybag in the row was 40 cm, and the distance between rows was 70 cm. The plants were watered twice a day at the vegetative stage and reduced to twice a week, in the morning. How many weeks old when wataering was done 2x a week?

Introduction of *H. armigera* eggs. *H. armigera* larvae were obtained from Situ Gede (Bogor, Indonesia), and maintained in a laboratory using artificial diet (Grzywacz et al. 2011). Infestation of plant with *H. armigera* eggs was carried out after the silk (female flower) were completely formed or 45 days after corn planting. In the laboratory, the egg were laid by moth on gauze cloth. The cloth with eggs then cut and sticked to the corn silk. To each cob, 20 eggs have been introduced. After the plants were infested with eggs, corn cob were encased by fine gauze cloth to prevent predators and parasitoids, because *H.armigera* larvae are cannibal so the number of larvae was left on each cob each one larvae.

Preparation and application of biopesticides. The treatment consisted of *Hear*NPV polyhedral suspension, *L. kalimantanense* conidial suspension and mixture of polyhedra and conidia suspensions and control (water sterile). *L. kalimantanense* were cultured using parboiled rice media and incubated in the incubator at 24 C. After 21 days, conidia were harvested, filtered and counted by using haemocytometer (Goettel and Inglis 1997). Final density of conidia obtained was 2.8 x 10^8 conidia/mL. The conidia were suspended in a solution of Triton X-100 in sterile water (0.1 %). One cob received 11.2 mL suspension using the recommended rate of 400 L spray volume for 1 ha of corn. Hand sprayer was used to deliver 11.2 mL suspension to each cob. Suspension of *Hear*NPV polyhedra was prepared from cadavers of *H. armigera* infected by NPV homogenized in mortar and filtered with fine nylon cloth. The sediment was centrifuged at 2975 g to separate the polyhedra from the larval debris that passed the cloth. Polyhedral suspension mixed with sterile water containing Triton X-100 (0.1% concentration) and the density of polyhedra inclusion body (PIB) were counted using a haemocytometer. *Hear*NPV with final concentration of 2.8 x 10^6 PIB/mL was used as treatment. The choice of the concentration of conidia and polyhedra is based on preliminary study in the laboratory which caused about 70% mortality of second instar larvae. The mixture of two biopesticdes was made by mixing equal volumes of the two suspensions. All preparations were done on the same day as the application.

The application of biopesticides to the cob was realized by spraying with a hand sprayer, 3 days after the eggs hatched. Each cob received 11.2 mL suspension of corresponding treatment. Borders and rows between plots were left untreated (240 plants). Spraying was done twice with three days interval. Three weeks after application of fungal and viral biopesticides, the residual effects of the biopesticides on corn silk and in the soil were assessed according the method described below. The experimental treatments followed group randomized design.

Observation variables. One treatment consisted of 10 plants and each plant had one larva. Each treatment was repeated 4 times so that there were 40 plants for one treatment. The total plant for 4 treatments are 160 plants.

The percentage of damage to corn cobs was calculated at harvest time using the formula:

$$P = (n / N) \times 100\%$$

where P = Percentage of cob damage (%), n = Number of damaged corn cobs (fruit), and N = Total number of cobs observed.

Residue of fungal conidia on corn silk and soil. The soil was sampled from each polybag and mixed. From these soil aggregate samples, 10 g were weighed and suspended with 90 mL of sterile distilled water in a 250 mL Erlenmeyer and vigorously shaken. Serial dilution was made from 1 mL soil suspension until 10^{-3} dilution and 1 mL was spread onto sterile PDA in a 9 cm Petri dish. After several days, the number of fungal colonies were counted and when the conidia were fully formed and developed, microscopic observation were performed at 21 days after inoculation. The fungi were identified based on their morphological characters according to the key determinations of Becnel (1997). The same procedures were applied to assess the residue of conidia from the corn silk.

Residue of *Hear*NPV. Extraction of occlusion bodies from corn silk and soil was performed at 15 days after application using the method of Hunter-Fujita and co-workers (1998). The silk of each cob were cut and mixed, from which 12.5 gram silk were randomly sampled. Soil weighing 12.5 gram was collected from each polybag at approximately 5 cm depth. It was then mixed until homogeneous. The corn silk and soil samples were each cleaned for 5 min at 4 ºC using ultrasonic cleaner to release the biopesticide. Then to the sonicated samples, 25 mL SDS desorbent (0.1%) were added and allowed to stand for 90 minute. The supernatant was separated from the sediment. The sediment was taken and allowed to stand for 20 min in desorbent, before sonication for 5 min at 4°C. The sediments were discard while the combined supernatants were centrifuged for 5 min at 180 g. The sediment were discarded and the supernatant was centrifuged again during 20 min at 2975 g. The sediments were resuspended in 100 mL of sterile water and centrifuged for 20 min at 2975 g to remove impurities. The supernatant was discarded and the samples were again suspended in 3 mL deionized water and observed under a microscope. The polyhedra inclusion body/mL concentration were calculated using a haemocytometer. The suspension that contained polyhedra were used as virus suspension treated to larva *H. armigera* through feed contamination. Subsequently disease symptoms and the presence of polyhedra was observed as a part of biological identification of NPV.

Data analysis. The experimental data were analysed by ANOVA using SPSS program version 16.0 (Sujianto and Agus 2009). In case of any significant difference between treatments, data analysis was continued with Least Significant Difference (LSD) in level α 0.05.

RESULTS AND DISCUSSION

Larval population. The application of all entomopathogen isolates had a significant effect on the population of *H. armigera* larvae (F= 70.154, df =15, P= 0.000). The population of *H. armigera* larvae were significantly different between treatment and control (Table 1). The number of larvae in the control treatment (10 plants) was 9.75, or in average one larva per cob. This was because the control plants were not treated with isolates and so there was no interference with larval feeding activity during which the insect larvae stage had high feeding activity. The number of larvae in the control treatment was higher than the other treatments, this was because the control plants were not applied to insect pathogens.Treatment of *L. kalimantanense* alone caused high mortality of larvae, yet only 1.75 larvae were found on 10 plants. The highest mortality was shown by treatment involving *Hear*NPV. The as low number as 0.75 larva was observed in the treatment of both *Hear*NPV alone and mixture *Hear*NPV and *L. kalimantanense.*

Table 1. Larval survival after application of entomopathogenic isolates of and HearNPV on the *H. armigera* larvae (n = 10)

Treatment	**Number of larvae ± SE (Average)**
Control	9.75 ± 0.25a
HearNPV	0.75 ± 0.47b
Mixture of HearNPV and *L. kalimantanense*	0.75 ± 0.75b
L. kalimantanense	1.75 ± 0.47b

The numbers followed by different letters in the same column are significantly different according to the LSD test 5% level.

The results were consistent with preliminary laboratory experiment data, where HearNPV was found more effective in controlling *H. armigera* larvae and capable of causing 100% mortality within 4 days at concentrations of 10^7 polyhedra inclusion body (PIB)/mL whereas *L. kalimantanense* was able to control only 41.2% within 7 days at a density of 10^7 conidia/mL. NPVs belong to the group of viruses that have rapid infection course to killing insects in 4-7 days (Grzywacz et al. 2011). HearNPV have been shown effectively control *H. armigera* in the field at concentration level of HearNPV 6 g /liter (Ompusunggu et al. 2015).

The highest larval mortality attained was from HearNPV and the mixture at 92.5% while the lowest mortality was from *L. kalimantanense* at 82.5%. The results are consistent with 70-100% mortality of *H. armigera* from HearNPV treatment (Miranti 2001; Ompusunggu et al.2015)

Percent corn damage. The application of all entomopathogen isolates had a significant effect on percent corn damage (F= 78.152, df =15, P= 0.000). Treatment with *Hear*NPV protected the cob effectively as only 17.5 % cob were damaged. When the fungal suspension were added to the viral suspension, the damage increase until 22.5 %. Treatment by fungal suspension alone, only protected the cob by 50%. The highest damage was noted in the control treatment (97.5%) (Table 2). All treatment of biopesticide either applied singly or in combination significantly lowered cob damage as compared with control. The low percentage of corn cob damage with *Hear*NPV treatment was due to larval mortality. It has been demonstrated that NPV can also effectively infect the corn ear worm (Tenrirawe 2011)

Table 2. Percent corn cob damage after entomopathogen applications

Treatment	Corn cob damage (%) ± SE	Reduction in corn cob damage (%)
Control	97.5 ± 0.25a	-
*Hear*NPV	17.5 ± 0.47b	17.94
HearNPV and *L. kalimantanense* mixture	22.5 ± 0.40b	23.07%
L. kalimantanense	50.0 ± 0.47c	51.28%

The numbers followed by different letters in the same column are significantly different according to the LSD test at 5% significance level.

Larvae treated with *Hear*NPV die because polyhedra inclusion body (PIBs) enter the mesenteron, the main digestive organ which functions as an absorber of nutrients and secretion of digestive enzymes. When the virus infects the insect mesenteron, the histological structure of the peritrophic membrane which is very important in the digestive process is damaged and the digestive process is disrupted and ultimately the larvae die (Granados and Orsaro 1990; Grzywacz et al. 2011).

The amount of cob damage was closely related to the number of *H. armigera* larvae (Table 2). Larvae that bore into the cob will leave dirt on the cob and creates a climate suitable for the growth of fungi that produce mycotoxins that damage the cob (Zaidun (2004). Additive effects on mixed applications did not occur in viruses, when compared to the *Hear*NPV application. The same thing was reported by Gundannavar et al. (2004), in the combined pathogen of *N. rileyi, B. bassiana* and *Hear*NPV, the application of a single virus isolate caused mortality of *H. armigera* larvae to be higher than the combined isolates, but in this study mixed applications (*L. kalimantanense* and *Hear*NPV) more effective than application *L. kalimantanense*, cob damage in mixed applications was 22.5%, and 50% in *L. kalimantanense*. The results are consistent with laboratory results that demonstrated the disruption of larval feeding activity in a mixture of HearNPV and *L. kalimantanense* thus the amount of virus consumed was reduced. Therefore, when compared to viral treatment, lower mortality of *H. armigera* was observed when *L. kalimantanense* was used.

Fungal conidia on corn silk and soil. The result of isolation from corn silk of the plant treated with fungi *L. kalimantanense* showed that no conidia residue have been successfully isolated after 15 days of conidia application; similar result was obtained from soil of control plant. However, from the soil on which the plants have been sprayed previously by conidial suspension, 13 cfu (colony forming units) grew in the PDA media, but none were found on corn silks or in control soil. It is assumed that those fungal conidia grew in the media, originated from the spray droplets that felt to the soil. In the soil, the conidia remained protected against degradation by UV sunlight.

The isolation results on corn did not show conidial residue at 15 days after application, as well as control soil. The results of this study are consistent with Lerche et al. (2009) who reported that *Lecanicillium* spp. exposed to UV-B rays for three hours were still able to grow, but exposure for four hours caused the fungus to die. UV-A and UV-B originating from sunlight directly cause cell death and mutation (Valero et al.2007; Begum et al. 2009). UV-C caused delays and decreased germination of fungal conidia caused by increased respiration and metabolic activity, thereby reducing food reserves in the conidia (Rahmatzadeh and Khara 2007).

The results of isolation from the soil of plants that have been previously sprayed with conidia suspension treatment and grown on PDA media obtained 13 cfu/mL, but none were found on corn silks or in control soil. Earlier studies demonstrated that *L. lecanii* density in soil decreased rapidly on the first month after inoculation, then stabilized after 6 to 10 months. *L. lecanii* was able to survive on agricultural land for 14 months and at 10^2 conidia/g of soil, growth, sporulation, germination and virulence in aphids did not change (Xie et al. 2015). The presence of conidial residues in treated soil occurs because the soil is an environment suitable for entomopathogenic fungi (Krueger and Roberts, 1997). Conidia in soil can last longer because it is protected from extreme environmental factors such as UV radiation, temperature and drought, but its infectivity was strongly influenced by the physical and chemical properties of the soil (Ekesi et al. 2003). Conidial viability of *Lecanicillium* depended on the duration of sun exposure, 4 h exposure resulted in 19.2% decrease in conidial viability which increased to 78% when exposed for 12 h under sunlight (Prayogo 2004).

Residue of *Hear*NPV. The viral occlusion body (OB) of *Hear*NPV can be detected from corn hair and plant soil treated with *Hear*NPV after 15 days after treatment. The presence of OB on the ground comes from the sprayed material on corn hair which falls to the ground, while the OB on corn hair is ascribed to the insect cadaver. Insect cadaver plays an important role in protecting viral OB from UV radiation. In this study the amount of OB virus residue was not estimated, but the concentration was sufficient to kill the larvae. Qualitative examination of dead larvae after being fed with food contaminated with the OB virus shows that the OB virus has the same properties as OB that were applied, both morphologically (OB form) and biological (virulence OB) (Fig. 1).

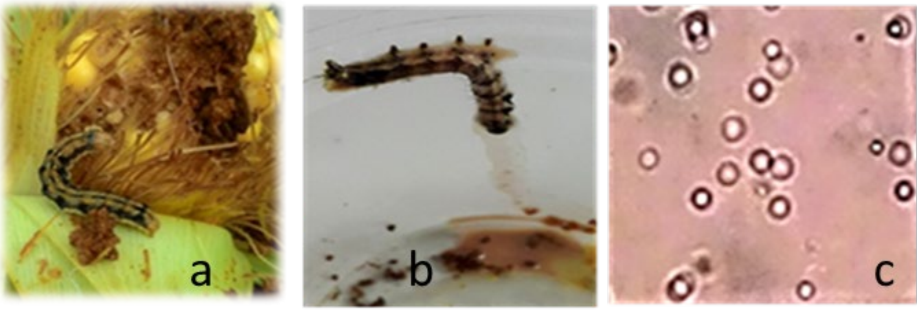

Fig. 1. *Hear*NPV infection in *H. armigera* larvae, a. Healthy larvae, b. Larvae infected by *Hear*NPV, c. PIBs in larvae infected by *Hear*NPV.

*Hear*NPVinfected larvae experience integument color changes, becoming darker, moving more slowly and moving toward the sun. In the final stage of viral infection, the larval body cells become lysis. The infected larva dies in a dependent state forming an inverted V letter. When the integument larvae are torn, the haemolymph fluid contains a lot of polyhedra which spreads.

The recombinant virus expressing neurotoxin (HzSNPV.LqhIT2) and wild type *H. zea* NPV (HzSNPV.WT), sprayed on cotton plants five times during the growing season, were still detected in the soil at 26-35 cm depth and remained distributed between 0-2 cm throughout the plot. The HzSNPV.WT virus was detected as 11-13 OB/g at a depth of 0 -14 cm; while the wild type virus was undetectable below 14 cm. The survival of the virus in the soil was also monitored on three wild-type viruses. *Autographa californica* NPV (AcNPV.WT), *A. californica* NPV expressed scorpion toxin

(AcNPV.AaIT), and *A. californica* NPV expressed juvenile hormone esterase (AcNPV. JHE-S201G). The amount of OB available in the recombinant NPV was greater than that of the wild type virus after 17 months (Fuxa et al. 2001).

CONCLUSION

L. kalimantanense and *Hear*NPV have the potential to control *H. armigera*. The application of HearNPV was more effective than *L. kalimantanense* in the field. Additive effects on mixed applications (*Hear*NPV and *L. kalimantanense)* did not occur, when compared to the *Hear*NPV application. Mixed application was not recommended because it decreases *Hear*NPV virus activity. *Hear*NPV has a higher pathogenicity against *H. arimigera* larvae, compared to *L. kalimantanense*, because *Hear*NPV is a specific host so virulence is higher, while *L. kalimantanense* has a wider range of hosts *L. kalimantanense* and *Hear*NPV are able to develop in nature and cause epizootics, so these are considered important in pest management.

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TECHNOLOGY TRANSFER PATHWAYS OF INFORMATION AND COMMUNICATION TECHNOLOGIES FOR DEVELOPMENT (ICT4D): THE CASE OF THE WEATHER-RICE-NUTRIENT INTEGRATED DECISION SUPPORT SYSTEM (WeRise) IN INDONESIA

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ABSTRACT

Sustaining ICT4D project outputs after a project's implementation period is among the challenges of technology transfer. This study aimed to develop Technology Transfer Pathways (TTPs) for the Weather-rice-nutrient integrated decision support system (WeRise), a seasonal climate predictions-based ICT4D tool developed by the IRRI-Japan Collaborative Research Project (IJCRP) for Indonesia. It utilized the stakeholder approach, and employed focus group discussions, key informant (KI) interviews, individual surveys, and literature review for data collection. Data were analyzed through content analysis, stakeholder analysis, process mapping, and descriptive statistics. The Contingent Effectiveness Model of Technology Transfer was used as a framework for the analysis. Research findings showed two possible TTPs. The first pathway is via the traditional public domain: from research institutions to extension agencies, then to farmers. It involves a set of government agencies who could undertake localization, further development, operation and maintenance, technology assessment and information dissemination, and institutionalization. An alternative pathway would also involve an existing multi-stakeholder platform that could facilitate coordination, feedback, and monitoring. Both pathways have interconnected sub-pathways, coinciding with Douthwaite et al.'s (2017) Theory of Change which shows that agricultural research for development achieves impact through technology development and adoption, capacity development, and policy influence.

Keywords: modern extension advisory services, digital tools, climate-smart agriculture

INTRODUCTION

Information and Communication Technologies for Development (ICT4D) projects aim to bridge the digital divide by providing equitable access to up-to-date communication devices which include various associated services and applications (Rouse 2011). The ICT4D value chain covers key areas including readiness, availability, uptake, and impact. Readiness includes systemic prerequisites including infrastructure. Availability refers to the implementation of the ICT4D initiative. Uptake pertains to access translating to actual usage. Impact includes outputs, outcomes, and contributions of the ICT to broader development goals (Heeks 2010). Among the UN sustainable development goals is zero hunger which targets doubling agricultural productivity and incomes of small-scale food producers (UN 2015).

Rainfed rice farmers usually have small landholdings, and production is characterized by low yield and high poverty incidence due to uncertainties as it relies on rainwater availability. The onset, duration, and amount of rainfall have become difficult to predict amidst climate change, which has caused more weather variabilities (IRRI 2015). Timely access to the right information could enable smallholder farmers to make informed decisions which could affect their livelihoods and impact food security.

Funded by the Ministry of Agriculture, Forestry and Fisheries of Japan, the IRRI-Japan Collaborative Research Project (IJCRP) developed the Weather-rice-nutrient integrated decision support system (WeRise), an ICT4D tool aimed at improving the livelihoods of small-scale rainfed rice farmers in the context of climate change. It is an online application that applies seasonal climate predictions in a crop growth model. Based on the upcoming cropping season's weather characteristics, crop growth development, soil characteristics, and farm management practices, WeRise provides advisories on the optimum sowing timings, fertilizer application schedule, and the suitable variety for planting. Advisories could be generated three months before the cropping season; thus it could give farmers enough time to plan their resource utilization and crop production schedule more efficiently. With proper resource utilization through the strengthened capacity for climate change adaptation, WeRise could help transform rainfed rice production into a more productive and sustainable production system ultimately contributing to food security (Johnson 2016). WeRise was developed using the Scale Interaction Experiment–Frontier Research Center for Global Change (SINTEX-F), a seasonal climate predictions model, and ORYZA, a crop growth model. Indonesia was selected for WeRise development because of its significant rice demand and larger rainfed rice areas compared to other countries in the region. Moreover, Indonesia experiences substantial damage from El Niño Southern Oscillation. SINTEX-F has a high skill in predicting this phenomenon (Hayashi et al. 2018).

IJCRP intends to handover WeRise to Indonesia by the end of its implementation on September 2020. In Indonesia, agricultural technologies for the public domain (e.g., WeRise) generally follow the traditional Technology Transfer Pathway (TTP): from research institutions to extension agencies in-charge of dissemination to farmers (Jamal et al. 2016). Research institutions and funding agencies often lack the incentive, capacity, legal mandate, and operational flexibility to monitor the research investments (Zuniga and Correa, 2013). Hence, sustaining ICT4D project outputs is challenging. Developing possible TTPs may be considered part of the project's exit strategy. The exit strategy would facilitate systematic transitions; help gain credible commitment of stakeholders to project sustainability thereby increasing the likelihood of achieving the sustainable development outcomes that the project initially sought out (Gardner et al. 2005).

This study adapted the Contingent Effectiveness Model of Technology Transfer (CEMTT), a qualitative model developed by Bozeman (2000) as a framework to develop the TTPs. It was ideal as it enabled identification of various actors for the uptake and dissemination of WeRise, in terms of their linkages/relationships and associated characteristics, entry points for project implementation, and barriers and prerequisites to a successful technology transfer (Matsaert 2002).

MATERIALS AND METHODS

Elements of the Contingent Effectiveness Model of Technology Transfer (CEMTT). Technology transfer has been defined in various ways and contexts. This study uses the following definition:

> *Technology transfer is the process of movement of technology from one entity to another. The movement may involve physical assets, know-how, and technical knowledge (Souder et al., 1990 and Ramanathan, 1994 cited in Ramanathan, 2008; Bozeman, 2000).*

Unlike technology diffusion which often refers to passive spreading of a specific technological knowledge related to a specific innovation of interest within a specific population, technology transfer is a proactive process, intentional and involves agreement (Rogers, 2003; Hameri, 1996; Autio and Laamanen, 1995; Ramanathan 1991; Hameri, 1996 cited in Ramanathan, 2008).

The study adapted the CEMTT which looks into various determinants of effectiveness, including the technology itself, the demand environment, and the associated characteristics of the transfer agent and the potential transfer recipients (Fig. 1). The CEMTT suggests that a critical mass of demand determines the technology transfer's success and the success rate is higher if technology recipients were sets of government agencies. Since the demand environment is dynamic, new technologies should have flexible infrastructure rather than a set of fixed institutionalized resources. Co-funding among agencies is also helpful in inducing demand. Moreover, CEMTT assumes that the parties involved in the technology transfer may have several goals and effectiveness criteria. For instance, the effectiveness of technology transfer may be evaluated not only based on the number of adopters, but also on the scientific and technical human resource development that may result from the capacity building that needs to be implemented during the process, and political rewards such as increased funding that may arise as a result of the technology transfer process (Bozeman 2000). These are in addition to contributions to economic development and market impact, which the project initially sought, that could translate into achieving Indonesia's sustainable development goals of food security and poverty reduction through increased profits for farmers.

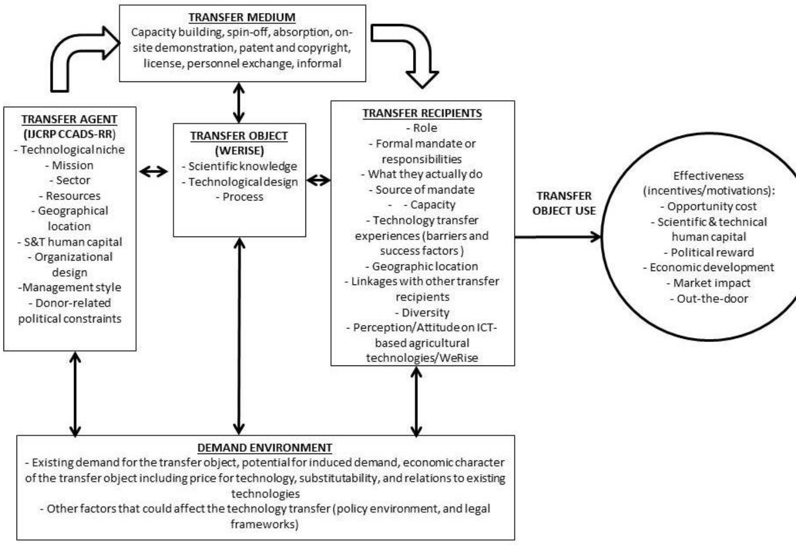

Fig. 1. Conceptual framework of the study
Source: modified from Bozeman, 2000.

Research sites. For its primary data requirements, the study focused on the cases of Segala Anyar Village located in Pujut district in Central Lombok, West Nusa Tenggara (WNT, S8˚ 46' 19", E116˚ 46' 17"), and Serdang Village located in Serdang District in Deli Serdang, North Sumatera (NS, N3˚ 38' 19", E98˚ 49' 27"). Indonesia has 12 rainfed rice producing provinces. WNT and NS are among the six rainfed rice producing provinces where the IJCRP sites are located. The basis for study site selection was described by Hayashi et al. 2018.

Regency profile. With a population of approximately 900,000, Central Lombok is among the eight regencies of the WNT province of Indonesia. It has a total land area of 1,208.39 km^2 and has the largest rainfed rice area (i.e., 13,642 ha. out of its 87,064 ha. total rice area) among the regencies/cities in Lombok Island. Central Lombok is subdivided into 12 districts and 139 villages. Forty-three percent of Central Lombok's labor force is engaged in agriculture (BPS, 2015). It has long dry seasons. Approximately half of Central Lombok was affected by severe drought in 2014 (Sudaryonto 2017). Deli Serdang has a population of 2 million and is among the 25 regencies of NS. With a total land area of 2,241 km^2, the Deli Serdang Regency is comprised of 22 districts and 380 villages in the rural areas and 14 villages in the suburban areas. During the period 2014-2016, a total of 278 natural disasters occurred in Deli Serdang. Topping the list are typhoons (22%), floods (14%), volcanic eruptions (5%), and landslides (4%). Deli Serdang is the third top wetland rice producer of the province of North Sumatra in 2015. Fifteen percent of its labor force is employed in agriculture (BPS, 2016).

Data collection methods and research instruments. Desk review of secondary sources including IJCRP's Annual Review and Planning Meeting (ARPM) documentations, project reports, principles and implementation plan, and other secondary literature was done before and after primary data collection.

Face-to-face individual interviews of 60 rainfed rice farmers (i.e., 30 farmers per study site) were conducted in May 2016 in NS and WNT. Due to limited time and budget, the sample size (n) of 30 farmers per study site was based on the rule-of-thumb for in-depth surveys. It was assumed to be sufficient to generate information from a relatively homogenous population. Data collected were on socio-economic and demographic characteristics, general farm characteristics and production practices and constraints, cropping calendar, historical production utilization, weather extreme experiences, cost of production, and knowledge, attitude, and skills related to ICT4D. A total of 10 Focus Group Discussions (FGDs) (i.e., five per site) with key informants (KIs) from the Assessment Institute for Agricultural Technology (AIAT), farmers' associations, and extension agencies at the provincial, district and sub-district levels of WNT and NS were also held. There were 49 participants from NS and 43 from WNT in the FGDs. Questions asked included their roles, mandates, capacities, perceptions and previous technology transfer experiences including other stakeholders they have worked with. FGDs with heads and directors of key institutions were also held in Bogor, Indonesia in August 2016 and August 2018 to solicit feedback on the latest version of WeRise and its potential for rainfed rice production in Indonesia and identify a dissemination pathway.

Consultations with other KIs including those from some institutions who joined the FGDs in Bogor were also held during the initial stages of project implementation. The consultations and ARPMs of the IJCRP were useful in understanding the dynamics of technology transfer at the national and local levels. The instruments for the individual interviews and FGD guides were developed in the English language, pilot-tested, revised, and translated to Bahasa with the help of project partners. Prior to the interviews and FGDs, the survey respondents and FGD participants were oriented about WeRise. Researchers from AIAT WNT and NS and Indonesian Center for Rice Research (ICRR) who served as facilitators, enumerators, and translators were also given an orientation on WeRise, survey objectives and data to be collected.

