Adoption and diffusion of Integrated Pest Management Technology: a case of irrigated rice farm in Jogjakarta Province, Indonesia

Joko Mariyono*

PhD Candidate in Economics at The Australian National University, Canberra. Mailing Address: Crawford School of Economics and Government, JG. Crawford Building #13 The Australian National University, Canberra ACT 2601 Australia,

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The institutionalization of IPM technology in Indonesia relies on farmer-to-farmer diffusion. The study aimed to analyze the adoption and diffusion of the technology at farm level which conducted in three consecutive seasons of 2000/2001. Two villages in Moyudan sub-district of Jogjakarta Province, where a chronic pest infestation exists, were chosen. The study showed IPM technology has been adopted by both IPM-participating and non-IPM participating rice farmers. It was indicated that diffusion of IPM knowledge in this area of study where every farmer faced the same problems of severe pest infestation.

Keywords: IPM technology, IPM training, irrigated rice farm, adoption and diffusion, pest infestation

Introduction

Integrated pest management (IPM) technology, a package of practices that utilises natural predators and careful timing of right doses, is one of the most important measures to cut the use of pesticides. The technology has been introduced in Indonesia to cope with problems resulting from the unwise use of pesticides during the 1970s and 1980s. It is not surprising evidence that the application of pesticides during the periods has increased substantially along with incredible amount of subsidies (Irham and Mariyono, 2002). This was considered one of the key successes in the intensification programme in Indonesia, that is, the substantial increase in rice production because of the increase in crop yield through intensive use of inputs including chemical pesticides. But, most of the researchers believe that without indiscriminate use of pesticides, increases in application of pesticides lead to a number of

* Corresponding author: Joko Mariyono; e-mail: joko.mariyono@anu.edu.au

consequences such as elimination of natural enemies, pesticide-resistant pests, and frequent pest outbreaks, so that crop losses increase (Barbier, 1989; Conway and Barbier, 1990; Rola and Pingali, 1993; Zilberman and Castillo, 1994; Saha *et al.*, 1997). In addition, pesticides also impacted on human health (Wilkinson, 1988; Rola and Pingali, 1993; Antle and Capalbo, 1994; Antle and Pingali, 1994; Kishi *et al.*, 1995; Nhachi, 1999) and the environmental contamination (Pimentel *et al*., 1993; Bond, 1996).

IPM programme and dissemination of IPM technology

The Indonesian Government has implemented the IPM programme with support of the UN's Food and Agriculture Organization (FAO) since May, 1989 for dissemination IPM technology among rice-based farmers trough a pilot project. The programme 'provides an ideal case to contrast extension for sustainable agriculture with that supporting high external input agriculture. IPM is being introduced into a farming system, irrigated rice, in which the Green Revolution has been successful during the past twenty years' (Rolling and van de Fliert, 1994: 98).

This programme was realisation of a Presidential Decree (INPRES 3/86), three years before, which banned fifty seven brands of pesticides from rice cultivation, and declared IPM the national pest control policy. A policy measure progressively reduced the subsidy on pesticides, which was previously 85%, to zero in 1990 (Untung, 1996). These policy measures created a favourable climate for the implementation of Indonesia's National IPM Programme. It was the first phase (1989-1992) of large-scale attempt to systematically introduce sustainable agricultural practices as a national, public sector effort. During the first phase it had trained around 200,000 farmers intensively, and many more by other methods. Locations of FFS were purposively selected with criteria of easy accessibility and the presence of active farmer groups. Farmers participating in the school were also purposively selected for the program. Farmers with more prosperous and better informed in the selected villages were encouraged to be participant of the school.

The second phase (1993-1999) was sponsored by the World Bank. In this phase the programme was multiply expanded in scales. Since 1994, the pilot FFS activities have been taken over by the National IPM Training Project funded by the World Bank (World Bank, 1993). The project promoted IPM and improved crop cultivation of rice and other food and horticultural crops. More regions have been covered and more actors have been involved. However, the target was not to reach all Indonesian farmers. The strategy of the program was to train a fraction of farmer community, instead of to train all farmers in the community. Thus, the spread of IPM knowledge relies on farmer-to-farmer diffusion (Feder *et al*., 2004a). During implementation of second phase of the project, villages where FFSs were carried out were still subjectively selected with the same criteria by the project management in collaboration with Agricultural Services official both in provincial and district levels. With the assistance from agricultural office at sub-district level and farmer group leaders, farmers were also purposively selected with certain criteria, for instance: rice farmer, literacy, and ability of active discussion.

Statement of problems

During the first few years of the IPM Programme, pesticide use dropped by approximately 50 per cent and yields increased by around ten per cent (Pincus, 1991). Despite this impressive success, work of Irham (2001; 2002) showed that the programme has diminished pesticide use and increased productivity and the household incomes of different socio-economic groups. These confirm the fact cited by Useem *et al*. (1992) and Untung (1996) that Indonesian IPM programme has been successful in reducing pesticide use and escalating rice production. Winarto (1995) gave the impression of supporting the success of IPM programme by showing process of transfer IPM knowledge at farmer level. Studies by Kuswara (1998a, b); Paiman (1998a, b) and Susianto *et al*. (1998) highlight some cases of successful IPM implementations in some sub-districts. In wider scale, Irham (2002: 75) sums up the impact study of Indonesian IPM programme conducted by SEARCA in 1999 that ‘at least the farmers can maintain the current yield with lower cost of pesticide’. In Agro-Chemical Report (2002) it is stated that Indonesia has been one of the leaders in the use of IPM in Asia. Since 1989, a national IPM programme has helped farmers in Indonesia to reduce their dependence on pesticides and increase their harvests. It has also dramatically reduced the incidence of pesticide-related illnesses and environmental pollution.

However, the successful implementation of IPM technology in Indonesia has been questioned by Feder *et al*. (2004a) finding that the IPM training has failed to deliver IPM technology since there is no difference between farmers participating the training and ones not participating, in terms of growth in rice yield and reduction in pesticide use. Another study by