Sample and Sampling Design. Farmer-respondents for the individual interviews were purposively selected with the help of the extension workers and farmer leaders in the study sites. Selection was based on the farmer's availability and willingness to participate in the study.

For the FGDs conducted in May 2016, participants were also selected purposively with the help of AIAT partners, extension workers, and farmer leaders. FGD participants were selected based on their previous experiences in technology transfer and/or if they are working in agencies with extension as part of their mandate or major role. In general, the participant's perceived roles on technology transfer include technology information dissemination, capacity building, technology assessment through research (i.e., demonstration plots and conduct of comparative studies), changing the mindsets of farmers, coordination and policy formulation. Each group comprised of 8-13 participants. The composition of the participants for the FGD in Bogor was recommended by the IRRI Representative and Liaison Scientist. FGD participants in Bogor together with KIs consulted during the initial stages of project implementation are key officials of selected Indonesian National Agricultural Research and Extension System mostly from the Indonesian Agency for Agricultural Research and Development (IAARD) of the Ministry of Agriculture (MoA) with influence at the policy level.

Data Analysis. Descriptive statistics including means, percentages, and frequencies using the Excel software data analysis tool were used to analyze the data. Tables were used to present and summarize the data. The classical content analysis, a qualitative analytical technique, was used to analyze the focus group data of this study. Content analysis is the "study of recorded human communications" involving coding, a "process of transforming raw data into a standardized form." The classical content analysis is essentially a quantitative method with its system of categories at its core (Babbie 2001 cited in Kohlbacher 2006). In this analytical technique, the codes are categorized and counted (Onwuegbuzie et al. 2009). Process mapping and stakeholder mapping were also done to analyze the key institutions in terms of their capacities and linkages, identify potential entry points, and develop the TTPs.

RESULTS AND DISCUSSION

Demand environment. Rice provides more than half of the calorie and protein intake requirements of Indonesians. Approximately 19 million people rely on rice production as their source of income and employment. Irrigated areas supply approximately 80% of Indonesia's domestic rice production, hence; contribute significantly to Indonesia's food security. However, irrigated rice production is threatened with land conversion problems, deteriorating irrigation facilities, and high cost of development and rehabilitation of irrigation facilities. Areas for potential expansion are now limited due to increasing water scarcity aggravated by competing water uses of various sectors (agriculture, household, industrial) and climate change (Sumaryanto 2014). Enhancing rice production in rainfed rice areas is among the potential solutions to address some of these challenges (Sulaiman et al. 2019).

Two project study sites were examined to gain an understanding of the rainfed rice ecosystems and develop WeRise according to the local context. Majority of the respondents in the study sites are male with an average age of 43 and 45 years old for WNT and NS, respectively. Farming is the major source of income of most respondents, while other sources included employment, pension, and business. Most of the respondents fall below the poverty line or may be considered poverty-prone. On average, the respondents have been engaged in rice farming for approximately half of their lifetime. Majority of the respondents in WNT own their lands while in NS, most respondents are renting. Most of the respondents from both sites (46%) have finished senior high school. All respondents in NS had formal schooling with three out of the 30 having acquired Bachelor's degrees while six out of the 30 from WNT have no formal schooling at all.

Although the farm characteristics and crop production practices of the respondents at the two sites generally differ, they face similar constraints including weather and information-related constraints particularly difficulty in determining the onset and distribution of rainfall for the upcoming cropping season. Farmers mostly rely on local wisdom and/or their own experiences for information on crop production and weather according to the face-to-face survey. Only a few receive weather forecast once a year from a government agency. Participants of the farmer group FGDs mentioned rainfall prediction, nutrient management, and description of varieties as among the information they need. The Cropping Calendar Information System Technology, locally known as Kalender Tanam or Katam, an ICT4D tool developed by the IAARD provides these information particularly the average rainfall conditions for a planting season; a forecast on the start of planting time; potential threats of climate-related hazards such as flooding, drought, and pest and disease attacks; recommended variety; type and amount of fertilizer to respond to climate-related hazards; and available farming machinery. Since its launch in 2011, the upgraded versions of Katam have been released but usage remains low. Some studies show that, in certain villages, farmers seem to have never heard of it (Anggarendra et al. 2016). Moreover, feedback of its dissemination indicates that its recommendations are not implemented because they are not suitable to the local conditions/local practices (52.75%) and the recommended variety and water are not available (43.25%) (Yulianti et al. 2016). The latter indicates that Katam might be more suitable for irrigated conditions.

WeRise could be integrated with Katam as a special module targeting the rainfed rice conditions. This was suggested during the presentation on National Strategy and on-going researches to map CCADS-RR in Indonesia (Zaini and Jamil 2015). CCADS-RR succeeded the IJCRP on Climate Change Adaptation in Rainfed Rice Areas (CCARA) which started the development of WeRise.

> *"Every six months, new data of the integrated cropping calendar (ICC a.k.a. Katam) are released and distributed to extension workers and to the local government. In the past, IAARD makes a copy of the cropping calendar and give it to lower level of extension workers (BPP) and sub-district level. WeRise could be combined with ICC (an existing tool) to prevent confusion among farmers. WeRise and ICC could be made into one model."- Director, ICRR*

> *"WeRise could be integrated into ICC or just simply be a stand-alone tool that specializes in rainfed rice areas only. It could also be included as a package with ICC depending on how farmers will take it. Advantages and disadvantages should be examined." - Deputy Director for Research and Collaboration, Indonesian Center for Agricultural Land Resources Research and Development (ICALRRD)*

The following proposed TTPs, which show technology transfer recipients and their potential roles in the uptake and dissemination of WeRise, could facilitate this.

WeRise technology transfer pathways. The Indonesian Agroclimate and Hydrology Research Institute (IAHRI), ICRR, Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG), and Indonesian Central Bureau of Statistics (BPS) could undertake localization/further development, and operation and maintenance of WeRise (Fig. 2). The AIATs in the respective rainfed rice producing provinces could be in-charge of technology assessment, information dissemination and feedback to the developers in coordination with the local governments and extension offices at the provincial and district levels and farmer groups.

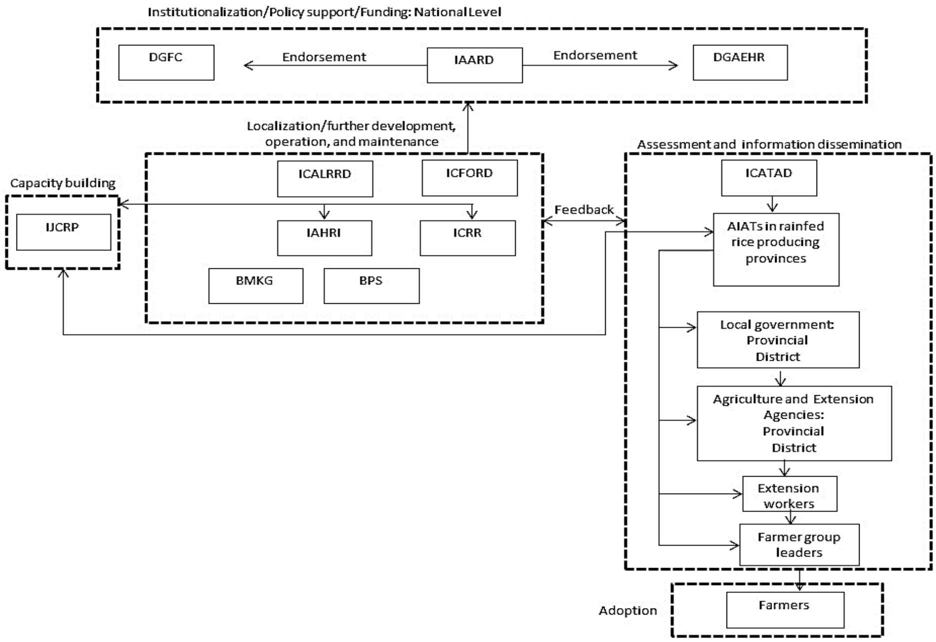

Fig. 2. WeRise technology transfer pathway in Indonesia (Option 1).

IAHRI, ICRR and AIAT; and their coordinating institutions ICALRRD, Indonesian Center for Food Crops Research and Development (ICFORD), and Indonesian Center for Agricultural Technology Assessment and Development (ICATAD); respectively are under the IAARD of MoA. Except for ICFORD, these potential technology transfer recipients are part of the National and Provincial Taskforces of Katam. The National Taskforce led by IAHRI is in-charge of developing and maintaining Katam and producing the recommendations while the Provincial Taskforce led by AIAT is responsible for technology information dissemination, collecting feedback at the provincial and district levels, and validation through interviews and FGDs with farmers (Yulianti et al. 2016). ICALRRD, ICFORD, and ICATAD could provide links to the IAARD director. IAARD provides support to other technical agencies of the MoA including the Directorate General of Food Crops (DGFC) and the Directorate General of Agricultural Extension and Human Resource (DGAEHR) through technology and institution innovation, policy synthesis, and agricultural development analysis (Rafani 2014). The DGFC is tasked to formulate and implement policies related to increasing the production (seed supply, cultivation practices, marketing, post-harvest, processing) of major commodities including rice (Rumanti et. al. 2016). The DGAEHR is tasked to strengthen the agricultural extension system, revitalize agricultural training and establish credible education programs. Under the DGAEHR are the Agricultural Extension Center and the Agricultural Training Center. Its major programs encourage the youth to engage in farming and promote cyber extensions for technology information dissemination to address the shortage of extension workers. Still within its scope is the College of Agricultural Extension (STPP) where junior extension workers are trained (Andoko et al. 2018). IAARD, DGFC, and BPPSDMP could, therefore, play major roles in the institutionalization, policy support, and funding at the national level to sustain WeRise.

An alternative of the TTP (Fig. 3) will include the Provincial Technology Commission (PTC), a multi-stakeholder platform that could serve as a coordination and feedback platform, facilitate integration of WeRise in the policy, research and technology development programs of the province; and play a major role in the institutionalization, policy support and funding at the local level. PTC was established under a gubernatorial decree with members from the Provincial Research and Development Agency (PRDA), Chamber of Trade and Commerce, agriculture agencies, province-based academic institutions, legislative members, and farmer groups. The proposed TTPs have three interconnected sub-pathways, coinciding with the Theory of Change by Douthwaite and co-workers (2017) which shows that agricultural research for development achieves impact through technology development and adoption, capacity development, and policy influence.

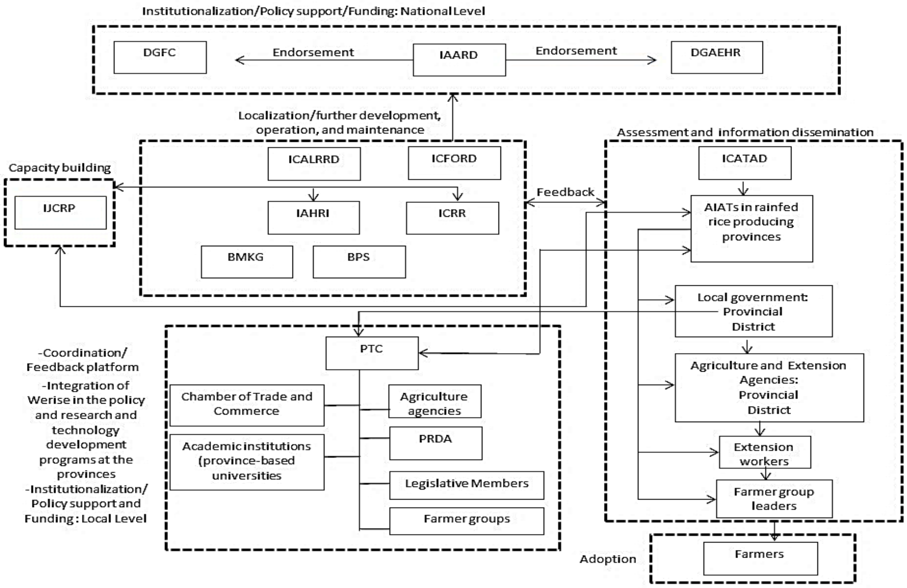

Fig 3. WeRise technology transfer pathway in Indonesia (Option 2).

Constraints to technology transfer. These include resource limitations, inherent characteristics of end-users, and the absence of enabling mechanisms (Table 1). The FGD participants counter these constraints by printing results and bringing it to the end users since internet access was a problem.

Table 1. Constraints encountered during technology transfer among FGD groups. (n=8)

Problems encountered	AIAT	Provincial	District	Sub- district	Total*
Lack of access to/insufficient facilities	2	1	2	1	6
Insufficient technology information facilitators	2	1	1		4
Budget constraints for a wider scale technology validation	1		2	1	4
Internet access	1		1		2
Insufficient technology training	1		1		2
Lack of trust on facilitators/local knowledge prevails	1		1		2
Low awareness level/education of farmers		1	1	1	3
Absence of a reward and punishment system for extension workers				1	1
Government program on increasing cropping index and accelerating planting time is contrary to the ICT tool recommendation on optimum cropping calendar	1				

Source: FGDs, 2016.

* Frequency counts are number of FGD groups where the item/theme has emerged/was mentioned.

Prerequisites of effective technology transfer. The FGD participants also identified factors to ensure their active participation in technology transfer activities (Table 2). From these factors, it could be gleaned that the prerequisites of an effective technology transfer identified by the FGD participants include the dimensions of the CEMTT. These are the associated characteristics of the transfer object, transfer recipients, transfer object use, and context-enabling mechanisms (Table 3).

Table 2. Factors to ensure active participation in technology transfer.

Factors to ensure active participation in technology dissemination (n=FGD groups)	FGD group				
	AIAT	Provincial	District	Sub district	Total
Dissemination is part of the main tasks/functions	1	1	2		4
Appropriate facilities are available (e.g., laptop, internet, handphone, camera, motorcycle, etc.)		2	1	1	4
Reward and punishment mechanisms are in place		1			1
The technology is ready for dissemination.		1			1
The technology has good accuracy.		1		1	2
The technology could increase rainfed rice productivity.			1		1
The technology is easy to use.			1		1
The technology could help farmers in deciding when to plant.			1		1
Knowledge and experience on rice production	1				1
They should understand the technology.		1			1
The area planted to rainfed will be increased			1		1
The technology could minimize disadvantages (risks) of farmers in rainfed rice areas.				1	1
Posters and other dissemination materials are available.				1	1
Good coordination among institutions		1			1

Source: FGDs, 2016.

Table 3. Prerequisites for an effective technology transfer.

Prerequisites for an effective technology transfer	Count
Transfer object associated characteristics (i.e., readiness, accuracy, and ease of use)	4
Transfer recipient associated characteristics (i.e., mandate, capacity -knowledge, skills and resources at disposal)	11
Transfer object use-effectiveness criteria (i.e., market impact - technology could help farmers in deciding when to plant and increase productivity)	4
Context-enabling mechanisms (incentives/reward and punishment, good coordination among institutions)	2

Source: FGDs, 2016.

Operationalizing the TTPs. Given the constraints encountered in previous technology transfer activities and the factors identified as prerequisites to technology transfer, the following should be considered in operationalizing the TTPs for WeRise in Indonesia:

Capacity building. WeRise will be transferred in forms applicable to the roles/level of use of the transfer recipients. For the Katam National Taskforce led by IAHRI who could operate, maintain, and further develop/localize WeRise in the context of the Katam platform, capacity building would include the transfer of scientific knowledge, technological design, and the development process. As the demand environment is dynamic, the capacity building should aim to equip the transfer recipients with knowledge, skills, and resources (database, development manual/codes) needed to operate the system freely. The freedom to operate is among the concerns laid out by stakeholders for project sustainability.

Farmers trust experts such as extension workers for more complex technical information (Feder and Slade 1984; Howell 1984, pp. 174, 179 cited in Feder et. al., 2004). Extension workers are among the major source of information of farmers, as primary WeRise infomediaries. Capacity building of extension workers from AIATs and local extension agencies on technology information dissemination should be undertaken. The foundations of WeRise development, navigation, generating and understanding the advisories and disseminating the information to end users/farmers using field language (simple and easy to understand at the farmers' level) should be included in the capacity building. By the end of the capacity building, certified WeRise facilitators should be equipped to communicate the WeRise advisories to the end-users (farmer groups/farmers) ahead of the cropping season.

The farmer respondents were not asked how they prefer to receive information such as the WeRise advisories. Face-to-face meetings (i.e., group/coordination meetings, training of extension workers) and printed materials which were utilized the most with Katam, coincides with the most preferred mode of information delivery (transfer medium) by farmers in the Philippines. Farmers preferred lectures because they could instantly ask questions (Manalo and van de Fliert 2011). Following lectures are print publications because farmers consider them as useful reference materials they go back to in case concepts have been unclear to them initially. Online information lagged behind the other mediums. Through capacity building, the constraints encountered in previous technology transfer activities particularly the insufficient number of technology information facilitators, insufficient training on the technology, low awareness level of farmers, lack of trust on the extension workers will be addressed.

Trust building. To establish proof that indeed WeRise works, on-farm validation activities/on-site demonstration plots are necessary and identified during the FGDs with extension agencies and farmer groups as among the most effective dissemination strategy in addition to capacity building (i.e., training/seminar and LAKUSISI or train-visit-supervise approach). Demonstration plots were the least utilized transfer medium (6%) for Katam (Yulianti et al. 2016). This could be attributed to its cost. IJCRP has ongoing validation activities in selected project sites but these are limited due to budget constraints. FGD participants also mentioned budget constraints to conduct a wider scale technology validation as among the technology transfer constraints. Given the resource limitations, creativity is needed in resource generation whether in monetary or in-kind. Sub-districts have lands that could be used as demonstration plots. The provincial governments through the PRDA have a budget to conduct their own R&D but lack the capable researchers. Collaborative arrangements may be explored. Existing farmer field schools could serve as venues for introducing WeRise. To create sustained adoption, farmer cooperators who have good farming practices and capable of taking risks (with capital) are important stakeholders. They are usually innovators or leaders in their communities.

Coordination platform. Good coordination among the technology transfer recipients is among the prerequisites identified for an effective technology transfer in this study. Coordination with provincial extension agencies is a concern in disseminating another ICT4D tool developed by IRRI (Santoso et al. 2010). The decentralization of Indonesia's extension system resulted in weak coordination as district levels are given more freedom in planning development programs independently. This could result in disintegrated programs at the provincial level (Margono and Sugimoto 2011).

The alternative TTP proposed (Option 2) includes an existing multi-stakeholder platform, the PTC which could be maximized to facilitate coordination and feedback. There might be no need to establish a new platform as what was done during the Site-specific nutrient management (SSNM) rollout in Indonesia. To facilitate dissemination, a Fertilizer Working Group (FWG) was established to formulate fertilizer recommendation across national institutions. But activities of the FWG have been limited because members have regular jobs and no specific budget was allocated for the activities (Santoso et al. 2010). Informal WeRise groups/small clusters consisting of WeRise champions) may also be established to serve as a platform for feedback, monitoring, and evaluation.

Policy advocacy. PTCs have inherent problems including the frequent change in leadership of its member institutions as incumbent heads are the PTC representatives by default, low participation rate, and some district offices may not be represented (Saediman 2015). Policy advocacies by IJCRP to create an enabling environment for the TTPs to materialize could help address these problems.

Legal framework. Technology transfer is deliberate and involves an agreement. The IJCRP has been implementing WeRise development and validation activities with partners through PLAs (Partner Letter Agreements), a legal framework executed by the representative heads of IRRI and partner agencies. The success of technology transfer is often affected by the absence of a clear legal framework for the exploitation of the IPR resulting from the research (Zuniga and Correa 2013).

WeRise is considered an international public good. IRRI and MAFF expressly decide that global accessibility and impact, as well as any commercial licensing and use of all intellectual assets/properties developed under the IJCRP, will be subject to the Consultative Group on International Agricultural Research (CGIAR) Principles and Guidelines on the Management of Intellectual Assets (IRRI, 2015). By the end of the project, a cooperative R&D agreement (i.e., MOA) with IRRI or MAFF/JIRCAS and the lead transfer recipient who will be in-charge of operating and maintaining the system will have to be executed. A legal instrument could articulate the technology transfer recipients, agent and their roles and responsibilities (resource contributions) in the technology transfer. A detailed work plan could also help in implementation.

Institutionalizing WeRise may be done at the national level and provincial level where it could be part of the implementation of a bigger development program. For instance, in the implementation of UPSUS (Upaya Khsusus), a national self-sufficiency program involving rice; Pemupukan Hara Spesifik Lokasi (PHSL) (Nutrient Manager for Rice), soil test kits, and a planting system, were recommended to be used as part of a technology package. This strategy would enable bundling or integrating WeRise into the provincial R&D programs (i.e., agricultural crop insurance, best crop management practices) and the chance of adoption could increase.

Maintainance of WeRise. The cost to operate and maintain WeRise will in effect be shouldered by the technology transfer recipients. The success rate is higher if sets of government agencies are involved as it allows co-funding. The cost and available resources to operate, maintain, and localize WeRise should be considered in transferring WeRise to Indonesia in particular to IAHRI to increase the chance of sustaining it. A possible advantage would be on the more efficient use of data. WeRise cost on data acquisition may be decreased as a local Indonesian agency (BMKG) could provide the data requirements to operate and maintain WeRise as with Katam.

Generating fees (e.g., tapping telecom providers for counterparts, asking farmer groups to pay a meager amount for every advisory, bundling of WeRise advisories with other information that farmers will be willing to pay for such as input prices, etc.) from WeRise is possible. In these cases, the applicable law and IP policies of the technology transfer agent and recipients should be applied. Other ways to facilitate the operation and maintenance by the technology transfer recipients can be through reducing costs by scouting a web server for bulk data storage and national agencies as providers of seasonal climate predictions.

Post-technology transfer support. To facilitate a smooth transition towards project sustainability, IJCRP should provide post-technology transfer support, details of which should be discussed and agreed with the institutions who will be in-charge of WeRise uptake and dissemination. Monitoring and evaluation should also be done after the transfer to evaluate how the transfer progresses and if a redesign of the pathways is necessary.

CONCLUSIONS AND RECOMMENDATIONS

The proposed TTPs include a set of government agencies currently involved in the development, validation, and dissemination of Katam, an ICT4D tool, as technology transfer recipients. Absorption or integration of WeRise with Katam to cater to rainfed rice conditions, capacity building of technology transfer recipients, and on-site demonstrations to establish proof of accuracy are major transfer media to sustain WeRise after the end of IJCRP implementation in September 2020. The proposed TTPs would allow co-funding among the government agencies, maximization of resources including data utilization, and do not necessitate the need to establish new entities. IJCRP as the transfer agent plays a critical role in laying the groundwork to ensure a smooth transition by getting the commitment of the transfer recipients to project sustainability via a legal framework so the latter may be able to maximize WeRise and its associated research outputs, policy advocacy to ensure a post-technology transfer support during the transition. Further examination of the PTCs in the rainfed rice areas which were found to be a potential coordination/feedback platform, to explore specific collaboration; and executing a technology transfer work plan among the technology transfer recipients are recommended.

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SOIL AND VEGETATION ANALYSIS OF REHABILITATED AND UNREHABILITATED AREA IN AN INACTIVE COPPER MINED OUT SITE IN MOGPOG, MARINDUQUE, PHILIPPINES

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ABSTRACT

After 10 years of establishing rehabilitation strategies, the present study analyzed the soil (i.e. pH, organic matter, N, P, K, Cu, bulk density and water holding capacity) and plant diversity to evaluate the 10 year rehabilitation efforts carried out in an inactive copper mined out site of Consolidated Mines Incorporated (CMI) in Mogpog, Marinduque, Philippines by the then University of the Philippines Los Baños Bioremediation Team. During the revisit of the area in 2016-2017, the experimental site was divided into rehabilitated and unrehabilitated areas by establishing six (6) 20m x 20m quadrats. Comparison of soil samples was done through Student's *t test*, while vegetation analysis was done by measuring the plant diversity using the species richness and Species Importance Value (SIV). After 10 years of rehabilitation, there was a minimal difference in soil characteristics between rehabilitated and unrehabilitated area except for pH. Vegetation analysis showed significantly higher mean species richness under rehabilitated area as compared with the unrehabilitated area. The rehabilitated area was dominated by vines and trees and had greater number of seedlings and saplings, while grasses dominated the unrehabilitated area. These findings showed the benefits of rehabilitation established

Key words: bioremediation, mycorrhizal fungi, diversity, assessment

INTRODUCTION

Mining is a process of extracting valuable minerals or ores from the ground and is often considered to have destructive processes that damage the landscape and environment. Its impact ranges from loss of biodiversity, contamination of air, soil and water; erosion, and health-related issues due to harmful chemicals used in mining operations. Because of these, rehabilitation is imperative to restore mined out area to a state similar to its pre-mining condition as closely as possible (IRR of RA 9742). This aims to convert a mined-out area to an area with a safe and stable condition that minimizes potential risks.

In 2017, the Philippine government ordered the mining firms to allocate and deposit their budget for activities intended to protect the environment and develop the neighboring community, or their operation will be suspended. The Philippines also became the first among the 50 countries implementing the Extractive Industries Transparency Initiative, a global standard for open and accountable management of oil, gas and mineral resources, to achieve satisfactory progress (EITI, 2017).

A number of mining firms had rehabilitated their decommissioned sites and their periphery. The Solid Earth Development Corporation had recently opened its rehabilitated site for ecotourism, and Coral Bay has achieved 30% rehabilitation in comparison to its original state. However, Mines and Geoscience Bureau listed 31 mining sites in the country abandoned, inactive or closed. One of these is previously mined for copper by Consolidated Mining Inc. (CMI) in Mogpog, Marinduque which was left inactive for more than 28 years.

In 2006, the UPLB Bioremediation Team, a group of researchers from the University of the Philippines Los Baños (UPLB), identified the upper most part of the mined-out rock dumpsite in Barrio Capayang for their rehabilitation project. This was a major component under the *Jatropha* Program of UPLB. The study applied several interventions such as soil amelioration with the use of mycorrhizal fungi (5g per plant), lime (214g plant^{-1}) and compost (500g plant^{-1}) added and mixed in a one foot^3 hole, during field planting. In addition, NPK (14-14-14) fertilizer was applied to all plants at the rate of 25 g plant-^{1} (Aggangan et al. 2017).

The compost which was obtained from Folia Tropica Quick-Acting Organic Plant Food (Los Baños, Laguna) has the following analysis: 1.28% Total N, 1.05% Total P, 2.41% Total P_2O_3 (available P), 1.53% Total K, 1.84% Total K (water soluble K), 55.3% organic matter, 22 C:N ratio, and pH of 6.3. The Bioremediation Project focused on growth performance of rehabilitation species and microorganisms, including their ability to concentrate heavy metals (Aggangan et al. 2012; Cadiz et al. 2012; Llamado et al. 2013). Due to time constraint, the project team was unable to assess the long-term effects of rehabilitation in the mined out site, thus this study.

MATERIALS AND METHODS

The research area is a rock dumpsite of a copper mining operation by CMI within the boundary of Barangay Ino and Barangay Capayang in Mogpog, Marinduque, Philippines (Fig. 1). It is hilly approximately at 60 masl and located near a local mangrove forest and coastal zone *(*Cadiz et al. 2012*)*. Beside the study area is a 450 m wide open- pit that is filled with waters which become sources of water for irrigation of nearby rice fields *(*Tulod et al. 2012*)*. A total of six (6) quadrats were established on the topmost part of the inactive mined out site.

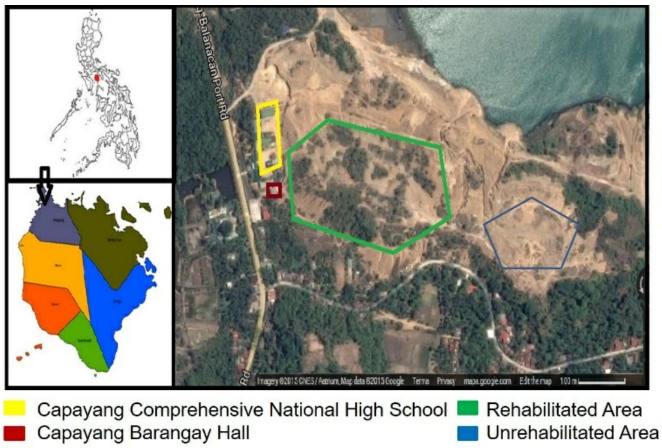

Fig. 1. Satellite map of the study area (Google Maps 2017)

Soil characterization. From each quadrat, soil sample, weighing approximately one (1) kilogram, was collected from a composite of 10 randomly collected soils. Samples were collected using a shovel around 10 to 20 cm deep in a 10 cm radius following sampling method of the DA-BSWM (Department of Agriculture-Bureau Soils and Water Management). Samples were placed in tied plastic bags and were labelled accordingly. Samples were then air dried, pulverized, sieved (2mm) and mixed thoroughly and were brought to the National Institute of Microbiology and Biotechnology (BIOTECH), UPLB for analysis (i.e. pH, organic matter (OM), P, and K).

Soil samples from each quadrat were also collected for bulk density analysis using canisters. This was done by removing 10 cm topmost part of the soil and canisters were pressed and hammered down until the topmost part of the canisters were filled up. Both ends were covered tightly and were labelled accordingly. Samples were brought to the College of Agriculture-Central Analysis Service Laboratory for laboratory analysis for bulk density. Soil samples for water holding capacity (WHC) were collected from each quadrat. This was done by clearing off the leaf and branch litter and dug 10-15 cm deep of soil using a shovel. Soil samples were placed in ziplock plastic bags labelled accordingly, and were brought to School of Environmental Science and Management (SESAM) Laboratory for analysis.

Soil physical and chemical analysis data were subjected to mean, standard deviation and student *t-test* descriptive statistical analysis, while t-Test for independent samples was used to test the significant differences between samples.

Plant diversity assessment. A calibrated string was placed to draw the boundaries of the quadrat. A quadrat measuring 20m x 20 m was used in counting vines and epiphytes. Within 20m x 20m quadrat, a subquadrat measuring 10 m x 10m was used in determining trees. Within this 20m x 20m quadrat, another subquadrat measuring 2m x 2m was used in assessing the shrubs, seedlings and saplings, another subquadrant measuring 1m x 1m was used for the inventory of grasses, ferns and seedlings. Establishment of subquadrats were randomly selected in each quadrat. The vegetation assessment was done following the methods by the Department of Environment and Natural Science-Environmental Management Bureau (DENR-EMB) and by Iskandar and Kotanegara (1995).

Plants in the sampling areas were identified, counted, measured and recorded. The diameter of trees was measured at 4.5 ft from the ground using a flexible ruler, while seedlings, saplings, and poles were measured at 10 cm above the ground. Grasses and ferns were measured by directly measuring the clumps and the area they covered.

Species richness per quadrat was based on the number of species recorded and Species Importance Value (SIV) was computed by getting the mean of relative frequency, relative dominance and relative density. Relative frequency is the ratio of the frequency of a species over sum frequency value of all species. Relative dominance is the ratio of dominance of a species over total dominance of all species. Relative density is the ratio of the total number of individuals of a species in all quadrats over total number of quadrats sampled.

SIV = relative frequency + relative density + relative dominance wherein:

$$\text{Relative frequency} = \frac{\text{number of sampled plots where a certain species is distributed}}{\text{number of total sampled plots}}$$

$$\text{Relative density} = \frac{\text{total number of a certain species in the total sampled plots}}{\text{number of species in the total sampled plots}}$$

$$\text{Relative dominance} = \frac{\text{sum total of DBH of a certain species in the total sampled plot}}{\text{sum total DBH of all species in the total sampled plots}}$$

Similarity of species in each quadrat was also determined by Bray-Curtis similarity matrix using Paleontological Statistics (PAST) version 1.68 software (Hammer et al. 2001).

RESULTS AND DISCUSSION

Soil characteristics. In spite of the amelioration added in the soil by the UPLB Bioremediation Team, only small changes were observed. Results of soil analysis showed no significant difference between the rehabilitated area and unrehabilitated area except for pH as shown by the *t-test* (Table 1). The overburden of excavation to uncover mineral ores raises environmental problems like loss of nutrient qualities and microbial activities. Metal-contaminated and metal-rich soils inhibit soil-forming process and plant growth (Favas et al. 2014). These rocks which are heterogenous in size were dumped, topping out the fertile or uncontaminated soil (Arsh 2017 and Yaseen et al. 2012).

Physical characteristics of the soil include bulk density and water-holding capacity. Bulk density for the rehabilitated area and unrehabilitated area were 1.25 m/cc and 1.41 m/cc, respectively. Both results fall under the classification described as suitable for plant growth according to USDA (2008). The water holding capacity (WHC) of the rehabilitated area and unrehabilitated area were 29.99% and 27.07%, respectively. The WHC was highly dependent on the amount of soil organic matter OM); such that, mined out area is expected to have low OM due to the absence of vegetation and other organisms that would contribute to its formation. The OM analysis in rehabilitated area was higher (0.50%) than the unrehabilitated area (0.39%). However, the low OM of soil in both areas is due to the nature of these dumps which are composed of unweathered rocks excavated during mining. These dumps covered the topsoil when these soil layers are excavated and stockpiled (Ssenku et al. 2014). Furthermore, the microorganisms inhabiting the topsoil are covered by the excavated rocks; thus, a longer period of time is needed to have a soil microbial activity similar with the topsoil (Ssenku et al. 2014).

Soil pH in both, rehabilitated and unrehabilitated areas were both acidic. However, the rehabilitated area was slightly more acidic than the unrehabilitated area (Table 1). Extracting copper, nickel and gold from mineral ores are highly associated with high amount of pyrites and other sulphides present in rock as wastes from mining operations. The spontaneous oxidation of minerals commonly known as pyrite which, when in contact with water or humid atmosphere, will react and release acidic effluents such sulfidic materials. (Bertland et al. 2017; Cuevas and Balangcod 2014).

Table 1. Mean soil physical and chemical characteristics (n= 6) in the mined out site under rehabilitated and unrehabilitated areas in Mogpog, Marinduque, Philippines. Values with different subscript letters are not significantly different (Student's *t-test*, p > 0.05)

Soil Parameters	**Rehabilitated area**		**Unrehabilitated area**	
	Mean	**SD**	**Mean**	**SD**
pH	4.13^{a}	0.15	4.80^{b}	0.14
OM **(%)**	0.50	0.14	0.39	0.04
N **(%)**	0.01	0.005	0.01	0.0
P (ppm)	68.50	9.68	77.50	0.50
K me/100g soil	0.23	0.04	0.25	0.05
Cu (ppm)	314	90.74	604	386
WHC (%)	29.99	0.18	27.07	0.08
BD	1.25	3.62	1.4	2.55

Degraded soils such as mined-out areas have very low essential nutrients (Favas et al. 2014). Similar results were obtained in our study. The macronutrients, N and K, in both rehabilitated and unrehabilitated areas areas were low (Table 1). Limited N in the soil can be attributed to the high Cu concentration which negatively affects the microbial activity, including the nitrogen fixation by microorganisms (Domingo and David 2014; Ssenku 2014). Low amount of K in the soil may be due to its solubility which makes them prone to leaching (Bradshaw 1997). Phosphorus content (rehabilitated area: 68.5 ppm and unrehabilitated area: 77.5 ppm) shows that both areas have exceeded the amount needed for plant growth according to the paper of Kruse (2007). This can be attributed to phosphorus fixation which is highly dependent to pH, where acidic soils increase mineralization compared to basic soils (Rodriguez and Fraga 1999). The Cu concentration in the rehabilitated area was much lower than in the unrehabilitated area. Soils with high Cu content allow only tolerant plants to grow (Chen 2000). High amount of Cu was still recorded from mined out rock waste dump even after mineral extraction. The difference in Cu content in both areas can be attributed to the rehabilitation efforts wherein rehabilitation species accumulated Cu in its roots, stems, leaves and seeds (Aggangan et al. 2015; Cadiz et al. 2010; Fontanilla and Cuevas 2010; Lange et al. 2016). Low soil pH directly and indirectly facilitated absorption of Cu. Moreover, low pH makes Cu more soluble for plant uptake (Ghosh 2015).

Plant diversity assessment. Plant inventory was done to determine the species diversity and species importance value (SIV) of the mined out site in Mogpog, Marinduque. Laurila-Pant et al. (2014) stated that plant diversity is acknowledged as basis for a healthy ecosystem. It favors and benefits the environment, as well as the plant species in the area. Each plant contributes distinctive root structure and adds residues to the soil. Plant diversity influences the composition and number of soil microorganisms that produce different variety of root exudates (Cadiz et al. 2012; Harantova et al. 2017, Llamado et al. 2013; Soderberg et al. 2002 as cited by Chen et al. 2008). It protects and improves water availability of the soil and it also supports and provides habitat for larger organisms (Glaesner et al. 2014).

Table 2 lists the plant species in the course of rehabilitation. Plants listed under the first column were plants observed in 2006 (i.e. before the start of the rehabilitation efforts) and were considered the pioneer species. These include *Acacia auriculiformis*, *Davallia solida*, *Nephrolepis sp., Saccharum spontaneum*, and *Tremna orientalis* (Cadiz et al. 2012). The second column were four tree species used for the rehabilitation by the Bioremediation Team in 2007; namely, *Jatropha curcas, Pterocarpus indicus, Bauhinia purpurea and Cassia spectabilis* the species (Cadiz et al. *2012*), and the last column shows the species which were observed during the period (2016-2017) covered by the present study. These plant species were not present during the initial establishment of rehabilitation strategies. These recruited plant species were *Passiflora sp., Clitorea ternatea, Centrosema sp., Merremia tridentata, Melothria pendula, Psidium guajava, Leucaena leucocephala, Chromoaena odorata, Breynia vitis-ideae* and *Morinda sp.*

Table 2. Plant species in the mined-out sites in the course of the rehabilitation of the mined-out sites conducted in Mogpog, Marinduque.

Existing vegetation prior to rehabilitation	Species used for rehabilitation	Recruited plant species
Tremna orientalis	*Cassia spectabilis*	*Passiflora sp.*
Saccharum spontaneum	*Pterocarpus indicus*	*Clitorea ternatea*
Nephrolepis sp.	*Jatropha curcas*	*Centrosema sp.*
Davallia solida	*Bauhinia purpurea*	*Merremia tridentata*
		Melothria pendula
		Psidium guajava
		Leucaena leucocephala
		Chromolaena odorata
		Breynia vitis-ideae
		Morinda sp.

This indicates that aside from the species used in the rehabilitation, there were newly established plant species in the rehabilitated area. This also connotes that the rehabilitation efforts may have nurtured the seeds brought by wind or animals, such as birds, that led to the establishment of recruitment species.

Table 3 shows the mean Species Importance Value (SIV) under the rehabilitated area and the unrehabilitated area. The highest SIV (32.75) was noted in *A. auriculiformis* under the rehabilitated area. On the other hand, *S. spontaneum* had the highest SIV (58.90) under the unrehabilitated area and was also higher than the mean SIV of the same species under the rehabilitated area. The results indicate that grasses predominate under the unrehabilitated area, while more diverse vegetation was observed under rehabilitated area. Grasses can dominate marginal and open land areas more successfully than other species. Furthermore, grasses are more effective in adapting in mined-out areas because of their ability to tolerate and adapt to low soil nutrient at the same time take advantage of wide open space of mined-out area which provides high opportunities to capture sunlight. Similarly, grasses occupy the early stage of succession and seedlings or young trees occupy the latter stage (Harantova et al. 2017; Prafulla and Uniyal 2011). Similar observation was noted by Cuevas and Balangcod (2014) in non-grazed advanced seral stage (Cuevas and Balangcod 2014).

However, *S. spontaneum* was still the species with the second highest SIV under the rehabilitated area. Similar observation was noted by Harantova et al. (2017) and Prafulla and Uniyal (2011) where a transitional stage occurs from grass to trees. Consequently, the rehabilitation species serve as nurse species that support and facilitate the growth of other species (Sudarmaji and Hartati 2016). *Saccharum. spontaneum, A. auriculiformis* and *Nephrolepis sp.* were among the species recorded in the area in 2006, prior to rehabilitation activities. These species are widely known to have roots which are heavily colonized and infected with myccorhizal fungi (Agganan et al. 2015). The presence of mycorrhizal colonization increases plant tolerance to heavy metal contamination. This explains their tolerance and proliferation in the copper rich waste dump. In addition, the high SIV of *A. auriculiformis* can be explained by its ability to survive in in hospitable sites. They are fast growing and drought resistant. Although it is an exotic species, it is commonly used in reclaiming wasteland areas, including decommissioned mining sites. In addition, *A. auriculiformis* is a legume of the family Fabaceae and its presence in the area can help improve the quality of the soil through its nodule-containing nitrogen-fixing bacteria. Moreover, its pods are wide, flat, hard and twisted in irregular coils that are initially green which turn to brown and open upon ripening. Its black seeds hang out on strings of yellow aril to attract birds which in turn carry seeds that increase survival in the mined-out area. *S. spontaneum* is a perennial grass and is commonly found along riverbanks, roadsides and railroads. It grows on fertile soil but also found to grow in sandy soils and wastelands. It is capable of propagating vegetatively, and or through seeds which can be dispersed by wind (Yadav et al. 2016; Mani 2013). Furthermore, its ability to adapt to any environment and easy seed dispersal makes it easy for this species to establish itself even in mined-out areas.

Table 3 also shows the low SIV of plants that were planted during rehabilitation. The species that were considered pioneers had the second highest SIV under the rehabilitated area and the unrehabilitated area. This observation is similar with the findings of Harantova et al. (2017) and Prafulla and Uniyal (2011) which showed that after eight (8) years of restoration of the mined-out site, the planted species were still present. However, these species have been replaced by higher successional species after 23 years. Furthermore, the growth of the latter successional species may have occurred originally in the area prior to mining activities or could have occurred in the neighboring areas (Hanief et al. 2007; Mudraka et al. 2016).

Table 3. Mean species importance values (SIV) of plants in the mined out site in Mogpog, Marinduque, Philippines.

Species	Mean SIV	
	Rehabilitated Area	Unrehabilitated Area
Acacia auriculiformis	**32.75**	10.01
Saccharum spontaneum	23.94	**58.90**
Davallia solida	20.49	31.08
Nephrolepis sp.	9.57	-
Pterocarpus indicus	3.84	-
Melothria pendula	2.61	-
Psidium guajava	0.99	-
Jatropha curcas	0.94	-
Bauhinia purpurea	0.77	-
Leucaena leucocephala	0.75	-
Breynia vitis-ideae	0.74	-
Morinda sp.	0.74	-
Chromoaena odorata	0.74	-
Passiflora sp.	0.54	-
Merremia tridentate	0.53	-
Centrosema sp	0.53	-
Clitorea ternatea	0.53	-

The percentage (%) cover based on basal area in the mined out sites is presented in Table 4. There were no existing vines and trees in the unrehabilitated area as compared with the rehabilitated site. It also shows that there were healthier and denser seedlings, saplings, shrubs in the rehabilitated area compared with the unrehabilitated area (Figs. 2 and 3).

In terms of percent cover, the unrehabilitated area has higher basal area than the rehabilitated site due to the higher percent cover by grasses in the former. However, trees, saplings and seedlings dominated the rehabilitated area. Unlike grasses that form clusters, trees, saplings and seedlings form one main trunk or stem. This explains why the unrehabilitated area has a higher percentage (%) cover. This parameter gives idea on density, growth and size of trees present in a given area. Using basal area for determining the percent (%) cover helps make cover assessment of plant growth more reliable since it is not affected by recent grazing history and seasonality (Cade 1997).

Table 4. Mean percent (%) cover based on basal area of plants under rehabilitated and unrehbilitated areas of the mined out site in Mogpog, Marinduque, Philippines.

Plant Habit	Percent (%) Cover	
	Rehabilitated Area	Unrehabilitated Area
Vines	present	0
Trees	0.11	0
Seedlings	0.28	0.02
Grasses	0.99	6.12
TOTAL (%)	**1.38**	**6.14**

Ecological patterns of plants in the mined out area. The plant species assemblage based on Bray-Curtis similarity matrix is presented in Fig. 4. It illustrates the level of similarity of plant species among sampling sites. The figure shows two major clusters separating the two areas having 10% similarity. Here, numbers 5 and 6 represent the unrehabilitated area while numbers 1, 2, 3 and 4 represent the rehabilitated area. The species in both areas have significantly low similarity and is therefore indicative of the influence of the rehabilitation methods employed. Within the two unrehabilitated areas (represented in Fig. 4 as lines 5 and 6), a 50% similarity was observed. Among the rehabilitated areas (represented in Fig. 4 as lines 1, 2, 3 and 4), area 4 has the least similarity with the other rehabilitated areas. However, there is a 60% similarity of area 4 with its subclusters 1 and 2. Copper content of this quadrat may also play an important role, since it is in this area where Cu content is least.

Fig. 2. Vegetation cover of the rehabilitated area located at the top most part of Consolidated Mines Incorporated (CMI) rock dumpsite in Mogpog, Marinduque, Philippines. February 15, 2016 (Photo credits: Katrine Mae B. Mante)

Fig. 3. Vegetation cover of the unrehabilitated area (area without intervention) located at the top most part of Consolidated Mines Incorporated (CMI) rock dumpsite in Mogpog, Marinduque, Philippines. February 15, 2016 (Photo credits: Katrine Mae B Mante).

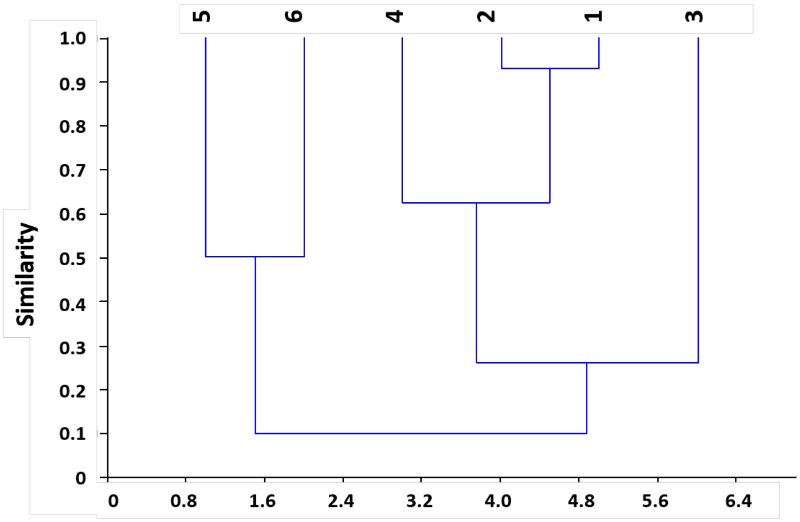

Fig. 4. Plant species assemblage based on Bray-Curtis similarity matrix.

CONCLUSION AND RECOMMENDATION

The result of the study showed that there was no significant difference in soil chemical analysis between rehabilitated and unrehabilitated area. However, the mean species richness was higher in the rehabilitated area than in the unrehabilitated area. Vegetation cover of the mined out rehabilitated area showed higher basal area for seedlings and saplings than the unrehabilitated area. Vines and trees were also present in the rehabilitated area but were absent in the unrehabilitated area. This showed that soil amendments used during the earlier rehabilitation efforts have helped increase the growth of other plant species. Cluster analysis showed that there was 90% difference between rehabilitated area and unrehabilitated area in terms of vegetation. Rehabilitated area showed higher basal areas of vines, trees, saplings and seedlings than the unrehabilitated area since only grasses provided high basal area cover in this site.

Rehabilitation of mined out sites proved to be necessary and effective as indicated in the improvement of vegetation cover and diversity. However, it takes time for the soil to improve since the area is all exposed rocks. Weathering of rocks takes a long process and the production of detritus plant materials also takes time. It is necessary that long time monitoring of rehabilitated areas be made to come up with management strategies that could help improve rehabilitation efforts.

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THE NITROGENASE ACTIVITY AND INDOLE-3-ACETIC ACID PRODUCTION OF *AZOSPIRILLUM* SPP. ISOLATES FROM RICE ROOT AND RHIZOSPHERE SOIL AND THEIR EFFICIENCIES ON GROWTH PROMOTION OF RICE

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ABSTRACT

Azospirillum is considered as an important bio-fertilizer for promoting rice growth and yield. This study aimed to isolate *Azospirillum* spp. from the paddy fields in Thailand, to evaluate ability of *Azospirillum* spp. for the nitrogenase activity and indole-3-acetic acid (IAA) production and to determine their efficiencies to promote rice growth. This study were conducted during 2016–2017 at the Land Development Department. Fifty-eight isolates of *Azospirillum* (*Azospirillum brasilense*, *A. lipoferum*, *A. oryzae* and *A. formosense*) isolated from rice root and rhizosphere paddy soil in Thailand were screened using polymerase chain reaction (PCR) with *Azospirillum*-specific primers and identified using 16S rRNA gene sequence analysis. The analysis used the detection of the *nifH* gene involved in nitrogenase activity for all 58 *Azospirillum* isolates, while the *ipdC* gene involved in IAA production was detected. Meanwhile *nifH* was found in all isolates, only 49 isolates were observed *ipdC* as a DNA band of 313 bp approximately. The different nitrogenase activity levels of the various species were determined using acetylene reduction assay. The nitrogenase activity was in the range 17.8-1,212.0 nmol C_2H_4/mg protein/h. IAA production was in the range 8.8-114.7 μg/mL, measured by spectrophotometry. Efficiency of sixteen isolates was tested on rice growth *in vitro* conditions. There were no significant differences among the 16 isolates for the percentages of rice seed germination. The effect of *Azospirillum* on rice growth during 15 days in N-free nutrient solution was determined. The results showed that three isolates promoted longer shoots as compared to the non-inoculated samples, while nine other isolates induced longer roots.

Keywords: auxin, *ipdC* gene, nitrogen fixer, *nifH* gene, paddy soil

INTRODUCTION

Nitrogen has a substantial effect on rice growth and yield because 75% of plant nitrogen is contained in chlorophyll which is an important organelle in the photosynthetic system (Osotsapar, 2015). Consequently, nitrogen can lead to an increase in the biomass, height, number of panicles, leaf size and yield. Nitrogen is always deficient in paddy soils because it can be easily lost by leaching, erosion and evaporation in gas form (Osotsapar 2015). *Azospirillum* spp. are microaerophilic bacteria that can help retain nitrogen. Therefore they can decrease the nitrogen deficiency problem through the fixation of atmospheric nitrogen (N_2) and its conversion to ammonia (NH_3), especially, under the microaerophilic conditions in flooded rice fields (Sahoo et al. 2014). In addition, these bacteria are able to promote rice growth and yield because they are not only nitrogen fixers but they also produce phytohormones. These phytohormones, such as auxin (indole-3-acetic acid; IAA) and gibberellin, can stimulate plant growth by increasing nutrient absorption and the rate of photosynthesis (Fayez et al. 1985; Kokila and Bhaskaran, 2016). Research has shown that *Azospirillum* application to the soil increases rice biomass as well as nitrogen accumulation (García de Salamone et al. 2010). From these advantages, *Azospirillum* spp. are interesting in developing as a bio-fertilizer to increase rice yield in

Thailand. However, there were a few studies on the effect of *Azospirillum* on paddy field in Thailand. Moreover, various *Azospirillum* from different regions showed different efficiencies (Han and New 1998). Thus, high efficiency *Azospirillum* spp. should be isolated and screened with rice growing. Molecular biological techniques, rapid and very accurate, are necessary to detect and identify species of microorganisms. The universal primers of the 16S ribosomal RNA gene and *Azospirillum*-specific primers have been adopted for investigation; they were designed from the 16S rRNA gene, *ipdC*, encoding a key enzyme for IAA production and the *nifH* gene, which operates as a regulatory and structural gene in the nitrogenase enzyme (Shime–Hattori et al. 2011; Lin et al. 2011). The study sought to isolate, evaluate the nitrogen fixation and IAA production ability of *Azospirillum* spp. from the root rice and rhizosphere soil in paddy fields in Thailand and to determine their efficiencies to promote rice growth. Molecular biological techniques were used to identify and detect the different activity levels of the isolates.

MATERIALS AND METHODS

Isolation of *Azospirillum* spp. Initially, 49 samples of rhizosphere soil and 49 samples of rice root were collected from paddy fields in various provinces of Thailand: Tak, Kamphaeng Phet, Nakhon Sawan, Chai Nat, Ang Thong, Suphan Buri, Phra Nakhon Si Ayutthaya, Ubon Ratchathani, Buri Ram, Surin, Maha Sarakham and Nakhon Ratchasima (Table 1). The soil samples were taken at a depth of 0-15 cm. *Azospirillum* spp. were isolated from each root sample following the isolation method of Akbari et al. (2007). After incubation at 30°C for 2-7 days, the white pellicle was streaked on Rojo Congo (RC) medium (Rodriguez-Cáceres, 1982) for purification. Each scarlet-red colony was ensured by culturing it into N-free semi-solid medium (NFb medium) (Dobereiner et al. 1976). Purified *Azospirillum* isolates were kept in RC agar slants at 4°C. For soil samples, 0.1 mL of serial dilution (10^{-1} to 10^{-3}) were cultured onto an N-free semi-solid medium at 30°C for 3-5 days. Finally, isolation was processed using the method for the root samples.

Table 1. Location of sampling sites from paddy field in Thailand and number of samples.

Location	Number of samples	Location	Number of samples
Huai Khan Laen, Wiset Chai Chan, Ang Thong	2	Nong Bua Lakhon, Dan Khun Thot, Nakhon Ratchasima	2
Khu Salot, Lat Bua Luang, Phra Nakhon Si Ayutthaya	1	Nong Bua, Khong, Nakhon Ratchasima	1
Lakchai, Lat Bua Luang, Phra Nakhon Si Ayutthaya	1	Ta Khu, Pak Thong Chai, Nakhon Ratchasima	1
Thanonhak, Nang Rong, Buri Ram	1	Ta Khit, Banphot Phisai, Nakhon Sawan	4
Nikhom, Satuek, Buri Ram	2	Wang Yang, Si Prachan, Suphan Buri	4
Ban Yang, Phutthaisong, Buri Ram	1	Ban Pho, Mueang, Suphan Buri	1
Nang Lue, Mueang. Chai Nat	4	Mueang Bua, Chumphon Buri, Surin	2
Tha Phutsa, Khlong Khlung, Kamphaeng Phet	2	Nam Ruem, Mueang, Tak	4
Don Klang, Kosum Phisai, Maha Sarakham	1	Wang Prachop, Mueang, Tak	1
Na Pho, Kut Rang, Maha Sarakham	1	Wang Hin, Mueang, Tak	4
Chok Chai, Chok Chai, Nakhon Ratchasima	3	Ko E, Khueang Nai, Ubon Ratchathani	1
Thai Charoen, Nong Bun Mak, Nakhon Ratchasima	1	Pa-Ao, Mueang, Ubon Ratchathani	3
Nong Chaeng Yai, Bua Yai, Nakhon Ratchasima	1		

Molecular screening for *Azospirillum* spp. Strains of *Azospirillum* were screened using polymerase chain reaction (PCR) with specific primers for the genus *Azospirillum* (Azo494-F; 5'- GGC CYG WTY AGT CAG RAG TG-3'and Azo756-R; 5'-AAG TGC ATG CAC CCC RRC GTC TAG C-3') (Lin *et al*., 2011). The total DNA of the bacteria was extracted by suspending it in a 1.5 mL microtube, containing 50 µL of sterile distilled water and boiling it at 100°C for 5 min. The PCR reaction mixtures were composed of 3 µL of DNA suspension, 20 pmol of each primer, 1X PCR buffer, 0.2 mM of dNTPs, 2.5 mM of $MgCl_2$ and 2 U of Taq DNA polymerase. The thermal profile compound of the three steps involved initial denaturation at 94 °C for 5 min, 35 cycles of 94 °C for 1 min, 68°C for 1.5 min and 72°C for 0.5 min, and a final extension at 72°C for 7 min (Lin *et al*., 2011). After amplification, the PCR products were run with the electrophoresis system on 1.5% agarose gel in a 1X TAE buffer.

Identification of *Azospirillum* isolates using 16S rRNA gene sequence. The positive isolates of *Azospirillum* were identified using 16S rDNA sequence analysis. The total DNA of the bacteria was extracted using the same method described in the previous step. The PCR mixtures each in a total volume of 25 µL contained 2 µL of bacterial DNA, 10 pmol of each primer (A1F: 5'- ATT CCG GTT GAT CCT GC -3' and 1541R: 5'- AAG GAG GTG ATC CAG CCG CA -3'), 1X PCR buffer, 0.2 mM of dNTPs, 2.5 mM of $MgCl_2$ and 2 U of Taq DNA polymerase. The thermal profile was initial denaturation at 94 °C for 5 min, 35 cycles of 94 °C for 1 min, 58°C for 1 min and 72°C for 1 min, and a final extension at 72°C for 5 min, followed by confirmation using gel electrophoresis on 1% agarose in 1X TAE buffer. The PCR products were sequenced using a Thermo Sequence Fluorescent Labeled Primer Cycle Sequencing Kit (Amercham Pharmacia Biotech), Macrogen, Inc (Korea). The obtained partial 16S rDNA sequences were aligned using Nucleotide BLAST (http://blast.ncbi.nlm. nih.gov) for identification at the species level.

Molecular detection of genes involved in nitrogenase activity and Indole-3-Acetic Acid (IAA) production. The total DNA of each of the isolates was extracted using a TIANamp Bacteria DNA kit (Tiangen, China). The *nifH* genes were detected using PCR with the primer pair PolF (5'-TGC GAY CCS AAR GCB GAC TC-3') and PolR (5'ATS GCC ATC ATY NTC RCC GGA-3') (Poly *et al*., 2001). The PCR mixtures each in a total volume of 25 µL contained 1 µL of DNA template, 10 pmol of each primer, 1X PCR buffer, 0.2 mM of dNTPs, 2.5 mM of $MgCl_2$ and 2 U of Taq DNA polymerase. The PCR thermal profile was 30 cycles of 1 min at 94 °C, 1 min at 55°C and 2 min at 72°C, with a final extension of 5 min at 72°C. The *ipdC* genes responsible for IAA production were detected using PCR with the primer pair A32f (5' ACC CCT CCA CAA TTT CCG GCG CAT 3') and A42r (5' CGC CAC CCC TAG AGT GGA GCT GTA 3'), described by Shime-Hattori *et al*. (2011). The PCR mixtures of *ipdC* gene amplification each in a total volume of 25 µL contained 1 µL of DNA template, 10 pmol of each primer, 1X PCR buffer, 0.25 mM of dNTPs, 1.5 mM $MgCl_2$ and 2.5 U of Taq DNA polymerase. The thermal profile was initial denaturation at 94°C for 3 min, 35 cycles of 94 °C for 30 s, 52°C for 30 s and 72 °C for 1 min, with a final extension at 72°C for 5 min. PCR products were run with the electrophoresis system on 1.5% agarose gel in 1X TAE buffer.

Determination of nitrogenase activity and IAA production. Nitrogenase activity and IAA production were evaluated in strains of *Azospirillum* using a completely randomized design (CRD) in triplicate. Nitrogen fixation was estimated based on the nitrogenase activity using acetylene reduction assay (Boddey, 1987; Reis *et al.,* 2015). Each *Azospirillum* isolate was cultured at 30°C for 48 h in a 250 mL flask containing 100 mL of N-free semi-solid medium (NFb medium). The flasks were sealed using a rubber stopper and atmosphere containing 10% acetylene in the tubes was created by removing air and replacing it with equal volume of acetylene gas in the flask and incubated at room temperature for an hour. Later, 1 mL of the gas was analyzed using a gas chromatograph (GC-2014, Shimadzu, Japan), equipped with a flame ionization detector assay for ethylene concentration. Then, it was validated with a standard calibration curve.

Estimation of the IAA quantity was determined following the method described by Meunchang et al. (2006). Each *Azospirillum* isolate was cultured at 30°C for 48 h in N-free broth supplemented with 100 mg/L of tryptophan, 0.2 g/L of yeast extract and 1 g/L of $(NH_4)_2SO_4$, followed by measurement using the Salkowski colorimetric technique (Glickmann and Dessaux 1995).

Effect of *Azospirillum* spp. on Seed Germination and Rice Seedling Growth. The experiments were set up in three replications using a CRD that consisted of 17 treatments including a non-inoculated control and 16 isolates of *Azospirillum* which showed higher potential of nitrogen fixation and IAA production. Each *Azospirillum* isolate culture was prepared in a 250 mL Erlenmeyer flask containing 100 mL N-free broth, with 1 g/L of yeast extract and 2.5 g/L of NH_4Cl. The culture was incubated at 30°C with constant shaking at 120 rpm for 48 h. The rice seeds were surface-sterilized using 1% chloramine T for 15 min and washed four times with sterilized distilled water.

For seed germination, sterilized seeds were immersed in each *Azospirillum* culture (75 rice seeds per selected isolate) for 3 h. The control consisted of 75 rice seeds immersed in a sterile medium for 3 h. After inoculation, the seeds were aseptically placed on a sterilized Petri dish (25 rice seeds per dish) on sterilized filter paper with the aid of sterilized forceps (Hossain et al. 2015). Finally, the Petri dishes containing seeds were placed in the dark for 3 days.

For rice seedling growth, sterilized seeds were transferred onto a sterilized plate containing sterilized filter paper and sterilized distilled water (to maintain the moisture of the filter paper), followed by incubation at 30 ± 2°C until germination. The germinated seeds were transferred into sterilized test tubes (size 25x150 mm), which contained 40 mL of N-free nutrient solution (Somasegaran and Hoben 1985) and a piece of folded filter paper to support the seedling. A sample of 0.1 mL of *Azospirillum* culture was used for inoculation in each treatment except for the control. The shoot height and root length of seedlings were measured at 15 days after planting.

The analyses of variance of data were determined and the differences among means were compared by LSD at 0.05.

RESULTS AND DISCUSSION

Isolation and identification of *Azospirillum* spp. Fifty-eight *Azospirillum* isolates were identified from the rhizosphere soil and rice root samples of paddy fields in Ang Thong, Suphan Buri, Buri Ram and Nakhon Ratchasima provinces, Thailand. Typical colonies of bacteria on the RC medium were scarlet-red to pink and 0.5-4 mm in diameter after incubation at 30°C for 5 days. Using the *Azospirillum*-specific primers, DNA bands size of about 263 bp were obtained after PCR-based amplification according to Lin *et al*. (2011).

For identification based on 16S rRNA gene sequences, the 16S rRNA gene of the *Azospirillum* isolates was amplified using PCR and had a PCR product size of about 1,500 bp. The partial sequences of the 16S rRNA gene of all isolates were compared with GenBank using Nucleotide BLAST. The results (Table 2) showed a similar percentage of *Azospirillum* (95-100%). *Azospirillum* isolates were similar to *Azospirillum brasilense* (54 isolates), *A. lipoferum* (1 isolate), *A. oryzae* (1isolate) and *A. formosense* (2 isolates).

Table 2. Identification based on 16S rDNA sequences of various *Azospirillum* isolates using Nucleotide BLAST

Isolates	Closest species in GenBank (Accession number)/similarity (%)	Isolates	Closest species in GenBank (Accession number)/similarity (%)	Isolates	Closest species in GenBank (Accession number)/similarity (%)
ATr2	*Azospirillum brasilense* (FR667893.1)/98	NMr1	*Azospirillum brasilense* (HE646778.1)/ 99	SRr1	*Azospirillum brasilense* (HE646778.1)/ 99
ATs2	*Azospirillum brasilense* (CP007794.1)/ 100	NMr2-1	*Azospirillum brasilense* (HE646778.1)/ 99	SRr2-1	*Azospirillum brasilense* (HE646778.1)/ 99
AYr1	*Azospirillum brasilence* (CP012917.1)/ 99	NMr2-2	*Azospirillum brasilense* (HE646778.1)/ 99	SRr2-2	*Azospirillum brasilense* (HE646778.1)/ 99
BRr1-1	*Azospirillum brasilense* (HE646778.1)/ 99	NMr3	*Azospirillum brasilense* (HE646778.1)/ 99	SPr4	*Azospirillum brasilense* (HE646778.1)/ 99
BRr1-2	*Azospirillum brasilense* (HE646778.1)/ 99	NMr4-1	*Azospirillum brasilense* (HE646778.1)/ 99	SPr5	*Azospirillum brasilense* (HE646778.1)/ 98
BRr1-3	*Azospirillum brasilense* (HE646778.1) / 99	NMr4-2	*Azospirillum brasilense* (HE646778.1)/ 99	SPs2-1	*Azospirillum brasilense* (KY010286.1)/ 97
BRr2-1	*Azospirillum brasilense* (HE646778.1)/ 99	NMr4-3	*Azospirillum brasilense* (HE646778.1)/99	SPs2-2	*Azospirillum brasilense* (FR667893.1)/ 97
BRr2-2	*Azospirillum brasilense* (HE646778.1)/ 99	NMr5-1	*Azospirillum brasilense* (HE646778.1)/ 99	SPs3-1	*Azospirillum brasilense* (CP007794.1)/ 97
BRr2-3	*Azospirillum brasilense* (HE646778.1)/ 99	NMr5-2	*Azospirillum brasilense* (HE646778.1)/ 99	SPs3-2	*Azospirillum brasilense* (KP676405.1)/ 99
BRr3	*Azospirillum brasilense* (HE646778.1)/ 99	NMr7	*Azospirillum brasilense* (FR667893.1)/ 99	SPs3-3	*Azospirillum brasilense* (KP676405.1)/ 99
BRr4	*Azospirillum brasilense* (HE6467781)/ 99	NMr8-1	*Azospirillum brasilense* (KT737492.1)/ 100	SPs5	*Azospirillum brasilense* (FR667893.1)/ 99
BRs1	*Azospirillum lipoferum* (KM009070.1)/ 99	NMr8-2	*Azospirillum brasilense* (KT737492.1)/ 95	Tr1	*Azospirillum brasilence* (HE646778.1)/ 100
BRs2	*Azospirillum oryzae* (NR_117482.1)/ 99	NMr9-1	*Azospirillum brasilense* (HE646778.1)/ 100	Tr5-1	*Azospirillum formosence* (KU836620.1)/ 97
BRs4	*Azospirillum brasilense*	NMr9-2	*Azospirillum brasilense*	Tr5-2	*Azospirillum brasilence*

Isolates	Closest species in GenBank (Accession number)/similarity (%)	Isolates	Closest species in GenBank (Accession number)/similarity (%)	Isolates	Closest species in GenBank (Accession number)/similarity (%)
	(FR745918.1)/ 99		(HE646778.1)/ 99		(HE646778.1)/ 100
CNr4-1	*Azospirillum brasilense* (FR667893.1)/ 100	NMr9-3	*Azospirillum brasilense* (HE646778.1)/ 99	Tr7	*Azospirillum brasilense* (CP012917.1)/ 99
CNr4-2	*Azospirillum brasilense* (FR667893.1)/ 99	NMs1	*Azospirillum formosence* (KU836617.1)/ 99	UBr1	*Azospirillum brasilense* (CP007794.1)/ 99
KPr2-1	*Azospirillum brasilense* (CP007794.1)/ 97	NMs3-1	*Azospirillum brasilense* (HE646778.1)/ 97	UBr2	*Azospirillum brasilense* (FR667893.1)/ 99
KPr2-2	*Azospirillum brasilense* (CP007794.1)/ 97	NMs3-2	*Azospirillum brasilense* (HE646778.1)/ 99	UBr4	*Azospirillum brasilense* (FR667893.1)/ 99
MKr1	*Azospirillum brasilense* (AB480699.1)/ 100	NMs6	*Azospirillum brasilense* (KU351165.1)/ 97		
MKr2	*Azospirillum brasilense* (KT737492.1)/ 100	NWr1	*Azospirillum brasilense* (KJ194586.1)/ 97		

Azospirillum spp. are important as bio-fertilizer through biological fixation of nitrogen that has a special role in enhancing plant growth and increasing yield. These bacteria were isolated from samples of the rhizosphere soil and of plant roots, shoots and leaves, and have been reported to improve the growth and yield of several plant species. (Shime–Hattori et al. 2011; Cassán and Diaz-Zorita 2016; Kanimozhi and Panneerselvam 2017). In the current study, the number of *Azospirillum* isolates from rice roots (77.59%) was found more than from the rhizosphere soil (22.41%) in paddy fields in Thailand. *A. brasilense* (93.10%) was the dominant species, as reported in Hartman and Baldani (2006). They reported that *A. brasilense* and *A. lipoferum* were common and dominant species associated with agronomic plants such as maize, wheat and rice. However, the other species, including *A. lipoferum*, *A. oryzae* and *A. formosense* were also found. The efficacy of *Azospirillum* for N_2 fixation and IAA production was investigated.

Molecular detection of genes involved in nitrogenase activity and IAA production. The efficacy of *Azospirillum* for N_2 fixation and IAA production was investigated using the molecular technique. The *Azospirillum* samples isolated in this study contained the *NifH* and *ipdC* genes which expressed activity of N_2 fixation and IAA production, respectively. The *nifH* gene responsible for nitrogen fixation was found as a DNA band at around 360 bp in all isolates (Table 3). This study also amplified *ipdC* gene fragments in 49 isolates, which a size of about 313 bp. However, 9 isolates (BRs1, BRs2, BRs4, MKr1, NMr7, NMs1, NMs3-2, SPs3-1 and Tr5-1) were negative (Table 3).

Table 3. PCR test results by primers of *NifH* and *ipdC* gene for 58 isolates of *Azospirillum*

Isolate	Gene		Isolate	Gene		Isolate	Gene	
	NifH	***ipdC***		***NifH***	***ipdC***		***NifH***	***ipdC***
ATr2	+	+	NMr1	+	+	SRr1	+	+
ATs2	+	+	NMr2-1	+	+	SRr2-1	+	+
AYr1	+	+	NMr2-2	+	+	SRr2-2	+	+
BRr1-1	+	+	NMr3	+	+	SPr4	+	+
BRr1-2	+	+	NMr4-1	+	+	SPr5	+	+
BRr1-3	+	+	NMr4-2	+	+	SPs2-1	+	+
BRr2-1	+	+	NMr4-3	+	+	SPs2-2	+	+
BRr2-2	+	+	NMr5-1	+	+	SPs3-1	+	-
BRr2-3	+	+	NMr5-2	+	+	SPs3-2	+	+
BRr3	+	+	NMr7	+	-	SPs3-3	+	+
BRr4	+	+	NMr8-1	+	+	SPs5	+	+
BRs1	+	-	NMr8-2	+	+	Tr1	+	+
BRs2	+	-	NMr9-1	+	+	Tr5-1	+	-
BRs4	+	-	NMr9-2	+	+	Tr5-2	+	+
CNr4-1	+	+	NMr9-3	+	+	Tr7	+	+
CNr4-2	+	+	NMs1	+	-	UBr1	+	+
KPr2-1	+	+	NMs3-1	+	+	UBr2	+	+
KPr2-2	+	+	NMs3-2	+	-	UBr4	+	+
MKr1	+	-	NMs6	+	+			
MKr2	+	+	NWr1	+	+			

+ and - indicate the presence and absence of the expected amplicon, respectively.

Various *Azospirillum* isolates in this study contained the *NifH* and *ipdC* genes which expressed activity for N_2 fixation and IAA production, respectively. *NifH* encoded the dinitrogenase reductase protein (Fe protein, *NifH*), a component of the nitrogenase enzyme complex (Steenhoudt and Vanderleyden 2000). For the *ipdC* gene, it encodes phenylpyruvate decarboxylase for the production of IAA (Reem et al. 2015; Jijon-Moreno et al. 2015). In our study, the *NifH* gene was observed from all *Azospirillum* isolates while mostly *Azospirillum* isolates had IAA expression by *ipdC* gene. On the other hand, some of them may produce IAA by other pathways, according to a report of Jijon-Moreno et al. (2015). However, the PCR detection of *Azospirillum* isolates is considered to reduce the step of isolation in the laboratory, which accelerated the process and decreased the selection bias (Shime–Hattori et al. 2011).

Nitrogenase activity and IAA production. The efficiency of nitrogen fixation based on nitrogenase activity in the 58 isolates showed differences after 48 h of incubation. Acetylene reduction assay of various *Azospirillum* isolates had a range of 17.8-1,212.0 nmol C_2H_4/mg protein/h (Table 4). Based on these values, strains of *Azospirillum* could be grouped into three : 27 isolates with low nitrogenase activity (0-250 nmol C_2H_4/mg protein/h), 13 isolates with medium activity (250-500 nmol C_2H_4/mg protein/h) and 18 isolates with high nitrogenase activity (>500 nmol C_2H_4/mg protein/h). *A. brasilense* NMr9-2 isolated from rice roots had the highest nitrogenase activity. *A. brasilense* SPs2-2 isolated from rhizosphere soils had the lowest level.

IAA production by *Azospirillum* spp. in this study was in the range 8.8-114.7 µg/mL (Table 4) and could be divided into three levels: low (0-40 µg/ml), medium (40-80 µg/mL) and high (>80 µg/mL) found in 19, 32 and 7 isolates, respectively. *A. brasilense* BRr3 had the highest amount of IAA after 48 h of incubation, while *A. brasilense* NMr1 had the lowest amount of IAA.

Nitrogenase activity, *Azospirillum* fixes N_2 under microaerobic conditions when the nitrogen supply becomes limiting (Hartmann and Zimmer 1994). These bacteria can grow and fix N_2 effectively in an N-free semi-solid medium with low oxygen (Mala 2007). In the current study, the 58 *Azospirillum* isolates cultured in N-free, semi-solid medium showed nitrogenase activity as revealed by the detection of the *NifH* genes. The results were related to screening *NifH* genes that are concerned with Fe protein including the nitrogenase enzyme. However, the nitrogenase activity differed among isolates. *Azospirillum* isolated from the rhizosphere soils or the rice roots in the current study could perform in the range of 17.8-1,212.0 nmol C_2H_4/mg protein/h for nitrogenase activity. Various levels of nitrogenase activity of *Azospirillum* isolated from paddy fields have been reported. *A. amazonense* isolates, from rice root and plant tissue, had nitrogenase activity that was in the range 4.5-188.9 nmol C_2H_4/ mg protein/h (Rodrigues et al. 2008). *Azospirillum* spp. isolated from different rice rhizospheres at different locations in Odisha, India, were reported to produce between 58.88 and 161.22 nmol C_2H_4/ mg bacteria/h. (Sahoo et al. 2014). *Azospirillium* isolates from soil samples of a rice growing area in Bihar, India showed nitrogenase activity in the range 430-1,720 nmol C_2H_4/ mg protein/ h (Srivastwa and Kanhaiyaji, 2014). In Thailand, three isolates of *Azospirillum* sp. selected from rhizosphere soil and root rice samples were reported to have nitrogenase activity in the range 65-113 nmol C_2H_4/tube/ h (Meunchang et al. 2006).

In case of IAA production in the current study, the efficiency of *Azospirillum* spp. among isolates were different. The result may be due to their abilities on the control of IAA synthesis via a regulatory mechanism and the regulation of IAA biosynthesis were different (Hartmann and Zimmer, 1994). Previous research reported that *Azospirillum* spp. isolated from the roots of cereal crops, grass and some weeds in Iran had amounts of IAA in the range 29.0-761.0 ppm when determined using a colorimetric technique (Akbari et al. 2007). Furthermore, the IAA produced by five strains of *Azospirillum* isolated from the rhizosphere of wheat in Pakistan was reported in the range 0.84-30.49 mg/L (analyzed using high-performance liquid chromatography) (Ayyaz et al. 2016). In a study based on *Azospirllum* isolates from paddy fields in Thailand, three of the isolates were reported to produce IAA 47-69 mg/ L which was measured using the Salkowski colorimetric technique (Meunchang et al. 2006). While, the current study was in the range 8.8-114.7 µg/mL which some isolates could produce more than that report.

Table 4. Nitrogenase activity and IAA production of various *Azospirillum* isolates.

Isolate	Nitrogenase activity (nmol C_2H_4/mg protein/h)	IAA production (µg/mL)	Isolate	Nitrogenase activity (nmol C_2H_4/mg protein/h)	IAA production (µg/mL)	Isolate	Nitrogenase activity (nmol C_2H_4/mg protein/h)	IAA production (µg/mL)
ATr2	153.6^{nopqrst}	35.9^{rst}	NMr1	534.6^{bcdefghi}	8.8^{y}	SRr1	115.8^{rstu}	28.4^{uv}
ATs2	721.5^{abcd}	80.7^{e}	NMr2-1	582.4^{abcdefgh}	66.1^{ijkl}	SRr2-1	339.1^{efghijklm}	25.4^{vw}
AYr1	218.9^{klmnopqrs}	59.9^{lmn}	NMr2-2	377.9^{defghijk}	69.1^{hijk}	SRr2-2	554.4^{bcdefghi}	50.3^{p}
BRr1-1	134.9^{qrstu}	94.2^{c}	NMr3	490.0^{bcdefghj}	51.8^{op}	SPr4	931.0^{ab}	88.7^{cd}
BRr1-2	236.3^{jklmnopqr}	30.2^{tuv}	NMr4-1	143.2^{pqrstu}	27.5^{uvw}	SPr5	589.3^{bcdefgh}	58.0^{mno}
BRr1-3	531.9^{bcdefghi}	66.7^{ijkl}	NMr4-2	336.3^{fghijklmn}	47.0^{pq}	SPs2-1	148.3^{opqrstu}	57.7^{mno}
BRr2-1	405.8^{cdefghijk}	11.0^{y}	NMr4-3	35.6^{wx}	31.3^{tuv}	SPs2-2	17.8^{y}	13.5^{xy}
BRr2-2	148.1^{opqrstu}	42.5^{qr}	NMr5-1	173.7^{mnopqrst}	68.5^{hijk}	SPs3-1	433.1^{ijklmnopq}	72.2^{fghi}
BRr2-3	779.5^{abc}	75.0^{efgh}	NMr5-2	568.7^{bcdefgh}	20.4^{wx}	SPs3-2	527.7^{bcdefghi}	78.3^{efg}
BRr3	619.7^{abcdefgh}	114.7^{a}	NMr7	299.4^{fghijklmno}	52.2^{op}	SPs3-3	768.4^{abcd}	24.9^{vw}
BRr4	509.9^{bcdefghi}	30.4^{tuv}	NMr8-1	28.0^{vwx}	81.9^{de}	SPs5	37.7^{wx}	54.0^{nop}
BRs1	53.1^{xy}	80.0^{e}	NMr8-2	34.8^{x}	28.2^{uv}	Tr1	417.7^{cdefghijk}	80.6^{e}
BRs2	32.4^{xy}	51.3^{op}	NMr9-1	623.2^{abcdef}	71.6^{ghi}	Tr5-1	207.3^{klmnopqrs}	69.7^{hij}
BRs4	52.6^{vwx}	51.9^{op}	NMr9-2	1,212.0^{a}	101.9^{b}	Tr5-2	110.5^{stu}	66.1^{ijkl}
CNr4-1	160.6^{nopqrstu}	63.2^{jklm}	NMr9-3	109.7^{tuv}	51.0^{op}	Tr7	181.5^{lmnopqrst}	31.8^{tuv}
CNr4-2	294.6^{ghijklmnop}	51.4^{op}	NMs1	44^{vwx}	26.0^{vw}	UBr1	495^{bcdefghi}	79.0^{ef}
KPr2-1	196.7^{lmnopqrs}	60.4^{lmn}	NMs3-1	616.5^{abcdefg}	78.2^{efg}	UBr2	476.9^{bcdefghij}	61.9^{klm}
KPr2-2	184.8^{lmnopqrst}	69.6^{hij}	NMs3-2	34.2^{xy}	30.7^{tuv}	UBr4	781.6^{abc}	63.7^{jklm}
MKr1	82.2^{uvw}	34.0^{stu}	NMs6	770.5^{abcde}	54.1^{nop}			
MKr2	308.8^{fghijklmno}	39.0^{rs}	NWr1	282.5^{nop}	50.5^{p}			

Means in a column followed by the same lowercase letter are not significantly different according to LSD.

Effect of *Azospirillum* spp. on seed germination and rice seedling growth. The top-10 *Azospirillum* isolates (NMr9-2, UBr4, BRr2-3, NMs6, SPr3-3, SPr4, ATs2, NMr9-1, BRr3 and NMs3-1) for nitrogenase activity and the top-10 isolates (BRr3, BRr1-1, NMr9-2, SPr4, ATs2, Tr1, NMr8-1, BRs1, UBr1 and SPs3-2) for IAA production were selected for testing the rice growth. The response of rice inoculated with various strains of *Azospirillum* was observed in the initial developmental stages as shown in Table 5. The effect of inoculation was not significant in seed germination in the Petri dish at three days after inoculation. The seed germination rates among the 16 isolates were in the range of 94.7-100.0%. However, the effect on rice growth at 15 days after inoculation in N-free nutrient solution was determined and showed that *A. brasilense* NMr8-1 promoted the greatest shoot height (18.36 cm) but this was not significantly different from the effect of *A. brasilense* BRr1-1, *A. brasilense* NMr9-1, *A. brasilense* NMs3-1, *A. brasilense* NMs6, *A. brasilense* SPr4, *A. brasilense* SPs3-2 and *A. brasilense* SPs3-3. The longest root length (6.36 cm) was found by *A. lipoferum* BRs1. However, it was not significantly different from *A. brasilense* NMr8-1, *A. brasilense* NMr9-2, *A. brasilense* NMs6, *A. brasilense* SPr4, *A. brasilense* SPs3-2, *A. brasilense* SPs3-3, *A. brasilense* UBr1 and *A. brasilense* UBr4.

Table 5. Effect of *Azospirillum* inoculation on rice seed germination and rice seedling growth

Treatment	Seed germinated (%)	Shoot height (cm)	Root length (cm)
Control	94.67	14.40[cd]	3.70[d]
A. brasilense ATs2	100.00	15.70[bcd]	4.46[cd]
A. brasilense BRr1-1	97.33	16.08[abcd]	4.50[cd]
A. brasilense BRr2-3	96.00	15.03[bcd]	4.80[bcd]
A. brasilense BRr3	97.33	14.62[cd]	4.94[bcd]
A. lipoferum BRs1	100.00	15.58[bcd]	6.36[a]
A. brasilense NMr8-1	100.00	18.36[a]	5.54[abc]
A. brasilense NMr9-1	96.00	16.62[abc]	4.88[bcd]
A. brasilense NMr9-2	98.67	15.96[bcd]	5.56[ac]
A. brasilense NMs3-1	97.33	16.46[abc]	4.30[cd]
A. brasilense NMs6	98.67	16.38[abc]	5.32[abc]
A. brasilense SPr4	97.33	17.00[ab]	5.98[ab]
A. brasilense SPs3-2	97.33	16.40[abc]	5.18[abc]
A. brasilense SPs3-3	97.33	17.04[ab]	5.18[abc]
A. brasilense Tr1	98.67	13.74[d]	4.88[bcd]
A. brasilense UBr1	94.67	14.68[bcd]	5.60[abc]
A. brasilense UBr4	97.33	15.56[bcd]	5.48[abc]
$LSD_{0.05}$		2.38	1.38
CV (%)	2.85	11.88	21.32

Means in a column followed by the same lowercase letter are not significantly different according to LSD.

The current study found that most of the *Azospirillum* isolates promoted rice growth in the early stages. Three isolates (*A. brasilense* NMr8-1, *A. brasilense* SPr4 and *A. brasilense* SPs3-3) showed the greater rice shoot height than non-inoculation. Those isolates fixed N as 28.0, 931.0 and 768.4 nmol C_2H_4/ mg protein/ h, respectively and produced IAA as 81.9, 88.7 and 24.9 mg/L, respectively. While rice root length from 9 isolates (*A. lipoferum BRs1, A. brasilense NMr8-1, A. brasilense NMr9-2, A. brasilense NMs6, A. brasilense SPr4, A. brasilense SPs3-2, A. brasilense SPs3-3, A. brasilense UBr1 and A. brasilense UBr4*) was higher than non-inoculation. Which those isolates fixed N and produced IAA in the range of 28.0-1,212.0 nmol C_2H_4/mg protein/h and 24.9-101.9 mg/L, respectively. From this study, the rice growth promotion of various *Azospirillum* was different. This result was similar to that of Hossain et al. (2015). The effect on rice seed germination, shoot height and root length was probably due to nitrogen fixation and IAA production by *Azospirillum* which was coincided with the conclusion of Kannan and Ponmurugan (2010), Hossain et al. (2015) and Kokila and Bhaskaran (2016). Nitrogen is a major essential element for plant growth, so the nitrogen fixed by *Azospirillum* could lead to increase rice seedling height, leaf size, biomass and yield (Ohyama 2010; Osotsapar 2015). Moreover, the phytohomone released by *Azospirillum* also could stimulate rice seed germination, shoot height and root length (Kokila and Bhaskaran 2016).

CONCLUSION

Azospirillum is known to be a very active nitrogen fixer that promotes plant growth and yield. From the 58 strains of *Azospirillum* isolated from rhizosphere soil and rice roots in the current study, all isolates had the *nifH* gene and nearly all had the *ipdC* gene. Nitrogen fixation ability based on nitrogenase activity of *A. brasilense* NMr9-2 and IAA production ability of *A. brasilense* BRr3 were higher than other isolates. The effect of *Azospirillum* inoculation on rice seed germination rate were in the range 94.7-100.0% on the third day. While rice shoot height and root length on the fifteenth day was highest in the inoculation of *A. brasilense* NMr8-1 (18.36 cm) and *A. lipoferum* BRs1 (6.36 cm), respectively. The findings of this study are important step towards the development of bio-fertilizer for rice cultivation using these *Azospirillum* isolates.

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THE INFLUENCE OF FARMERS ENTREPRENEURIAL BEHAVIOR ON THE BUSINESS PERFORMANCE OF DAIRY FARMERS IN WEST BANDUNG REGENCY, INDONESIA

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ABSTRACT

The study sought to analyze the influence of the entrepreneurial behavior to the business performance of dairy farmers in West Bandung Regency, Indonesia. The research was conducted from January 2018 to February 2018. The importance of this research is that dairy cattle business has a great connection to upstream and downstream. Human resource development is one of the answers in the current era of globalization. Factors of entrepreneurial behavior and the business environment determine the success or failure of farmers in conducting dairy cow business activities. If dairy farmers succeed in developing a maximum dairy farming business with an entrepreneurial spirit that is developed, it can help the country by saving the country's foreign exchange, because the National milk needs are fulfilled with local milk from Indonesia. The analytical method used Structural Equation Modeling (SEM) with analytical tools data processing using LISREL 8.8. The data that was used in this research were the primary data collected through an interview process and the secondary data taken in accordance with the related institutions. The interview process took 149 people. The results of this research showed that business climate had positive and significant effect on the entrepreneurial behavior with a coefficient value of 0.25 and t-statistic of 8.87, whereas, the individual characteristics had positive and significant effect on the entrepreneurial behavior with a coefficient value of 0.55 and t-statistic of 8.56. The entrepreneurial behavior of dairy farmers had positive and significant effect with a coefficient value of 0.99 and t-statistic of 10.28, which means that the entrepreneurial behavior will improve the business performance of dairy cattle business in West Bandung Regency, Indonesia.

Keywords: business climate, entrepreneurial spirit, individual characteristics, structural equation modelling (SEM)

INTRODUCTION

Livestock plays an important role in the agricultural economy. Livestock in an area can increase the income of the local community if it gets facilities from the local government or institutions that cooperate with the farm. One of the national livestock commodities that can be relied upon to meet the demand of public consumption is dairy farm. Dairy farm produces fresh milk that becomes a staple food to fulfill daily food needs, especially for children in the growing phase. Dairy farm development in Indonesia aims to provide the need for high-nutritious animal protein such as milk. Other goal that will be achieved in dairy farm development effort in addition to increasing population, production, post-harvest and marketing of dairy farm and dairy products is to improve the welfare of farmers. The purpose of dairy farm development is to support the program of the government of milk self-sufficiency by 2020. Matondang et al. (2012) stated that community milk consumption in 2020 is estimated to be 6 billion liters of fresh milk in a year or 16.5 million liters per day. Thus, to fulfill the milk demand, at least 1,325,000 lactation cattle (with an average production of 4,600 liters per lactation) or 2.6 million dairy cattle population will be needed in order to support production plus 2.2 million tons of concentrate feed and 33.6 million tons fiber source feed (equal to 111,000 ha of grass) or 5.4 million tons of dry matter. Milk consumed by Indonesians varies ranging from fresh milk to milk powder, yoghurt, and other dairy products. Hence, Indonesian farmers have an important role in producing fresh milk for direct consumption or as main ingredient for dairy products. It is proved by data comparing the amount of milk production, milk consumption, and import of milk in Indonesia from 2009-2016 in Table 1.

Table 1. Total production, consumption and import of milk in Indonesia 2009-2016

Year	Dairy Cattle Production (Ton)	Milk consumption (Ton)	Import of Milk (Ton)
2009	827,200	2,277,200	1,450,000
2010	909,533	2,345,000	1,435,467
2011	974,694	2,964,000	1,989,306
2012	959,700	2,699,675	1,739,975
2013	786,900	2,985,816	2,198,916
2014	800,800	3,278,145	2,477,345
2015	835,100	3,838,215	3,003,115
2016	852,951	3,989,755	3,136,804

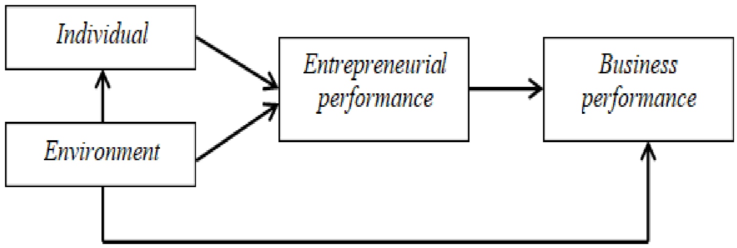
Source: Directorate General of Husbandry and Animal Health, 2016

The government covers Indonesian milk consumption by importing from various countries that are centers of milk production in the form of skim milk powder, whole milk powder, butter milk powder, and anhydrous milk fat. The neighboring countries importing milk are Australia and New Zealand. One of dairy milk producers and dairy farming areas in Indonesia is West Java Province. Dairy cattle production is dominated by West Bandung Regency. Dairy cattle production in West Bandung Regency were 40,818, 41,795, 26,382 and 37,290 cattle, in 2011, 2012, 2013 and 2016, respectively (BPS 2013).

Business development on dairy farm can also open up employment opportunities. The development of dairy farms in Indonesia basically aims to increase domestic milk production to anticipate the high demand for milk. In increasing milk production there must be human resource development as one of the answers in the globalization era, which is entrepreneurial behavior. The entrepreneurial behavior factor determines the success or failure of farmers in conducting their cattle business. This is supported by Muharasatri (2013) whereas entrepreneurial characteristics have a significant and positive relationship with dairy farm performance at KTTSP Kania Bogor. Entrepreneurial behavior is very necessary in the dairy cattle business to improve the performance in West Bandung Regency. The success of dairy farms also lies on the behavior of farmers who apply the entrepreneurial spirit. Entrepreneurial behavior can support the existence of more innovative and active behavior in exploiting and developing dairy farm business potential. Good entrepreneurial behavior may improve dairy farm business performance. Thus this entrepreneurial behavior can be influenced by internal factors and external factors. Pamela (2013), it was mentioned that good individual characteristic such as work experience can affect entrepreneurial behavior. Zainura et al. (2016) stated that external factors such as external factors such as availability of inputs, counseling and training support, assistance capital and means of production, promotion and marketing support, regulatory support business, compactness between farmers and access to market information can affect entrepreneurial behavior as these led to the increase of traits such as innovation, risk-taking, persistence, responsiveness with opportunities, and independence in order to improve business performance. Based on the explanation above, it is necessary to examine the influence of individual characteristics and business climate on the entrepreneurial behavior of dairy farmers and the influence of dairy farmers' entrepreneurial behavior on the performance of dairy farming. The aims of this study were to identify the influence of individual characteristics and business climate on dairy farmer entrepreneurial behavior and to analyze the influence dairy farmer entrepreneurial behavior on dairy cattle business performance in West Bandung Regency, Indonesia.

RESEARCH METHODS

The theory used in the research is the theory on Delmar (1996) which explains an entrepreneur in the small business sector who supports business in economic activities such as making new combinations in his business or supporting to renew his search for better. This research uses Delmar's (1996) theory because it has a proportion as a farm which is a scale of business carried out mostly by smallholders. The model of Delmar's theory (1996) can be seen in Fig. 1.



Source: Delmar (1996)

Fig. 1. Model of entrepreneurial behavior towards business performance.

The research was conducted in Lembang District, West Java because location selection was also based on several considerations that Lembang District is one of dairy farm centers in West Bandung Regency. The study was conducted from January 26, 2018 until February 26, 2018. The data used in this study were primary data and secondary data. Secondary data were obtained from offices related to dairy farms. The primary data were obtained through interviews using questionnaires to the dairy farmers and extracting information directly from the Field Extension Officer (FEO). The study population is farmers who have a dairy farm business in Lembang District. Determination of number of respondents was employed by purposive sampling technique based on certain intention and purpose. Purposive sampling technique has the criteria of farmers with a minimum of two dairy cows and not experiencing dry cage. The number of respondents in this study was taken based on SEM analysis. Hair et al (1998) said that research has four variables latent with each indicator more than three so the number of samples taken between 100 and 150 respondents. The number of respondents taken in this SEM-based study was 149 people. The operationalization of variables for farmer's individual characteristics, farmer's behavior, and farm's performance are shown in Table 2.

Data processing and data analytical methods. Data analysis used is descriptive analysis and quantitative analysis. Descriptive analysis conducted by researchers to dairy farmers in the form of open questions related to individual characteristics of dairy farmers and dairy cattle business. Processing quantitative structural equation modeling (SEM) data with the help of LISREL 8.8 analysis tools. The variables used in this study consist of latent variables and manifest variables. Latent variables are tested like exogenous latent individual characteristic (IB), exogenous latent business climate (KI), endogenous latent dairy cattle farmers' entrepreneurial behavior (PKP), and endogenous latent perspective of dairy cattle business performance (PKUP). These latent variables are affected by manifest variables. Latent variables and manifest variables are shown in Table 3.

Table 2. The operationalization of variables for farmer's individual characteristics, farmer's behavior and farm's performance

Variable	Indicator	Category	Code	Measurement Level (Scale)
Individual Characteristics Zainura et al. (2016) and Puspitasari (2013)	1. The previous job experience relates to running dairy farm business 2. Business motivation that comes from individual to learn how to increase the productivity of dairy farm business 3. Perception about the usefulness of the dairy business for daily life	Strongly disagree – Strongly agree 1-5	X11 X12 X13	Likert scale, whereas score 1= strongly disagree and score 5= strongly agree
Entrepreneurial Behavior of Dairy Farmers Dirlanudin (2010)	1. Innovative in utilization of dairy cattle waste 2. Farmers take a risk to earn high profit 3. Opportunity to take advantage of milk as processed products 4. Farmers are independent in searching for information about dairy farm business 5. If livestock feed resources are insufficient, farmers have to look for new resources	Strongly disagree – Strongly agree 1-5	Y11 Y12 Y13 Y14 Y15	Likert scale, whereas score 1= strongly disagree and score 5= strongly agree
The Performance of Dairy Farm Business Keeh *et al*. (2007); Sumantri (2013); Manev *et al*. (2005)	1. The income of Dairy farm business can fulfill daily life needs 2. Establishing the expansion of marketing territory by cooperating with the gift store or restaurant, except the KPSBU 3. The benefits of the competition using conventional method are starting to be reduced in dairy farm business 4. Farmers have good commitment in dairy farm business	Strongly disagree – Strongly agree 1-5	Y21 Y22 Y23 Y24	Likert scale, whereas score 1= strongly disagree and score 5= strongly agree

Table 3. Latent variables and endogenous variables

Latent Variables	Manifest Variables (Indicator)	Source
Exogenous latent Individual Characteristic (IB)	1. Experience (X11) 2. Farm business motivation (X12) 3. Perspective toward business (X13)	Zainura et al. (2016) Puspitasari (2013)
Exogenous latent Business Climate (KI)	1. Input materials availability (X21) 2. Infrastructures availability (X22) 3. Extension (X23) 4. Capital (X24) 5. Access to market information (X25) 6. Government support (X26) 7. Cohesiveness among farmers (X27) 8. Animal health center (X28)	Dirlanudin (2010)
Endogenous Latent Dairy Cattle Farmers Entrepreneurial Behavior (PKP)	1. Innovative (Y11) 2. Risk taking (Y12) 3. Independent (Y13) 4. Opportunity seeing (Y14) 5. Earnest pursuit (Y15)	Meredith et al. (1982), Delmar (1996), Manev et al. (2005)
Endogenous Latent Perspective of Dairy Cattle Business Performance (PKUP)	1. Income rate (Y21) 2. Marketing area expansion (Y22) 3. Ability to compete (Y23) 4. Dairy farm commitment (Y24)	Keeh et al. (2007), Sumantri (2013), Manev et al. (2005)

RESULTS AND DISCUSSION

Socio demographic characteristics. Characteristics of respondents can be seen in Table 4. The average formal education attainment of dairy farmers is 8.46 years, implying most of them have completed their elementary school. The average family member of the respondent farmer is 3.89 persons, indicating that the farmer family is relatively a small family. The number of family responsibilities leads to harder effort of farmers to run their business well. With the existence of family responsibilities in the form of many dairy cattle impacts on the family members to help their parents or spouses running the dairy cattle business. Dairy farming experience is an average of 16.48 years. Experiences obtained by farmers come from learning process provided by family and environment. Typically, this dairy cattle business has been done by their predecessor. Long experience teaches farmers trying to do better in maintaining their dairy farming. The average ownership of dairy cattle per farmer is 5 dairy cows, indicating that they are categorized as small-scale dairy farmers.

Table 4. Characteristics of respondents

No.	Items	Average
1.	N	149
2.	Age of household head (years)	41
3.	Formal education attainment (years)	8.46
4.	Dairy farming experience (years)	16.48
5.	Number of family members (persons)	3.89
6.	Average cattle owning (heads)	5

Influence of farmer entrepreneurial behavior on dairy cattle business performance in West Bandung Regency. The influence of farmer entrepreneurial behavior on dairy cattle business performance in West Bandung Regency was analyzed using Structural Equation Modeling (SEM). This SEM model analysis is a combination of a measurement model and a structural model in which latent variables are explained by manifest variables. The measurement model explains the relationship between manifest variables and latent variables while the structural model explains the relationship between one of the latent variables with another latent variable. SEM analysis uses predetermined theory, and then the predetermined theory that has been set in research is presented in path diagram form for easier explanation. In the measurement model, it can be seen how manifest variables are closely related to the latent variables with loading factor in the path diagram. The closeness of the relationship between latent variables can be seen from the gamma coefficient (γ).

Goodness of fit. Goodness of fit is used to see model suitability in general is good or not. Thus if there is a matching value that does not fulfill then it is advisable to do model respecification. Goodness of fit on model respecification can be seen in Table 5. Based on the data in Table 5, there is still goodness of fit assessment that has not been fulfilled, namely Chi-Square (χ2). The value of Chi-Square (χ^2) is still high while the value of goodness of fit has been fulfilled. This is not to say that the respecified model is rejected because the value of Chi-Square (χ^2) is not the main basis in goodness of fit assessment (Schermelleh-Engel and Moosbrugger 2003).

Table 5. Goodness of fit SEM model respecification

No.	GOF (*Goodness of fit*)	*Good Fit*	Result	Explanation
1.	*Absolute fit measures*			
	a. *Chi-Square* (χ^2)	Small value	181.24	*Poor fit*
	b. p-value	$p \geq 0.05$	0.00001	
	c. *Non-centrality Parameter* (NCP)	Small value	76.24	
	Interval		(42.79, 117.56)	
	d. *Goodness of Fit Index* (GFI)	≥ 0.90	0.96	*Good fit*
	e. *Root Mean Square Residual* (RMR)	≤ 0.10	0.086	*Good fit*
	f. *Root Mean Square Error of Approximation* (RMSEA)	0.05 < RMSEA ≤ 0.08	0.07	*Good fit*
	g. *Expected Cross Validation Index* (ECVI)	Small value from value of saturated ECVI	-1.35	*Good fit*
2.	*Incremental fit measures*			
	a. *Adjusted Goodness of Fit Index* (AGFI)	≥0.90, 0.80≤AGFI< 0.90 is *marginal fit*	0.91	*Good fit*
	b. *Non Normed Fit Index* (NNFI)	≥0.90, 0.80≤NNFI< 0.90 is *marginal fit*	1.08	*Good fit*
	c. *Normed Fit Index* (NFI)	≥0.90, 0.80≤NFI< 0.90 is *marginal fit*	1.00	*Good fit*
	d. *Relative Fit Index* (RFI)	≥0.90, 0.80≤RFI< 0.90 is *marginal fit*	1.00	*Good fit*
	e. *Incremental Fit Index* (IFI)	≥0.90, 0.80≤IFI< 0.90 is *marginal fit*	1.04	*Good fit*
	f. *Comparative Fit Index* (CFI)	≥0.90, 0.80≤CFI< 0.90 is *marginal fit*	1.00	*Good fit*

Measurement model. Model respecification made from the suggestion contained in the modification index. Suggestions on the index modification include adding path between latent variables and manifest variables and adding error covariances between two error variances (Wijanto 2008). Path diagram after doing model respecification can be seen in Figure 2 and Figure 3.

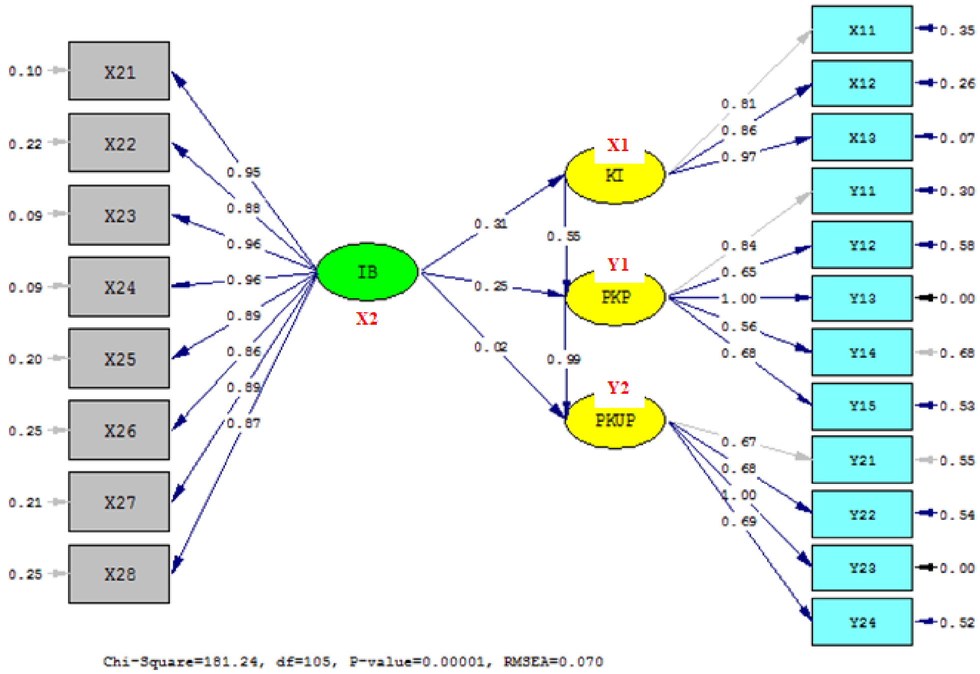


Fig. 2 Path diagram respecification based on standardized solution model of influence of farmer entrepreneurial behavior on dairy cattle business performance in West Bandung regency.

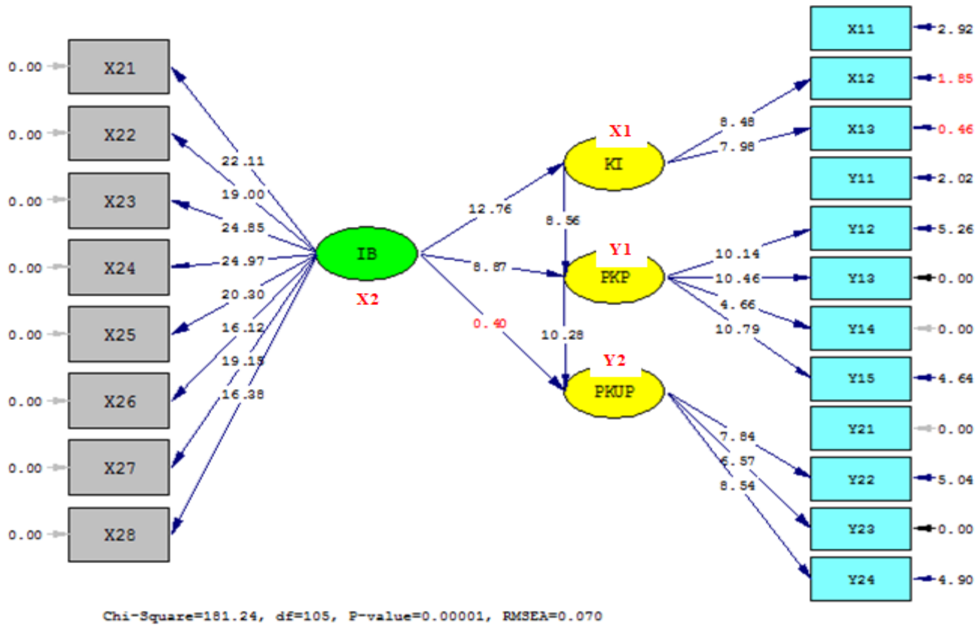


Fig. 3. Path diagram respecification based on T value model of influence of farmer entrepreneurial behavior on dairy cattle business performance in West Bandung regency.

From the result of model respesification, the standardized loading factor value and t value were obtained in Table 6. Model of suitability criteria measurement was measured based on the validity of indicator variable to latent variable. An indicator variable is said to be valid when it has standardized loading factor value greater than the tolerable factor loading limit of 0.30 (Igbaria et al. 1997) and has a t-value above 1.96 (Wijanto 2008). Based on the results of the standardized loading factor diagram and t-values diagram, it can be seen that all variables meet the validity requirement as indicated by standardized loading factor value more than 0.3 and the value of t-value above 1.96 (significant).

Table 6. Standardized loading factors and t values after model respesification

No.	Latent variable	Indicator variable	***Standardized loading factors*** **(≥0.30)**	t-value	Explanation
1.	Individual Characteristics (IB)	X11	0.81		Valid
		X12	0.86	9.48	Valid
		X13	0.97	7.98	Valid
2.	Business Climate (KI)	X21	0.95	22.11	Valid
		X22	0.88	19.00	Valid
		X23	0.96	24.85	Valid
		X24	0.96	24.97	Valid
		X25	0.89	20.30	Valid
		X26	0.86	16.12	Valid
		X27	0.89	19.15	Valid
		X28	0.87	16.38	Valid
3.	Dairy Cattle Farmers Entrepreneurial Behavior (PKP)	Y11	0.84		Valid
		Y12	0.65	10.14	Valid
		Y13	1.00	10.46	Valid
		Y14	0.56	4.66	Valid
		Y15	0.68	10.79	Valid
4.	Perspective of Dairy Cattle Business Performance (PKUP)	Y21	0.67		Valid
		Y22	0.68	7.84	Valid
		Y23	1.00	6.57	Valid
		Y24	0.69	8.54	Valid

Structural model. In the structural model, it can be seen the influence between latent variables. The latent variables viewed its influence can be seen in Table 7. The structural model evaluation includes t-value, and coefficient of each parameter (Wijanto 2008). The value of t-value in each latent variable must be > 1.96 indicating a significant relationship between the latent variables. Business climate had a direct positive effect with coefficient value of 0.31 and significant with t statistic of 12.76 > 1.96 on individual dairy farmer characteristics consisting of experience (X11), farm business motivation (X12), and perspective toward business (X13). Thus if the business climate has strong value through the reflection by the availability of input materials, the availability of infrastructure, extension, capital, access to market information, government policies, cohesiveness among farmers and animal health centers, the stronger are the individual dairy farmer characteristics in developing the dairy farm business. This is in line with Zainura et al. (2016) that the business climate has a positive effect on individual characteristics because one of the business climate factors can provide additional knowledge for the farmer. Human resources for business actors can be renewed to improve business quality is very important.

Table 7. Structural model among latent variables

No.	Relationship between latent variables	Value t > 1.96	Coefficient	Explanation
1.	IB →KI	12.76	0.31	Significant
2.	IB →PKP	8.87	0.25	Significant
3.	IB →PKUP	0.40	0.02	Not significant
4.	KI →PKP	8.56	0.55	Significant
5.	PKP →PKUP	10.28	0.99	Significant

Source: Results of data processing with LISREL 8.8, 2018

Business climate had a direct positive effect with coefficient value of 0.25 and significant with t statistic of 8.87 > 1.96 to farmer entrepreneurial behavior. Business climate has a strong value reflected in the availability of input materials, availability of infrastructure, extension, capital, access to market information, government policies, cohesiveness among farmers, and animal health centers. This is reinforced by a statement stating that the business environment influences entrepreneurial behavior because the business environment exerts an influence to an individual rapidly and precisely in making decisions in his or her business (Ehrich and Billett 2004; Lans et al. 2004). The indicator variables reflecting the most dominant latent variables of business climate are extension and capital. Extension is needed by the farmers to enrich farmers' human resources starting from good welfare, extension can be done by KPSBU (*Koperasi Peternak Sapi Bandung Utara*) or Dairy Farmer Co-operative of North Bandung and IPS (*Industri Pengolah Susu*) / Milk Processing Industry in partnership with KPSBU. Capital is really needed in the dairy farm business for farm maintenance, particularly on animal feed. This is in line with Zainura et al. (2016)'s finding that the extension and training support gained can improve innovation for businesses, respond to opportunities for their businesses, and become independent entrepreneurs.

Individual characteristics had a direct positive effect with the value of 0.55 and significant with t statistic of 8.56 > 1.96 on farmers' entrepreneurial behavior. Strong values in the entrepreneurial behavior of farmers are a reflection of good individual characteristics value consisting of experience, motivation of dairy farm business, and perception of their business. Indicator in latent variable of individual characteristic is influencing the effect of entrepreneurial behavior, one of them is the motivation of the farmers to do innovation in their business. Boyd and Vosikis. 1994 (1994) suggested that the ability in good person can have strong positive impact on intention in entrepreneurial and in entrepreneurial action for satisfactory outcomes. Indicator variables reflecting the most dominant variable of individual characteristics is business perception because the farmer has his own business view of his dairy farm business. Hence, it can be said that individual characteristics are very important in cultivating entrepreneurial behavior as evidenced by its high value of 0.55. This is in line with Puspitasari (2013) that entrepreneurial behavior can be grown by individual factors such as business motivation, perception of business, and business desires.

Farmers entrepreneurial behavior had a direct positive effect on the business performance perspective of farmers while business climate had a positive effect with the coefficient of 0.02 but was not significant because t statistic of 0.40 < 1.96 to the perspective of farmers' business performance. Consequently, it can be explained that by applying innovative behavior, dare to take risks, independent, responsive to opportunities, and diligently trying to improve business performance. The results of this research are consistent with the statement of Lumpkin and Dess (1996) that an effort will be successful if the business actor has a good orientation of entrepreneurial behavior. It is supported that one of farmer entrepreneurial behavior reflection is farmer's innovativeness significantly related to agricultural business performance (Gellynck et al. 2014). Entrepreneurial behavior has a positive correlation to the perspective of business performance, the entrepreneurial behaviors consist of innovative, not afraid to take risk, and competitive (Frese et al. 2002).

CONCLUSIONS

This study showed that entrepreneurial behavior significantly affected the business performance. Meanwhile, entrepreneurial behavior was significantly affected by business climate and individual characteristics. Among the reflection indicators, perspective of business performance, entrepreneurial behavior, business climate and individual characteristics can be significantly reflected from the highest influence of the ability to compete; independent; extension and capital; and perspective towards business, respectively. In terms of individual characteristics, even though most farmers inherited their dairy farms from their parents, it is important to run their dairy farms in the perspective of business whereas running dairy farms not as business as usual, but try to gain profit. At the same time, business climate of extension and access to capital will provide environment for dairy farmers to run their dairy farms in the motive of business. Having the perspective of business and business climate of extension and access to capital will make the farmers being independent whereas they can try to find opportunities in terms of information, technology and market as one of the entrepreneurial behaviors. Accordingly, dairy farmers having entrepreneurial behavior will have the ability to compete which is the reflection of business performance.

The pro government's policies toward dairy farmers that can be done by improving the business climate or environment in which can improve the entrepreneurial behaviors of dairy farmers. As mentioned earlier, extension and access to capital had the highest coefficient as the reflection of business climate, thus, government can provide professional dairy extension officers as well as specific scheme for capital or financial access at the centers of dairy farming areas since there is still no specific extension or capital access for dairy farmers. Dairy farmers will be able to consult to the extension officers if they face problems or if they want to apply new technology or method in their dairy farming. Meanwhile, if they want to try new method or technology or new things in their dairy farming that can increase their dairy farming productivity or selling, they can have access to finance their new way of dairy farming. This improvement in business climate will be leading to increasing entrepreneurial behavior and finally will increase business performance.

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IMPACTS OF THE COMMUNITY EDUCATION ON FARMERS' KNOWLEDGE AND BEHAVIOR IN PESTICIDE USE TOWARD PESTICIDE RISK REDUCTION IN VIETNAM: A CASE STUDY IN VEGETABLE PRODUCTION

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ABSTRACT

Farmers' knowledge and their behavior in pesticide use toward pesticide risk reduction (PRR) becomes a key issue in adopting IPM approach. Pesticide risks can possibly be reduced through community farmer education with a fortified IPM training focused on improving pesticide use. A community education program on PRR in safe vegetable production was first implemented in Hanoi city and Thai Binh province of the country in 2008. Two data sets were collected in 2008 and 2010 from 95 local officials, 170 pesticide users and 15 pesticide sellers before and after PRR implementation in 2 experimented and 2 control communes of Hanoi city and Thai Binh province. Findings show that the program has: i) improved knowledge of local officials, pesticide sellers and applicators in PRR; ii) strengthened community actions as well as individual farmers' behavior in PRR; iii) enabled local people to reduce pesticide risks in terms of hazards and exposure, as a result, the environmental impact quotients were reduced sharply from 20% to 78%; and iv) an extraordinary impact in supporting national pest management policy reform. The paper also draws some recommendations for improving PRR training and some legal policy issues for a sustainable vegetable farming.

Keywords: impacts, training, integrated pest management, hazards and exposure, double delta approach

INTRODUCTION

Vietnam started the integrated pest management (IPM) program in crop production in 1992 in order to help farmers acquire knowledge to become rationale decision makers on their own fields. The goal of the program was to empower small-scale farmers to become skillful and better-informed decision makers in managing the rice production system. The IPM program has been extended from rice to vegetable production since 1996 and a few years later to fruit cultivation (FAO, 2008). In order to meet Vietnam's growing demand for safe vegetables, there is an increasing need to adopt IPM to eliminate use of hazardous and persistent agro-chemicals through IPM farmer training in conjunction with better access to alternative pest management options and support for national pest and pesticide management policy reform. After two decades of IPM implementation, pesticide risk reduction (PRR) becomes one of key issues in adopting IPM approach. Pesticide risks can possibly be reduced through community farmer education with a fortified IPM training focused on improving farmers' knowledge and their behaviors in pesticide use toward pesticide risk reduction (McCauley et al. 2002; Gerd, 2007). Studies on the relevance, effectiveness and impacts of training are limited (Sabur and Molla 2001; Damalas and Koutroubas, 2017). Training of smallholder farmers on IPM and good agricultural practices in farmers' field schools (FFS) in better-off countries had positive effects (Wu and Hou 2012; Clausen et al. 2017), but is scarce in most low-income countries (Jørs et al. 2014; Gautam et al.

2017). Some bottlenecks are market dynamics, availability of personal protective equipment, and the lack of alternative means of pest control on the markets that hindered transformation of knowledge into practice (Vaidya et al. 2017).

Vietnam's Plant Protection Department (PPD) has been implementing fortified PRR training through a Community-based Training Program on PRR in Safe Vegetable Production with Vietnam's Good Agricultural Practices Orientation to reduce pesticide risks since 2008 (Vietnam National IPM Program, 2008). The program seeks to involve a full participation of all stakeholders of the community including IPM farmers, local leaders, mass organizations and public health center in pesticide risk reduction by following activities: 1) Conducting PRR training for pesticide applicators, local officials and pesticide sellers; 2) Formation of farmers' interest groups for pesticide risk reduction. The farmer groups were facilitated to form its own action plan, field studies for PRR and its members were trained in PRR-Vietnam's good agricultural practices (VietGAP); 3) Development and enforcement of local regulations on pesticide trade, use and management; 4) Consultation for development of safe vegetable production zone including improving infrastructure (tanks for keeping pesticide containers); 5) PRR information dissemination by mass media, local village meetings. The PRR training programs were first implemented in Hanoi city and Thai Binh province. After two years of PRR program implementation, there arose some questions on PRR training program: 1) Could the PRR education program help the vegetable production community with better knowledge and behaviors in pesticide use toward pesticide risk reduction. To answer this question, this research was carried out to identify impacts of this training program on: 1) local people's knowledge on PRR; 2) people's behaviors and decision making on PRR; 3) pesticide use and pesticide risk reduction 4) draw recommendations for adopting PRR approach to eliminate use of hazardous and persistent agro-chemicals with better access of alternative pest management options

METHODOLOGY

Study design. A "Double Delta Approach" (DDA) was employed to examine the impacts of PRR training. The use of DDA are to estimate differences between success indicators (e.g. changes in knowledge of and behaviors in pesticide risk management) before and after the PRR training for both PRR participants and non PRR-participants (control group) and then comparing the difference between the two groups. Hence, the effect of factors affecting the success indicators of both groups, other than PRR training, is "differenced out". With this design, two typical communes, namely Dang Xa and Le Chi (Hanoi city), Thai Giang and Thuy Son (Thai Binh province) were selected for an in-depth study for baseline and post PRR training surveys. Farmers in Hanoi's communes planted cabbages while those in Thai Binh produced melon. These vegetables are potential for consumer risks. These paired communes are similar and representative for the province in terms of pesticide risks, agro-ecological conditions, and vegetable production and IPM FFS activities. Farmers in these selected communes had a commitment that they continued grow the same vegetable at least three years (2008-2010). After the base-line survey, one of these two communes received a PRR training (called PRR commune) in 2008, the other did not get PRR training until 2010 (called control commune). Differences between PRR and control commune in terms of knowledge, decision making behaviors of farmers, pesticide dealers and local community officials and community actions, situation of hazards and exposures before and after PRR training are considered as impacts of the PRR training on farm and community levels (Table 1).

Table 1. Communes under study by provinces and study crops

Province	PRR commune	Control commune	Study Crops
Hanoi city	Dang Xa (Gia Lam district)	Le Chi (Gia Lam district)	Winter Cabbage (Nov to Jan)
Thai Binh	Thai Giang	Thuy Son	Spring Melon

province	(Thai Thuy district)	(Thai Thuy district)	(Apr to mid Jun)

Data collection. Secondary information including legislative documents on banned, restricted and permitted pesticides for vegetables and Vietnam's good agricultural practices (VietGAP), permitted pesticide list in Vietnam, pesticide lists for vegetable production were collected from Ministry of Agriculture and Rural Development (MARD, 2009), PPD and Provincial PPD, district plant protection departments and other relevant offices.

The PRR impact assessment comprises of a baseline data collection before the PRR activities and a post-survey data collection period one year later, during the same crop calendar as the baseline survey. The baseline survey was carried out in 2008 on three types of respondents, namely, community officials, pesticide applicators with the sample sizes of 95, 70 and 15 respondents, respectively. In 2009, the PRR program was implemented Dang Xa (Hanoi) and Thai Giang (Thai Binh) communes. PRR farmers in Dang Xa and Thai Giang communes continued cultivating their crops in 2010. Cropping seasons in 2008 and 2010 were similar in terms of climate, pest and disease conditions. Thus, the post-PRR training survey for impact assessment was conducted in 2010 in Hanoi city and Thai Binh province using repeated sampling (Table 2).

Table 2. Sample size by type of communes and type of respondents for the base-line and post PRR training surveys

	All			**Hanoi city**			**Thai Binh province**		
Type of Respondent	**PRR commune**	**Control commune**	**Sub total**	**PRR commune**	**Control commune**	**Sub total**	**PRR commune**	**Control Commune**	**Sub total**
Community officials	47	48	95	25	20	45	22	28	50
Pesticide Applicators	89	81	170	33	33	66	56	48	104
Pesticide sellers	8	7	15	5	4	9	3	3	6

Information on pesticides given by farmers were clarified in terms of World Health Organization's classification. Information on pesticide exposures were gathered by direct observation and interviews.

Methods of analysis. *Descriptive statistical methods* such as means, standard deviation, frequencies and cross tabulation were employed to describe changes in knowledge and behaviors of the respondents in the PRR and control communes before and after the PRR training program. Comparisons using DDA between two pairs of data sets before and after PRR training were analyzed. DDA= Δ_E-Δ_C *(Where Δ_E = Success indicator in 2010 (after PRR-Training) – Success indicator in 2008 (Before PRR Training) in a PRR commune) and Δ_C = Success indicator in 2010 (after PRR training) – Success indicator in 2008 (Before PRR training) in a control commune). Pesticide risk reduction* was measured in terms of reduction in hazards and exposure, i.e. the reduction in the number of pesticide types used in the whole community, number of sprays per farm and pesticide dose used per hectare; and percentages of applicators who used protective equipment, safe sprayer, and pesticide good container management and pre-harvest interval, respectively.

RESULTS AND DISCUSSIONS

Impacts on people's knowledge on pesticide risk reduction

Impacts on community officials' knowledge on pesticide risk reduction. If a person who is aware of four policy issues, namely, safe vegetable regulation, pesticide list for vegetables, regulation on pesticide trading and use, good agricultural practices for vegetable production (VietGAP) is considered to be those who completely know key government policies on pesticide risk management. PRR training has increased awareness of community officials on pesticide risk management policies about 10% in Hanoi and 20% in Thai Binh (Table 3). PRR training enabled local community officials to be aware of VietGAP and safe vegetable standards. The impacts in Thai Binh were found to be better than those in Hanoi (Table 3). The differences in terms of training curriculum and implementation of PRR program in two studied communes lead to a significant change in training impacts.

Table 3. Impacts on community officials' knowledge on pesticide risk management and regulation.

Impact indicator	PRR Commune 2010	PRR Commune Δ_E	Control Commune 2010	Control Commune Δ_C	Impact= Δ_E-Δ_C
HANOI CITY					
1. Awareness of government policies on pesticide managements	92.0	+13.2	70.0	+3.3	+9.9
2. Knowing 3 policies	40.0	+40.0	0	0	+40.0
3. Remembering VietGAP contents	60.9	+60.9	21.4	+21.4	+39.5
4. Remembering safe vegetable standards *	77.1	+10.5	60.0	-1.9	+13.5
THAI BINH PROVINCE					
1. Awareness of government policies on pesticide managements	90.9	+24.2	67.9	+4.9	+20.0
2. Knowing 3 policies	59.1	+53.5	0	0	+53.5
3. Remembering VietGAP contents	90.0	+90.0	0	0	+90.0
4. Remembering safe vegetable standards *	77.3	+44.4	35.7	+2.4	+42.0

*Percentages of respondents reporting a particular knowledge they perceived in total interviewed respondents

Impacts on sellers' knowledge on pesticide risk reduction. Sellers were asked to express their views on whether their shops meet required standards, reasons for note meeting requirements and their awareness of local regulation on PRR in both pre- and post-PRR training (Table 4).

Table 4. Impacts on pesticide sellers' knowledge on pesticide risk management and regulation.

Impact indicator	PRR Commune 2010	PRR Commune Δ_E	Control Commune 2010	Control Commune Δ_C	Impact= Δ_E-Δ_C
1. Wrong perception of good pesticide shop requirements	50.0	-12.5	66.7	+11.1	-23.6
2. Awareness of local regulation on PRR*	50.0	+50.0	0	0	+50.0

* Percentages of sellers reporting a particular issue they perceived in total sellers;

After PRR training, sellers had a better understanding of requirements for running a pesticide shop. There were less sellers in PRR communes who wrongly perceived of good pesticide shop requirements than those in control communes. It implies that sellers had better knowledge on shop requirements. PRR training enabled 50% of sellers to be aware of local regulation on PRR such as only trading permitted pesticides, opening the shop with a registered license and general requirements for selling pesticides.

Impact on applicators' knowledge on pesticide risk reduction. After training, numbers of farmers who were aware of three important policy regulations, namely safe vegetable standards, basic contents of Vietnam agricultural practices for vegetables and fruits (VietGAP) and internal commune regulations in the PRR communes increased significantly (Tables 5). The program had equipped farmers with a better knowledge in understanding right pre-harvest interval, a pesticide container, pesticide label, bio and chemical pesticides, permitted pesticide list and basic principle for pesticide use, timing for spraying. As a result, numbers of applicators in the PRR commune who were aware of these issues increased significantly (Table 5).

Table 5. Impacts on applicators' knowledge on pesticide risk management

Impact indicator	**Dang Xa (PRR)** 2010	Δ_E	**Le Chi (control)** 2010	Δ_C	**Impact =** Δ_E-Δ_C
HANOI CITY					
1. Awareness of safe vegetable standards	90.9	+32.7	69.7	+11.4	+21.3
2. Awareness of VietGAP	69.7	+69.7	3.0	+3.0	+66.7
3. Awareness of commune regulations	87.5	+87.5	6.1	+6.1	+81.4
4. Knowing a pre-harvest interval	90.9	+34.2	69.7	+9.7	+24.5
5. Perception of pesticide containers	78.8	+72.8	21.2	+1.2	+71.6
6. Knowing information in a pesticide label	60.6	+39.0	27.2	+12.1	+26.9
7. Knowing bio-pesticides	93.8	+47.0	82.6	+35.3	+12.0
8. Knowing a permitted pesticide list	51.5	+48.5	3.0	0	+48.5
9. Correct awareness of 4-right principle for pesticide use*	51.5	+45.5	6.1	+1.1	+44.4
10. Knowing best time for spraying	97.0	+47.7	51.5	+1.5	+46.2
THAI BINH PROVNCE					
1. Awareness of safe vegetable standards	100	+61.2	33.3	-3.5	+64.7
2. Awareness of VietGAP	98.2	+98.2	0	0	+98.2
3. Awareness of commune regulations	100	+100	2.1	+2.1	+97.9
4. Knowing a pre-harvest interval	91.1	+82.1	37.5	+28.7	+54.0
5. Perception of pesticide containers	85.7	+76.7	2.1	0	+76.7
6. Knowing information from in pesticide label	46.4	+23.0	8.4	-12.5	+35.5
7. Knowing bio-pesticides	100.0	+80.8	15.8	-2.4	+83.2
8. Knowing a permitted pesticide list	80.4	+77.4	0	-1.8	+77.4
9. Correct awareness of 4-right principle for pesticide use*	50.0	+48.2	0	-1.8	+50.0
10. Knowing best time for spraying	82.1	+44.8	37.5	-1.1	+45.9

Percentages of respondents reporting a particular knowledge they perceived or responded in total respondents
* 4-right principle: right vegetable, right amount and ingredient, right time and right spaying method

Impacts on people's behaviors on pesticide risk reduction

Impacts on local community actions toward pesticide risk reduction. The program enabled the local community to realise their responsibility and take collective actions towards PRR (formation of farmer interest groups for vegetable production, construction of pesticide container tanks, formation and enactment of internal PRR regulations, organization of PRR training, dissemination of PRR information, control and inspection of pesticide shops, gathering pesticide containers, constructing poster, booklets, self-control and PRR information sharing (Table 6). The program has built a self-reliance of local organization toward pesticide risk reduction.

Table 6. Local community actions toward pesticide risk reduction.

Impact indicator	Dang Xa (PRR)		Le Chi (control)		Impact= Δ_E-Δ_C
	2010	Δ_E	2010	Δ_C	
HANOI					
1. Do nothing, assign to cooperative to do PRR	4.0	-22.0	50.0	+27.8	-49.8
2. Formation of PRR farmer group	64.0	+64.0	0	0	+64.0
Number of PRR farmer groups formed (group)	5	+5	0	0	+5
3. Construction of pesticide container tanks	12.0	+12.0	0	0	+12.0
Pesticide container tanks built (tank)	7	+7	0	0	+7.0
4. Formation of local PRR regulation	28.0	+28.0	0	0	+28.0
5. Organizing PRR training	84.0	+84.0	0	0	+84.0
6. Information dissemination	72.0	+24.2	38.9	+2.0	+22.2
7. Control pesticide shops	56.0	+56.0	0	0	+56.0
Number of unqualified pesticide shop closed	1	+1	0	0	+1
8. Garthering pesticide containers	0	0	0	0	0
9. Development of foster, booklets, VCD	12.0	+12.0	0	0	+12.0
10. Self control and PRR information sharing	12.0	+12.0	0	0	+12.0
11. Pest surveillance and warning	28.0	19.3	16.7	0	+16.7
THAI BINH					
1. Do nothing, assign to cooperative to do PRR	13.6	-13.6	71.4	+55.8	-69.4
2. Formation of PRR farmer group	69.6	+69.6	0	0	+69.6
Number of PRR farmer groups formed (group)	6	+6	0	0	+6
3. Construction of pesticide container tanks	27.3	+27.3	0	0	+27.3
Number of container tanks built (tank)	4	+4	0	0	+4
4. Formation of local PRR regulation	50.0	+50.0	0	0	+50.0
5. Ogranzing PRR training	95.5	+95.5	0	0	+95.5
6. Information dissemination	86.4	+54.6	35.0	+3.2	+50.8
7. Control pesticide shops	72.7	+72.7	0	0	+72.7
Number of unqualified pesticide shop closed	2	+2	0	0	+2
8. Garthering pesticide containers	59.1	+59.1	0	0	+59.1
9. Constructing foster, booklets, VCD	45.5	+45.5	0	0	+45.5
10. Self control and PRR information sharing	31.8	+31.8	0	0	+31.8
11. Pest surveillance and warning	22.7	+13.6	28.6	+28.6	0

* Percentages of respondents reporting a particular community action in total respondents with an exception of numbers of farmer groups formed, tanks built and the closed shops.

Impacts on sellers' behaviors toward pesticide risk reduction. The PRR program enabled the shop keepers to change their practices toward risk reduction such as arranging shop with safe environment, fire controller, used right pesticide store methods (Table 7). Sellers recognized their responsibility in selling pesticides (untrained person selling reduced), used more protective clothing, stopped selling instant foods and drinks together with pesticides and sold more bio-pesticides (Table 7).

Table 7. Impacts on pesticide sellers' behaviors on pesticide risk reduction

Impact indicator	PRR Commune		Control Commune		Impact= Δ_E-Δ_C
	2010	Δ_E	2010	Δ_C	
1. Shop was cool with good airflow	100	+50.0	66.7	+33.3	+16.7
2. Shop was equipped with fire controller	50.0	+50.0	0	0	+50.0
3. Right pesticides store method	100.0	+87.5	11.1	0	+87.5
4. Untrained person selling pesticides	25.0	-25.0	66.7	0	-25.0
5. No use protective equipment (cloths, masks..)	0	-62.5	77.8	-22.2	-48.3
6. Selling other goods	100.0	+12.5	100.0	0	+12.5
Selling instant foods and drink	25.0	-46.4	66.7	0	-46.4
7. Average number of pesticide type/shop (type)	27.0	+2.0	43.4	+14.8	-12.8
8. Bio pesticide type share in total types (%)	19.4	+13.4	6.1	-1.0	+14.4

* Percentages of respondents having a particular behavior in total pesticide sellers with an exception averaged number of pesticides per shop and item No.7

Impacts on applicators' behaviors toward pesticide risk reduction. The training promoted farmer interest group formation, almost all farmers in the PRR communes had joined farmer groups (Table 8). After training, farmers had better confidence in selecting pesticides (based on their owned experiences) than the situation before PRR program enactment. The program enabled farmers used only pesticides in the permitted lists. As a result, it reduced number of pesticide types used in the field. The training increased numbers of farmers who often read the instruction label before pesticide use, placed their sprayers at safe places, rinsing mouth after spraying, while it reduced numbers of applicators who mixed wrongly pesticide cocktails (Table 8).

Table 8 Impacts on applicators' behaviors on pesticide risk reduction

Impact indicator	Dang Xa (PRR) 2010	Δ_E	Le Chi (control) 2010	Δ_C	Impact= Δ_E-Δ_C
HANOI CITY					
1. Joining farmer interest group	90.9	+90.9	0	0	+90.9
2. Information sources for selecting pesticides					
Applicators' experiences of pesticide use	51.5	+9.7	45.5	-2.8	+12.5
Seller's instruction	24.2	-27.3	54.5	+14.5	-41.8
3. Number of pesticide types used	11	-7.0	24	+6.0	-13.0
4. Reading the label before use	97.0	+42.0	57.6	+2.0	+40.0
5. Number of applicators mixed wrongly*	0	-42.5	31.8	-10.3	-32.2
6. Cleaning sprayers wherever convenient	90.9	-3.5	93.9	+10.5	-14.0
7. Keeping sprayers, pesticides at safe places	87.9	+46.0	21.2	-21.2	+67.2
8. Rinsing mouth after spraying	84.8	+72.8	21.2	+10.2	60.6
THAI BINH PROVINCE					
1. Joining farmer interest group	100.0	+100.0	0	0	+100.0
2. Information sources for selecting pesticides					
Applicators' experiences of pesticide use	30.4	+3.5	12.5	+1.5	+2.0
Seller's instructions	57.1	-0.4	70.8	+7.6	-8.0
3. Number of pesticide types used	12	-8	18	-1	-7
4. Reading the label before use	85.7	+40.9	43.8	0	+40.9
5. Number of applicators mixed wrongly*	10.8	-45.5	2.3	-55.5	+10.0
6. Keeping sprayers, pesticides at safe places	78.6	+18.3	68.6	+7.2	+11.1
7. Rinsing mouth after spraying	78.6	+60.6	18.8	+2.8	+57.8

* Percentages of respondents having a particular behavior in total respondents with an exception of the criteria No.3 and those marked with star symbols

Impacts on reduction hazards and exposure

Reduction of hazards. Risks to applicators may depend on types of pesticide use. By World Health Organization's (WHO) toxicity class, pesticides are categorized into four groups. By environmental effects, they are grouped into types including chemical and bio-pesticides. If applicators use more WHO's class III pesticides and bio-pesticides, it implies that they are wise rational applicators. It was found that after the PRR program implementation, the number of pesticide types used in the whole community, average number of sprays per farm in the crop as well as a dose of pesticide used per hectare of cultivated crop and number of wrong cocktailed applications reduced significantly as compared with those before implementation of the PRR program (Table 9).

Table 9. Changes in pesticide use after PRR program implementation

Impact indicator	**PRR Commune** 2010	Δ_E	**Control Commune** 2010	Δ_C	**Impact=** Δ_E-Δ_C
HANOI CITY					
1. Number of pesticide types used (type)	11	-7.0	24	+6.0	-13.0
Bio-pesticides used (%)	45.5	+39.7	20.8	+15.3	+24.4
Class II pesticides (%)	45.5	-21.2	66.7	-3.3	-17.9
Class III Pesticides (%)	54.5	+20.8	33.3	+3.3	+17.5
2. Average number of sprays per farm (spray)	3.9	-2.8	7.0	-0.7	-2.1
3. Pesticide used per ha (kg)	2.17	-0.38	7.91	+4.55	-4.93
4. Number of wrong cocktailed applications in total pesticide cocktailed applications (%)	0.0	-54.0	58.3	-0.3	-53.7
THAI BINH PROVINCE					
1. Number of pesticide types used (type) (%)	12	-8	16	-1	-7
Bio-pesticides used (%)	16.7	+16.7	11.1	+11.1	+5.6
Class II pesticides (%)	41.6	-30.4	31.2	-44.6	+14.5
Class III pesticides (%)	50.0	+22.2	37.5	-21.5	+43.4
2. Average number of sprays per farm (spray)	3.9*	-6.5	6.5*	-3.9	-2.6
3. Pesticide used per ha (kg)	6.35*	-4.42	4.40*	-0.13	-4.29
4. Number of wrong cocktailed applications in total pesticide cocktailed applications (%)	20.0	-54.0	36.9	-38.1	-15.9

% Percentages of a particular pesticide group in total pesticide types used in the whole community
* Significant at 1% level.

Reduction of exposure. After training, the PRR training enabled more farmers to use protective equipment when spraying, use better sprayers and practice rightly pre-harvest interval (Table 10). Farmers in the PRR communes were observed having better pesticide container management practices. Four to seven tanks were built in Thai Giang and Dang Xa communes, respectively for farmers to dispose pesticide containers during the course of PRR implementation. PRR farmers placed their pesticide containers in the tanks located in the fields. As a result, the fields in the PRR communes during cropping season was cleaner and less pesticide containers found in the field compared with the situation before the PRR implementation, whereas, the situation in the control communes seemed unchanged.

Table 10. Changes in using protective equipment when spraying

Impact indicator	PRR Commune		Control Commune		Impact= Δ_E-Δ_C
	2010	Δ_E	**2010**	Δ_C	
HANOI CITY					
1. Applicators always used protective tools (%)	100	+77.6	48.5	+23.5	+54.1
2. Applicators used defective sprayers (%)	0	-16.0	9.0	-1.0	-15.0
3. Applicators did right pre-harvest interval (%)	100	+46.3	51.5	0	+46.3
THAI BINH PROVINCE					
1. Applicators always used protective tools (%)	85.7	+66.2	35.4	+9.1	+57.2
2. Applicators used defective sprayers (%)	0	-30.4	10.4	-10.8	-19.6
3. Applicators did right pre-harvest interval (%)	100	+53.7	87.5	+38.5	+15.2

CONCLUSION AND RECOMMENDATIONS

The PRR program had positive impacts on: 1) improvement of local people's perception of and behaviors toward pesticide risk reduction; 2) strengthening community actions as well as individual farmers' behaviors in pesticide risk reduction; and 3) reduction of pesticide risks in terms of hazards and exposure. These findings are in line with those of several other studies and indicate that the program has built sustainability for safe vegetable production.

Although the impacts of the program are impressive, for the sake of strengthening these impacts, following measures are recommended: 1) Training contents should focus more on risk reduction and address the applicators' control of pesticide safety, i.e. the applicators should not only be told what they must do to reduce their exposure to pesticides, but why and how these behaviors will reduce their exposure. Furthermore, many organizational, social, and cultural barriers that prevent the applicators from working safely must be factored into the training program; 2) Training should be season-long training (12-14 week course) for applicators and maybe 2 days for local officials and sellers; 3) There should be guidelines on formulation and implementation of internal regulation for the local community; 4) more efforts should be devoted to instruct and consult with local authorities as well as mass organization to form and operate farmer interest groups, self-control and self-help farm groups; 5) to ensure long terms effects, development and implementation of a TOT program for PRR; 6) Further sustained programs that support the principles taught in the community education program are required to effectively decrease pesticide risk for farmworkers; 7) A legal framework and technique for treating the collected containers should be issued. Pesticide companies may be responsible to bear the cost for treating these collected containers

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INTENTION TO ADOPT A NEW VARIETY OF PADDY AMONG FARMERS IN TERENGGANU, MALAYSIA

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ABSTRACT

Rice security has been consistently in Malaysia's self-sufficiency program as it is a staple food for vast majority of the population. One of the main reasons of low paddy productivity is due to rice blast disease which is caused by fungus pathogen, *Magnaphorthe oryzae.* Putra 1 is one of the Universiti Putra Malaysia (PadiU Putra) technologies introduced in 2017 and has proven to be the best variety to combat blast diseases and increasing yield of paddy per acre based on trials that has been conducted in Besut, Terengganu. However, a clear perception about this new variety among paddy farmers is anonymous. Therefore, this research aims to explore the latent factors that could influence the adoption intention of Putra 1 by paddy farmers in Besut, Terengganu. Theory of Planned Behaviour (TPB) was used as theoretical framework to analyze the paddy farmer's intention to adopt Putra 1 as their new variety to replace the existing variety. Descriptive analysis and factor analysis were then performed in order to extract the latent factor from factor analysis while the descriptive analysis is used to measure the distribution of the data in term of it central tendency and normality. The interview of paddy farmers in Besut, Terengganu was done from April to May 2017.The results showed that four factors; , attitude, subjective norms, knowledge and perceived behavioural control significantly affect farmers' intention to adopt Putra 1. Thus, encouraging paddy farmers to adopt the new variety can help to control blast diseases, increase production and hence the level of self-sufficiency.

Keywords: Theory of Planned Behaviour, blast disease, factor analysis, Putra 1

INTRODUCTION

Paddy industry is always receiving special attention from the government due to its strategic importance to supply the staple food for Malaysian population. According to the Department of Agriculture (DOA) statistics report, the paddy farming covering more than 700 thousand hectares in 2016 and the total production is about 2.3 million metric tons (DOA 2018). Various efforts have been undertaken by the government to ensure the sustainability of the paddy industry such as the optimal level of input use, development of technology, farm management and input incentives to the farmers as well as price subsidies. Despite of various kind of efforts, the productivity of paddy is still low at 4.2 mt/ha on average though the potential could be as high as 10 mt/ha. The excess usage of chemicals above the recommended rate had make pests and weeds resistant to chemicals. In order to reduce the infestation, the seed varieties that are resistant to pest and diseases need to be developed and used. One of the serious and main diseases assaulting the paddy plant is blast disease that has a major contribution to low productivity of paddy in 85 paddy growing countries including Malaysia.

Rice blast disease caused by *Pyricularia oryzae* is the most critical rice disease in the rice growing regions in the world. The symptoms of rice blast include lesions that can be found on all parts of the plant (Tebeest *et al.*, 2007). In 2016 research and development unit of Universiti Putra Malaysia (UPM) has developed a new variety of paddy known as Putra 1 (ITAFos UPM, 2016). This variety is more tolerant to rice blast disease and able to increase the yield of paddy per ha. Nevertheless this new variety is unknown to most paddy farmers and the adoption process might take sometimes for fully adoption of this variety by paddy farmers. The field trials and awareness campaign has been conducted in Besut, Terengganu for 3 seasons from 2015-2016 and the field trials was successful in terms of controlling rice blast diseases and increasing yield. Thus, Putra 1 paddy variety could be the solution to paddy farmer's problems. Given the awareness about the existing of new paddy variety Putra 1, the knowledge about the advantages of the new variety in term of resistance to rice blast diseases and the performance of Putra 1 in term of its yield, it is inevitable to gauge paddy farmer's intention to adopt Putra 1 as their paddy seed in the future. The objective of this paper is to determine the latent factors that could significantly affect paddy farmer's intention to adopt Putra 1.

The Theory of Reasoned Action (ToRA) postulates that the behaviour of an individual is best anticipated by a person's intentions which are in turn affected by their attitude and perceived social pressure (Ajzen and Fishbein 1980). However, ToRA is unsuccessful in predicting behaviour which is not completely under individual volitional control. ToRA was limited in predicting skills. However the resources or opportunities available are not considered to be within the constructs of the ToRA or are likely to be poorly predicted by the ToRA (Fishbein 1993). The extension construct called perceived behavioural control was added to improve ToRA which is known as Theory of Planned Behaviour (TPB). According to Beedell and Rehman (2000), this new domain is to reflect factors that may influence an endeavor behaviour being carried out. Thus the intention to perform behaviours can be predicted from attitudes, subjective norms, and perceived behavioural control.

In TPB theoretical framework, attitudes is one of the constructs in influencing the individual perception. In this study the attitudes refer to farmers' evaluation either positive or negative towards the performance of Putra 1 variety. In addition, individual tend to commit a behaviour when they have both favorable evaluation and belief and in the same token belief that a significant number of other people will have a similar evaluation. Again this individual's perception of so called social pressure will put him or her either to perform or not perform the behavior as indicated earlier. Social pressure which is basically the subjective norm within the construct of TPB (Ajzen and Fishbein 1980). In the previous study by Uaiene et. al (2009) highlighted the probability of farmers to adopt new technology was via observation of neighboring farmers' behaviour who have adopted the technology (Uaiene et al. 2009). Meanwhile, perceived behavioural control refers to the people or in this case are the farmers' perception on the adoption of the technology whether it is easy or difficult to performing the adoption behaviour. In another words, people's behaviour is influenced by their belief and confidence in their ability to perform the adoption of the technology which is basically the self-efficacy beliefs of the individual's to execute the behavior required to produce the outcome in this case the intention to adopt the new paddy variety.

Literature disclosed that perception on innovation characteristics is significantly contribute to adoption behavior. A study by Jamal and co-workers (2013) indicated that the technology characteristics that could give benefits to farmers' can influence paddy farmers' intention to adopt new paddy variety specifically the fragrant rice variety in Malaysia (Jamal et al. 2013). In addition, the farmers' knowledge also give significant effect to their willingness in adopting new innovation such as in the case of chicken feed formulation (Mohamad et al. 2015). Thus farmers that have knowledge were more prepared to accept innovation compared to those farmers who do not have any knowledge at all.

Chhetri, (2007) in his study showed that farmers in Nepal were willing to change their behavior and be more interested in adopting new technology development as they have knowledge on that particular technology. Adoption of new varieties of seeds and the new farm management systems will occur when the farmers receive information regarding the benefits of new technology such as; the new technology can increase the productivity and consequently can improve the profitability to farmer (Feder et al. 1985).

Based on a study conducted in India, it was found that individual characteristics such as demographic factors (age, education, farm size) will also influence farmer's perception and adoption decision of new innovation such as their attitude toward organic farming (Patidar and Patidar 2015). Another studies conducted by Abdulai and Huffman (2005) on acceptance of new technology among farmers in Tanzania, indicated that education background and knowledge of farmers were important factors in determining the adoption of new technology among farmers. In the same token according to Sall et al. (2000), based on the study conducted in Casamance area of Senegal, it was found that the farm and farmer characteristics as well as their perceptions on technology specific characteristics influence the adoption decision related to improved varieties. Nur Shuhamin and Norsida (2016) in their study on Muda Agricultural Development Authority (MADA) granary area reported that knowledge and experience of farmers in paddy farming give significant effect in adopting new paddy seed variety. Thus given the above discussion the TBP is appropriate to analyze the paddy farmer's intention to adopt Putra 1 paddy variety introduced by UPM. The three constructs of TPB explain well the behavior of the farmers in deciding to adopt the new variety.

MATERIALS AND METHODS

The sampling frame for this study were paddy farmers who had been introduced to the new variety Putra 1 through seminar or training conducted by Universiti Putra Malaysia in collaboration with the Department of Agriculture (DOA), MOA. A structured questionnaire was employed as the instrument for primary data collection. The study was conducted in the integrated agriculture development area of North Terengganu (IADA) KETARA, Besut, Terengganu. IADA KETARA was selected as the study area due to its role as the first granary area where demonstration plots and field trials being conducted for PadiU Putra technologies of UPM, including the new variety Putra 1. In the same token 466 farmers who had undergone field trials in Besut, Terengganu were also selected as a sample size. There were about 70 farmers who had gone through the planting trials. The structured questionnaires were distributed to 110 paddy farmers by using systematic random sampling. Face to face interviews were conducted in April 2017. The descriptive analysis and factor analysis were used to analyse the data.

Instrument: Questionnaire. In order to achieve the objective of the study, nominal scale (open-ended and close-ended questions) and ordinal scale questions were structured to measure the demographic profile and interval scale (7-point Likert scale) in assessing the factors influencing farmers perception and intention to adopt new paddy seed variety Putra 1 based on TBP constructs, respectively. To measure respondents' attitude, subjective norm, perceived behavioral control and knowledge, they were asked to appraise a seven-point attitudinal Likert scale statements with a range of 1 (strongly disagree) to 7 (strongly agree).

The theoretical framework used in this study was based on Theory of Planned Behaviour (TPB) developed by Ajzen (2002), which is regulated by the intention to execute the specific behavior; attitude predicts the intention, perceived behavioral control and subjective norm (Fig. 1). Perceived behavioral control is termed as the people's perception about the difficulty or ease of executing a particular behavior (Ajzen, 2002) (Fig. 1). According to Ajzen (2002), the fundamental aspect of the TPB is behavioral intent that has been proven to be a good replacement for behavior. TPB is better at explaining behaviors rather than ToRA (Theory of Reasoned Action). Another advantage of this model is its specificity and thus TPB is more suited to examining specific adoption behaviors rather than a broad range of intended behaviors.

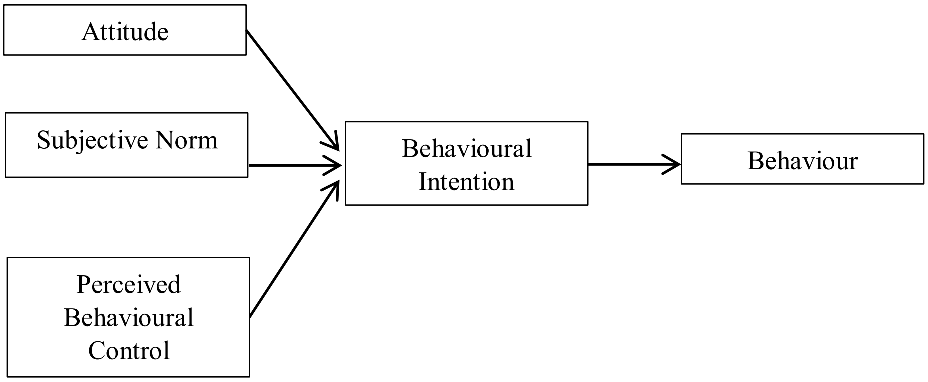

Fig. 1. Theory of Planned Behavior (Ajzen 2002)

Statistical analysis. Descriptive analysis was performed to analyze the socio-eco-demographic background of paddy farmers. Factor analysis was used to determine the latent factors that influence paddy farmers' perception and intention to adopt new paddy seed variety, Putra 1. As shown in Figure 1 there are 3 constructs which make up the TBP and their items within the constructs.

Exploratory Factor Analysis (EFA) was used to determine the underlying factors that influence farmer's intention to adopt Putra 1. Factor analysis will group together the statement items under a common underlying factor. Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of Sphericity were performed on all statements or items to confirm the appropriateness of applying the factor analysis as one of the analysis.

RESULTS AND DISCUSSION

A total of 110 respondents of paddy farmers in Besut, Terengganu took part in the survey. Socio-eco-demographic characteristics are presented in Table I. Majority of the respondents were male (98.2%) and were in the age range of 41 to 50 years old (28.2%). In terms of education level, most of the respondents have gone through secondary education (62.7%) while about 5.5% had gone through the non-formal education. Majority of the respondents are full time farmers (72.7%).

Most of the respondents had experienced in paddy farming for more than 15 years (40.9%) and have total farm size of less than 5 acre (46.4%). The most popular current variety applied by most farmers was MR219 (44.5%). Some paddy farmers used two different varieties in their field and thus the total frequency of current variety used was more than the number of respondents. They have been using several varieties of paddy in their field as an initiative to overcome pest and diseases (n=50, 45.5%). Most of the farmers were willing to adopt Putra 1 (n=107, 97.3%) and recommendation from fellow friends and the motivation from themselves were the other reasons that influence farmers to change the variety of rice used (n=11, 10%) (Table 2). Beside the three main constructs of TPB, the other factors that can influence the farmers' adoption to new variety of seed include is knowledge (Fig. 1).

Table 1: Paddy farmer's socio-demographic characteristics in Besut, Terengganu.

Characteristics	Frequency (n=110)	Percentage (%)
Gender		
Male	108	98.2
Female	2	1.8
Age (years old)		
21-30	13	11.8
31-40	23	20.9
41-50	31	28.2
51-60	16	14.5
More than 60	27	24.5
Educational level		
Non-formal	6	5.5
Primary	30	27.3
Secondary	69	62.7
Tertiary	5	4.5
Types of farmer		
Full time	80	72.7
Part time	30	27.3

Table 2: Paddy farmers' firmographic background in Besut, Terengganu

Variable	Frequency (n=110)	Percentage (%)
Farm size		
Less than 5 acre	51	46.4
5-10 acre	41	37.3
11-15 acre	10	9.1
More than 15 acre	8	7.3
Paddy farming experience		
1-5 years	18	16.4
6-10 years	29	26.4
11-15 years	18	16.4
More than 15 years	45	40.9
Current variety		
MR219	57	44.5
MR220	3	2.3
MR220CL2	17	13.3
MR263	7	5.5
MR69	16	12.5
MR284	28	21.9
Main reason for changing variety		
Low price	10	9.1
Readily available	2	1.8
More resistance to pest and disease	50	45.5
High yield	37	33.6
Others	11	10.0
In your perception, could Putra 1 variety give benefits as being promoted?		
Yes	106	96.4
No	4	3.6
Do you intention to try Putra 1 variety		
Yes	107	97.3
No	3	2.7

The KMO test result was 0.727 (Table 3). The value of 0.727 was acceptable as it was closer to 1 indicating that the sample size is adequate and the statement or items were appropriate. The Bartlett's test of Sphericity was significant at 1% level and indicated that the statement items used in factor analysis were also appropriate.

Table 3: Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**.727**
Bartlett's Test of Sphericity	Approx. Chi-Square	421.040
	Df	66
	Sig.	.000

There were four factors that influenced the paddy farmers' intention to adopt Putra 1 variety (Table 4). These are attitude, subjective norms, knowledge and perceived behavioural control. Only statements or items with a factor loading of at least 0.5 were considered as a significant items. The factor loading for four factors were from 0.611 to 0.897 with the total variance of 68.018, indicating that these four latent factors explaining approximately about 68 percent of variance in the paddy farmers' intention to adopt the new paddy variety Putra 1. The four latent factors were summarized as follows:

Attitude. The farmers' attitude has been recognized as the first factor. This factor consists of four sub-variables with total variance of 20.986 percent and eigenvalue of 3.496. The first sub-variable "I prefer to use variety that are more resistant to pest and diseases" showed the highest factor loading score (0.842). The results showed that those who have positive attitudes can influence their intention to adopt new paddy variety Putra 1.

Subjective Norm. The second factor which has influenced the paddy farmers' intention to adopt new paddy variety (Putra 1) is subjective norm. This factor comprises four sub-variables which explained by a total variance of 18.626 percent with eigenvalue of 2.181. The first sub-variable "I might use new variety (Putra 1) if it is recommended by seed sellers" showed the highest factor loading score (0.835). The results indicated that paddy farmers' intention to adopt new paddy variety (Putra 1) can be influenced by the social norms.

Knowledge. Knowledge is the third factor which explained by a total variance of 15.091 percent with eigenvalue of 1.773. This factor was described by three sub-variables: "basically, new paddy varieties are introduced to help farmers to increase the yield" (0.756), followed by "there might be different yields between variety Putra 1 and other varieties" (0.733), and "I believe that Putra 1, the new paddy variety has the potential to gain high yield" (0.722). These results indicated that knowledge has influence on the paddy farmers' intention to adopt new paddy variety (Putra 1).

Perceived behavioral control. The perceived behavioural control was recognized as the last factor with an eigenvalue of 1.393. This factor consisted of two sub-variables which were being explained by a total variance of 13.316 percent. The results showed that those paddy farmers' high self-efficacy will influence them to adopt new variety Putra 1.

The statistical analysis on factor analysis cumulative variance explained in this study using TBP constructs is 68.018, indicating that the total variance explaining the intention to adopt the Putra 1 paddy variety is explained by four constructs or factors in the TPB framework which is quite high and acceptable .The attitude factor has the highest variance of 20.986 indicating that this factor alone explain 20.986 percent of the variability of the attitude factor in the intention to adopt the new variety. Similarly others factors like subjective norm, knowledge and perceived behavior control explain about 18.626, 15.091 and 13.391 respectively the variability of the intention to adopt the new variety (Table 4). Thus these 4 factors are very important factors to be entrust to the paddy farmers.

Table 4: The summary of factor analysis

Items	Factor Loading
Factor 1: Attitude	
1. I preferred to use varieties that are more resistant to pest and diseases.	0.842
2. I like to use good quality variety based on my experience before.	0.812
3. For me, to try new varieties are very good.	0.800
4. I like to look at other farmers' result first before I decide either to use it or not.	0.742
Eigenvalues	3.496
Percentage of variance explained	20.986
Cumulative percentage	20.986
Factor 2: Subjective Norms	
1. I might use Putra 1 variety if it is recommended by seed sellers.	0.835
2. My thoughts about Putra 1 technology is influenced by my friends.	0.763
3. The adoption of Putra 1 technologies of other farmers will also influence me to adopt it.	0.757
4. I might use new paddy variety (Putra 1) if my friends use it.	0.611
Eigenvalues	2.181
Percentage of variance explained	18.626
Cumulative percentage	39.612
Factor 3: Knowledge	
1. Basically, new paddy varieties are introduced to help farmers to increase the yield.	0.756
2. There might have different yield between variety Putra 1 and other varieties.	0.733
3. I believe that Putra 1, the new paddy variety has the potential to gain high yield.	0.722
Eigenvalues	1.773
Percentage of variance explained	15.091
Cumulative percentage	54.703
Factor 4: Perceived Behavioral Control	
1. If I want, I can adopt Putra 1 if it can increase yield.	0.897
2. I am confident that I can adopt Putra 1 if it is more environmental friendly if I wanted to	0.875
Eigenvalues	1.393
Percentage of variance	13.316
Cumulative of variance	68.018

A reliability test checked whether all the factors are reliable in explaining the farmer's intention to adopt the new paddy variety. Cronbach's Alpha coefficient is used to reflect the average correlation among the items that have been selected. A reliability coefficient of 0.60 or higher is considered acceptable in most research situations. In this study, all of the statement items were over 0.60. The statement items of attitude generated the higher score, which Cronbach's Alpha coefficients of 0.826. Subjective norm, knowledge and perceived behavioral control have 0.770, 0.619, and 0.742 Cornbach's Alpha values, respectively (Table 5).

Table 5: Internal reliability test

Items	Items	Cronbach's Alpha
Attitude	4	0.826
Subjective norm	4	0.770
Knowledge	3	0.619
Perceived behavioural control	2	0.742

CONCLUSION

It is important to understand farmers' decision to adapt new variety of paddy. This present study will contribute to the existing literatures on the adoption of new variety of paddy (Putra 1) developed by PaddyU Putra Technologies at UPM. Putra 1 is a new variety of paddy that is more resistance to the pest and diseases in particular rice blast disease as well as it can produce higher yield as compared to the existing varieties being used by the paddy farmers. This study shows that there are four latent factors that can influence the farmers' adaption of new variety of paddy (Putra 1) namely; attitudes, subjective norms, knowledge and perceived behavioral control as stipulate by the TPB. Since this study is about intention to adopt the new variety of paddy that is resistance to rice blast diseases, the factor analysis has identified the attitude as the latent factor that has the highest variance explain regarding the intention to adopt the new variety. The information on the advantages of Putra 1 paddy variety has created positive attitude to the farmers. Thus more extension services have to be conducted to educate and disseminate information about the new variety. Demonstration and trial plots should be carried out in order to demonstrate and give opportunity for farmers to share their experiences.

In the same token, given the demonstration or trial plot for the Putra 1, it will create a knowledge to the farmers about the benefits of this new variety to combat with the blast disease as well as can increase the production of paddy. Thus, they are able to differentiate what is best for them in terms of value that Putra 1 has compared to existing varieties. Hence the positive attitudes from experienced paddy farmers who have gone through the demonstration trial plots will create a knowledge base about the choice to be made. Not only that, the whole interaction among the factors will provide self-confidence and belief about the advantages of the new Putra 1 variety that will lead to the intention to adopt the new variety.

In order for the government to introduce a new variety of paddy seed a lot of extension services has to be carried out in giving the information and explaining the advantages of the new variety over the existing one. The demonstration plot has to be carried out to ensure that the paddy farmers have the first hand information either from their fellow friends who have been volunteering to use their land as demonstration plots. This demonstration plot and the experiences by fellow paddy farmers will further enhance the intention of paddy farmers to adopt the new paddy variety Putra 1. Thus, government agencies such as DOA and agencies under the umbrella of Ministry of Agriculture and Agro-based Industry such as Muda Agricultural Development Authority (MADA), Kemubu Agricultural Development Authority (KADA) and Integrated Agricultural Development Project (IADP) should promote and create intention for the farmers to adopt this new paddy variety, which will help to increase paddy production and income of farmers. The issue of self-sufficiency in rice and dependence on imported rice can solved, not totally but at least at some higher level than what it is now.

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EFFECTS OF PARAQUAT DICHLORIDE APPLICATION ON SOIL ARTHROPODS AND SOIL CHEMICAL AND PHYSICAL PROPERTIES IN OIL PALM CULTIVATION

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ABSTRACT

A field experiment was conducted to evaluate the effect of paraquat dichloride application on soil arthropods and soil physical and chemical properties in an oil palm plantation. Different rates of paraquat dichloride were applied on weeds and soil arthropods were collected by pitfall trap and soil litter collection methods. A randomized block design with one factor was set up for analysing the data. The soil samples at 0-30 cm in depth were collected before and 12 weeks after paraquat dichloride application. The results showed that paraquat dichloride application did not affect significantly the number of species and arthropod population both from pitfall trap and soil litter samples. Generally, there were no significant changes in soil properties chemically and physically after paraquat application. It suggested that application of paraquat dichloride did not affect the chemical and physical properties of the soil in an oil palm plantation.

Keywords: number of arthropod species, pitfall trap, soil litter

INTRODUCTION

In the past few years, most herbicides have been used to inhibit weed growth or to control weeds that compete with crops for space, water, nutrients and ultimately affects crop yields (Varshney et al. 2012). Many active compounds of herbicides such as glyphosate - isopropylamine salt, propanil - 3'3'-dichloropropionanile, 2, 4-D acid -2, 4-dichlorophenoxy acetic acid are categorized as persistent soil pollutants, whose effects can last for decades while degrading soil properties and biota (Shaner and Leonard 2001). However, the interaction between herbicides and soil and also with soil arthropods and microorganism depends on the type of herbicide, soil type and microorganisms that exist in the soil (Nongthombam et al. 2008).

Paraquat dichloride is classified as a contact and non-selective herbicide that is widely used to control various types of weeds in crops and plantation. In Indonesia, this active ingredient is commercialized with many trademarks. Paraquat dichloride is very soluble in water and because of its ionic properties, so it is easily adsorbed by soil particles to become immobile in the soil (Costenla et al. 1990). Based on the type of soil, soil pH, temperature and the nature of cations that can be exchanged directly, these factors affect the adsorption-desorption of paraquat dichloride through the soil system (Gevao et al. 2000). The impact of pesticide application on the environment is very important. However, there are few studies about its eco-toxicological impact on biodiversity (arthropods) and soil chemical and physical properties. Therefore, the ecotoxicology study of paraquat dichloride is very necessary. The research sought to study the impact of paraquat dichloride related to ecological aspects, such as diversity and population of arthropods, as well as soil physical and chemical properties in an oil palm plantation.

MATERIALS AND METHODS

The research was conducted in an oil palm plantation in PTPN VIII, Cimulang Site, Bogor (6º31'N; 106º42'E), from August to November 2018. Soil analysis was carried out in the Laboratory of Chemistry and Soil Fertility, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB.

Pesticide application. There were five treatments used in this experiment, such as paraquat dichloride with three doses: 1.6 kg ion/ha (= 16 ml/l formulation) (A), 0.8 kg ion/ha (= 8 ml/l formulation) (B), and 0.4 kg ion/ha (= 4 ml/l formulation) (C); fungicide carbendazim (2 g/l) used as toxic standard (D); and control (E) without pesticide treatment. Each treatment was replicated 5 times. Therefore, the total experiment plots were 25 plots. A plot size was 18 m x 18 m containing 18 oil palm trees. Paraquat dichloride and carbendazim were sprayed on weeds at each plot as 0 week. The pesticides were sprayed using knapsack sprayer with spray volume was 400 l/ha.

Soil arthropods collection. Arthropod samples were collected from pitfall trap and soil litter that was taken on 0, 2, 4, 8, and 12 weeks after pesticide application.

Pitfall trap. Plastic cups (5-7 cm in diameter and 10 cm in height) were used as traps. The cups containing 100 ml of 4% formalin (in water) were buried in the ground. Formalin could killed and preserved the arthropod specimens that were trapped in cups. To prevent the trap from rain drop, a roof-like plate (20 cm x 15 cm) was placed on the trap. After 24 hours, the arthropod samples of each trap were transferred to plastic container (volume 200 ml) and the identified at laboratory.

Soil litter samples. Soil litter samples were collected from each plots (10 cm x 10 cm in plot size) by using hand shovel. The samples were placed in each labelled plastic bag, then brought to the laboratory. Each litter sample then poured into a berlese funnel for 1 to 3 days (depend on the litter humidity) to collect the arthropods. The arthropod specimens then were stored in the bottle containing ethanol 70% until identification.

Identification and diversity measurement of soil arthropods. The arthropods collected from pitfall trap and soil litters were identified until morphospecies taxonomic level using a stereo microscope. Individual number of each species of arthropod was counted and called as the population data. Furthermore, both data of morphospecies and individual number of arthropods were analyzed with Shannon and Simpson diversity index. Shannon index used to see species richness in an area, whereas Simpson index used to compare the species diversity and species domination between areas (Magurran 1988).

The equations used to calculate of Shannon and Simpson diversity indices are:

a. Shannon (H') = $-\Sigma p_i (\ln p_i)$; where p_i is the proportional abundance of the i^{th} species = (n_i/N)
b. Simpson (D) = $\Sigma n_i(n_i-1)/N(N-1)$; where n_i = the number of individuals in the i^{th} species, N = the total number of individuals

Data analysis. This experiment used a randomized block design (RBD) of one factor.Statistical analysis were conducted using SAS 9.0 and Tukey's Honestly Significant Difference (HSD) test following one-way analysis of variance (ANOVA)(α = 0.05) to describe the influence of paraquat dichloride treatments to the population of soil arthropods.

Effect of praquat dichloride to soil properties in oil palm plantation. Soil samples were taken at each treatment plot at a depth of 0-30 cm. Disturbed soil samples were taken from several subsamples with a simple random method, then composite into one sample per treatment plot. The soil samples were dried, crushed and then sieved until they passed the sieve 2-mm. After that, the soil samples were analyzed in the laboratory for analysis of soil chemical properties (pH, organic C, total N, available P, potential P and K, bases, cation exchange capacity (CEC), and base saturation (BS). The soil samples for physical properties were taken in the plot representing each of the treatment plots using a ring samples. The physical soil samples were analyzed in the laboratory for analysis of bulk density, porosity, and soil permeability. Soil sampling is carried out before and after application of herbicides.

Statistical analyses were conducted on chemical and physical properties of soil after spraying of herbicides. The data were analyzed using SAS 9.4 Software to create analyses of variance concerning effects of paraquat dichloride on the chemical and physical properties of the soil. If it was significantly different, the analysis was continued by further testing using the Duncan Multiple Range Test (DMRT) test for testing the difference of mean values with $\alpha = 0.05$.

RESULTS AND DISCUSSION

Effect on soil arthropod. The sampling results of pitfall traps showed that12 orders of arthropods were collected, including Scorpiones (spiders) and Acarina (mites) from class of Arachnida; Poduromorpha and Entomobryomorpha from class of Collembola; order/class of Diplopoda; and 7 orders from class of Insecta, such as Coleoptera (Staphylinidae), Hymenoptera (FormicidaeandScelionidae), Orthoptera (Gryllidae, Gryllacrididae, and Tetrigidae), Lepidoptera, Hemiptera (Pentatomidae and Reduviidae), Isoptera (Termitidae), and Thysanoptera. While, in the sample of soil litters, there were found 18 orders of arthropods, including Scorpiones, Pseudoscorpionides, and Acarina from class ofArachnida; Entomobryomorpha, Poduromorpha, and Symphypleona from class of Collembola;Scolopendromorpha from class of Chilopoda; order/class of Diplopoda; Isopoda; and 9 orders from class of Insecta, such as Orthoptera (Gryllidae, Gryllacrididae, and Tetrigidae), Coleoptera (Staphylinidae), Lepidoptera (Noctuidae and Psychidae), Hymenoptera (Formicidae and Scelionidae), Dermaptera (Forficulidae), Diptera, Hemiptera (Pentatomidae and Reduviidae), Isoptera (Termitidae), and Thysanoptera.

Figure 1 indicates the total of species number collected from pitfall traps and soil litter samples. At week-0 (one day before pesticide application), the number of species found was around 3-5 species per treatment plot. Generally, all pesticide treatments showed decreasing in number of arthropod species at two weeks after the pesticide application, whereas the number species in plot-E (control) was increasing. The decreasing in number of species may be caused by declining the plant species due to herbicide application, any movement of arthropods from treated plots to untreated plots or the effect of pesticide applications. At week-8 (8 weeks after pesticide application), the number of arthropod species was increasing at all pesticide applications, except at A treatment (16 ml/l). However, the number of species at A treatment increased at week 12 (12 weeks after pesticide treatment).

Effect on population of soil arthropods. The population of arthropod in all plots based on pitfall trap method were fluctuated in number (Fig. 2a). Two weeks after pesticide application (week-2), the arthropod populations in all plots were decreased, but at week-4 the population sharply increased. At week-8, the arthropod population in all plots were decreased, but at week-12 the athropod population was increased again.

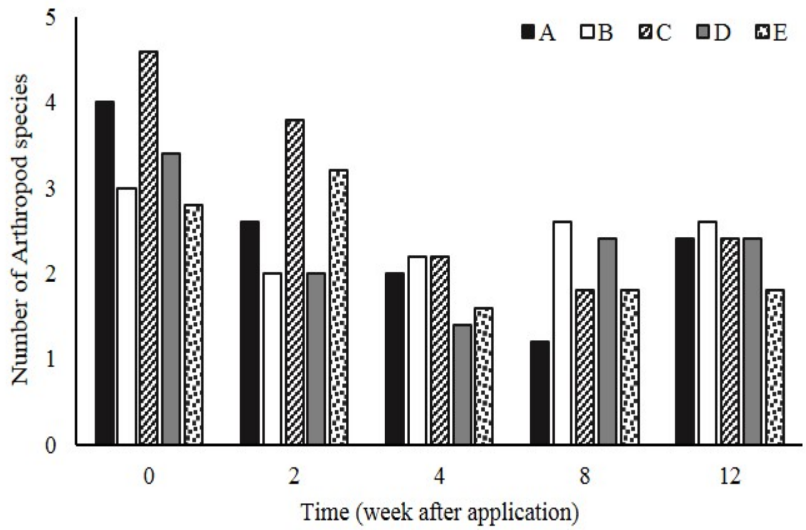

Fig. 1 Number of arthropod species collected from pitfall trap and soil litters

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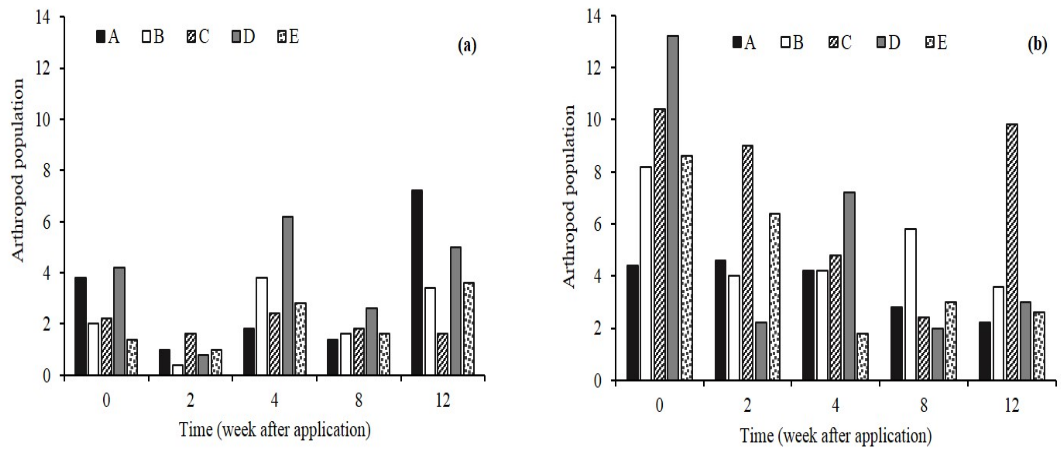

Fig. 2. Population of arthropods collected from pitfall trap (a) and soil litter (b) during five samplings.

In general, the number of arthropod species in soil litter samples was higher than from pitfall traps (Fig. 2b). The arthropod population from litter samples tend to decrease in A treatment (the highest concentration of paraquat dichloride). The similar pattern was occured in the treatment of B but in week-12, the population was increased more than three times in number. Meanwhile, the arthropod species population at other plots were fluctuated. The number of arthropod population both on pitfall trap and soil litters showed no significantly difference (Table 1).

Table 1. Population of arthropod collected from pitfall trap and soil litter during five times of sampling

Treatment	Sampling time (week after application)*				
	0	2	4	8	12
	Pitfall trap				
A	3.80 ± 4.71a	1.00 ± 1.73a	0.80 ± 0.84a	1.40 ± 2.61a	7.20 ± 2.95a
B	2.00 ± 1.58a	0.40 ± 0.55a	1.20 ± 0.84a	1.60 ± 1.82a	3.40 ± 1.82a
C	2.20 ± 1.92a	1.60 ± 1.95a	0.20 ± 0.45a	1.80 ± 2.49a	1.60 ± 1.82
D	4.20 ± 3.03a	0.80 ± 0.84a	1.00 ± 1.00a	2.60 ± 2.97a	5.00 ± 4.42a
E	1.40 ± 2.07a	1.00 ± 1.41a	1.20 ± 1.30a	1.60 ± 2.51a	3.60 ± 3.58a
	Soil litters				
A	4.40 ± 4.83a	4.60 ± 4.62a	4.20 ± 4.92a	2.80 ± 2.28a	2.20 ± 2.77a
B	8.20 ± 11.63a	41.60 ± 89.68a	4.20 ± 7.82a	5.80 ± 9.73a	3.60 ± 2.70a
C	10.40 ± 12.28a	9.00 ± 6.20a	4.80 ± 3.49a	2.40 ± 1.52a	9.80 ± 16.54a
D	2.80 ± 3.11a	2.20 ± 3.49a	2.40 ± 2.05a	2.00 ± 3.08a	3.00 ± 4.53a
E	8.60 ± 7.67a	6.20 ± 6.46a	1.80 ± 2.30a	3.00 ± 3.32a	2.60 ± 1.82a

* the number in the same column followed by the same letter is not significantly different based on Tukey's ($\alpha = 0.05$).

Species diversity and domination on the treatments of paraquat dichloride. The diversity of arthropod species was shown on Table 2. From week-0 to week-4, the highest species diversity was found in plot-C. Next, at week-8, the highest number of species found in plot-D, and at week-12 in plot-B. On the other side, there were species domination in every week of sampling. The insect from Family Formicidae (ants) dominated the arthropod species found at week-0 and 4. Meanwhile, at week-2 and 8, there was arthropod from group of Acarina (mites) that dominated the species found. Therefore, It showed that there was switching species domination between ants and mites during week-0 to week-8. Later, at week-12, group of Collembola dominated the arthropod species found.The physical properties of the soil (Table 2) on Cimulang's oil palm plantations were friable which can be seen from the relatively low bulk density, rather high porosity, and fast permeability.

Table 2. Species diversity of arthropod that collected from pitfall trap and soil litters according to Shannon and Simpson indices.

Treatment	Sampling time (week after application)*				
	0	2	4	8	12
	Shannon (H')				
A	7.95	6.01	4.65	2.72	4.70
B	5.85	1.44	4.68	5.03	5.68
C	8.68	7.25	4.82	4.39	3.72
D	6.65	4.90	3.30	5.42	5.07
E	5.85	6.33	4.02	4.21	3.77
	Simpson (D)				
A	0.08	0.08	0.12	0.24	0.21
B	0.15	0.89	1.23	0.21	0.11
C	0.06	0.11	0.16	0.11	0.52
D	0.16	0.09	0.17	0.11	0.13
E	0.10	0.12	0.10	0.14	0.23

Members of Acarina mostly found were Mesostigmata and Oribatida, and both usually found in soil. Mesostigmata is known as free-living predators. Few number feed on fungi, pollen, nectar, and plant fluids. Meanwhile the oribatid mites ingest solid foods, for example bacteria, fungi, microinvertebrates, and few are decomposting vegetation (leaf litter, lichens, and mosses).In soil, mites are contributing to the decomposition and nutrient cycling (Walter and Proctor 2013). Collembolaor springtails are also commonly found in the soil which contribute to organic material decaying. Therefore Collembola can be used as an indicator for soil fertility and disturbance. Moreover Collembola feed on fungi, and a member of Collembola (Foslomia) is known can decompose toxic material such as pesticide (Suhardjono et. al. 2012).

The initial soil properties. Soil characteristics (soil physical and chemical properties) prior to herbicide application on each experimental treatment on oil palm plantations are presented on Tables 3 and 4. Table 4 shows that the soil pH at the experimental site were a very acidic category except in the experimental plot E classified as acid, low C-organic content (trial plots A, B, C, and D) while in the E trial plots were classified as moderate, N-total of the plots were low to moderate, P-available were low in all experimental plots, and P-total in all trial plots were very high. The basic cations in the experimental treatments were very low to low (Ca) and low to medium (Mg) while the K and Na were very low, the cation exchange capacity (CEC) was classified as moderate except for the A treatment was low, and base saturation (BS) classified as very low (trial plots of B and C) to low (trial plots of A, D, and E).

Table 3. Initial physical properties of the each treatment before pesticide application.

Treatment	Bulk Density (g/cm^3)	Porosity (%)	Permeability (cm/hour)
A	0.98	63.0	8.97
B	0.95	64.2	9.67
C	1.02	61.6	7.04
D	1.01	61.9	7.53
E (control)	1.00	62.4	11.0

Effect on chemical and physical properties of Cimulang oil palm plantation soil. Paraquat dichloride application did not significantly affect the chemical properties of the soil, except soil pH total N. Paraquat dichloride had a significant effect on pH. The pH in experimental plots which were sprayed with paraquat dichloride at 4 ml/l (C) and carbendazim 2 g/l (D) were significantly higher than the experimental plots applied with paraquat dichloride at 8 and 16 ml/l (A and B). However, pH in the experimental plots C and D were not significantly different from controls (E). The total N-content in the control experimental plot (E) was significantly higher than the experimental plots which were sprayed with herbicides (Table 5).

Analyses of variance showed that paraquat dichloride did not significantly affect the bulk density and porosity but affected significantly the permeability of the soil. In paraquat dichloride treatment the concentration of 8 ml/l (experimental plot B) soil permeability was significantly higher than the treatment plot C, D, and E, but not different from the paraquat dichloride treatment concentration of 16 ml/l (Table 6).

Table 4. Initial soil chemical properties of the each treatment (before pesticide application).

Treatment	pH 1:5	Walkley & Black	Kjeldahl	Bray I	HCl25%		NNH4OAc pH 7.0					BS
	H2O	Org-C	Total N	P	P	K	Ca	Mg	K	Na	CEC	
		..(%)..	..(%)..	……...(ppm)………			……..…...(cmol(+)/kg)……….					..(%)..
A	4.35	1.60	0.25	5.25	180	58.7	1.73	0.61	0.07	0.11	12.5	20.6
B	4.26	1.73	0.28	4.68	240	56.8	1,58	0.53	0.09	0.09	16.1	14.2
C	4.30	1.70	0.15	4.76	280	54.3	1.64	0.54	0.06	0.08	17.7	13.6
D	4.45	1.79	0.13	6.16	418	77.5	2.57	1.15	0,06	0.08	18.5	20.8
E (Control)	4.51	2.09	0.18	5.06	388	69.3	3.59	1.11	0.07	0.10	18.6	25.0

Table 5. Chemical soil properties of the each treatment after pesticide application.

Treatments	pH 1:5	Walkley & Black	Kjeldahl	Bray I	HCl25%		NNH_4OAc pH 7.0					BS
	H_2O	C-org	N-Total	P	P	K	Ca	Mg	K	Na	CEC	
		.(%).	..(%)..	……..(ppm)……			…………(cmol(+)/kg)………….					.(%).
A	4.39 a	1.66	0.25 a	3.64	208	188	2.71	1.15	0.40	0.06	15.4	27.5
B	4.32 a	2.11	0.22 ab	4.02	215	42.6	2.22	0.89	0.08	0.05	16.2	20.1
C	4.90 b	1.73	0.21 ab	3.76	215	76.8	3.65	1.51	0.16	0.04	15.3	35.1
D	4.79 b	1.83	0.19 b	3.67	282	34.7	3.35	1.48	0.08	0.04	16.2	31.4
E (control)	5.04 b	1.91	0.31 c	4.01	265	41.7	3.99	1.35	0.10	0.04	15.7	34.6

Means followed by the same letter within a column show no significant difference (DMRT $P < 0.05$)

Table 6. Physical soil properties of each treatment after pesticide application.

Treatments	**Bulk Density (g/cm^3)**	**Porosity (%)**	**Permeability (cm/h)**
A	1.05	60.33	5.13 a
B	1.02	61.46	6.18 a
C	1.05	60.26	1.82 b
D	1.13	57.36	0.66 b
E (control)	1,06	60,08	1,55 b

Means followed by the same letter within a column show no significant difference (DMRT P < 0.05)

Comparison of soil properties before and after paraquat spraying. After paraquat application, there were changes in soil chemical properties (Figures 3, 4, and 5). These changes showed an increase in pH, from very acidic to acidic (experimental plots C, D, and E), but no changes were noted in trial plots A and B. The soil C-organic content is relatively higher after spraying herbicides and fungicides except in the control experimental plot (E), where weeding was done manually. An increase in soil organic-C on herbicide-treated land can be associated with faster herbicide decomposition by microbial activity that helps decompose organic matter and weeds die faster (Ayansina and Oso 2006). Decomposition of organic matter and weeds that die due to herbicide treatment can indirectly increase nutrient content and soil organic matter (Faqihhudin et al. 2013). The highest increase in C-organic content was seen in the treatment which was sprayed with paraquat dichloride concentration of 8 ml/l (Treatment B).

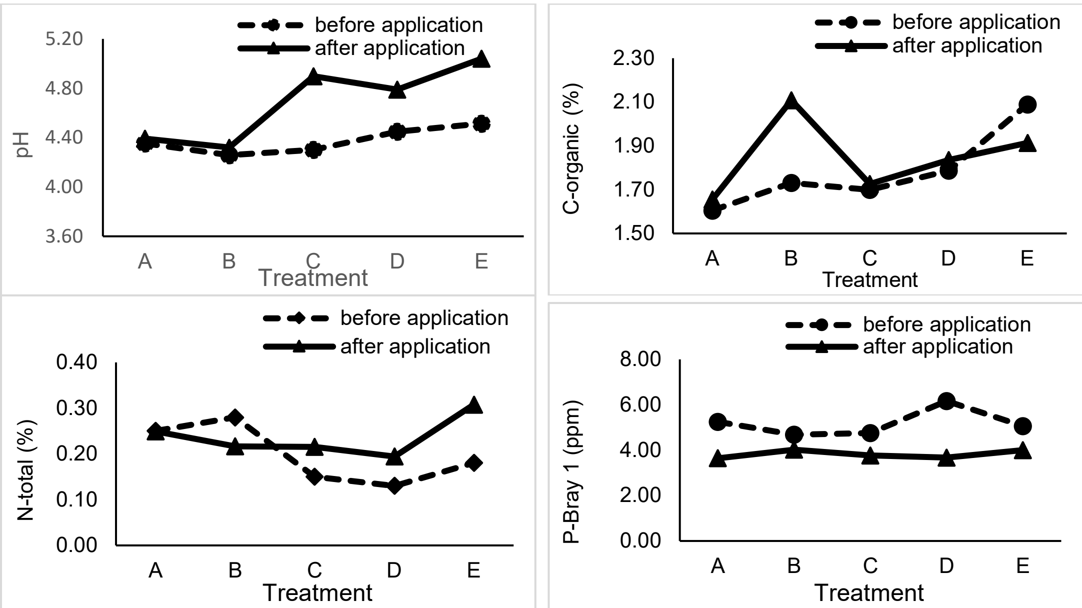

Fig. 3. The comparison of soil pH, organic C, total N, and Bray 1 P before and after paraquat dichloride application

Ca content after application of paraquat dichloride and carbendazim has increased from very low before application into a low category. The Mg content in the paraquat dichloride and carbendazim application plots is slightly increased towards the medium category. The K content in the experimental plot after application paraquat dichloride 16 ml/L increased from very low to the medium category. The Na content decreases after application pesticides. In the There was a significant reduction in Na concentration after herbicide application compared to controls (Sebiomo et al. 2012). Decreasing Na concentration occurs as a result of nutrient washing in soil solutions and herbicide degradation by soil microbes.

CEC in experimental plots after herbicides application is relatively similar to before application, although there is a slight decrease. This is likely to occur because when paraquat dichloride comes into contact with the soil, cationic (positive) / paraquat herbicides are quickly and strongly absorbed by negatively charged soil particles (Raeder et al. 2015) which results in decreased CEC after administration of herbicides. Base saturation in the B and C trial plots increased from very low category to low, but trial plots A, D, and E were still in the same category as before application herbicides and fungicides. . After application of paraquat dichloride , there was a relative increase in bulk density, decreased porosity and permeability of the soil. The differences between before and after application of paraquat dichloride were more due to the differences in spatial of the soil samples.

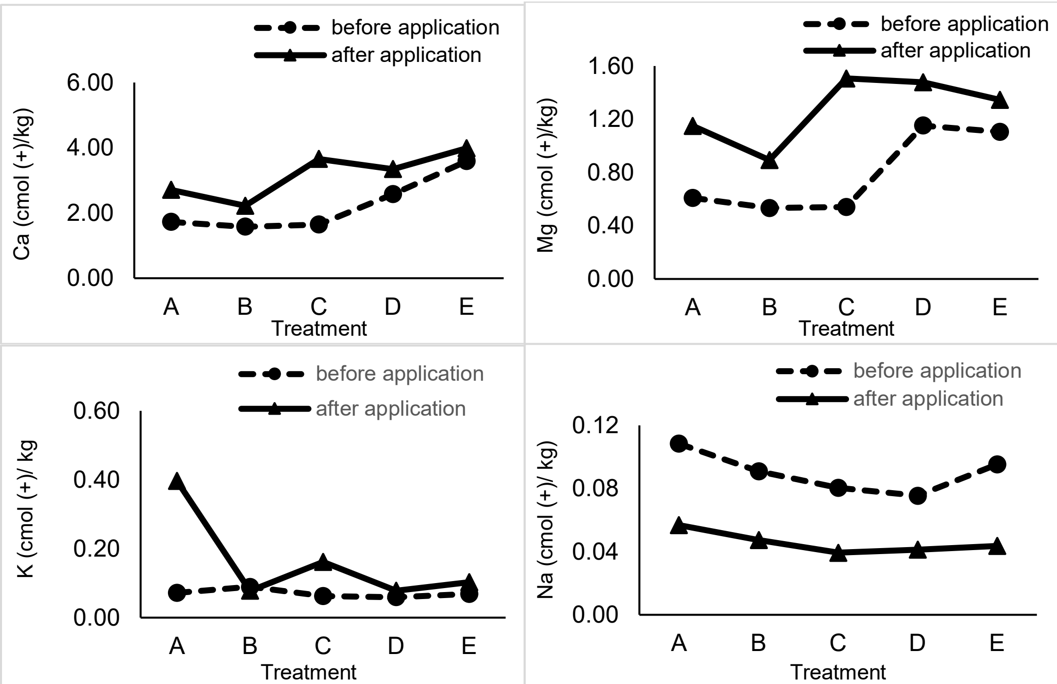

Fig. 4 . Comparison of basic cations before and after paraquat dichloride application

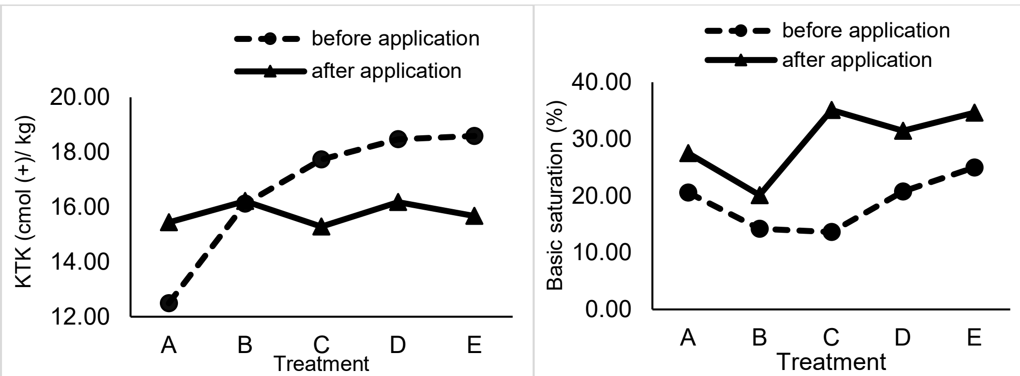

Fig. 5. Comparison of CEC and BS before and after paraquat dichloride application

CONCLUSION

Paraquat dichloride application did not affect significantly the number of species and arthropod populations. The application of paraquat in oil palm plantations did not have a significant effect in general on the soil physical and chemical properties. The application of paraquat significantly increased soil porosity compared to controls.

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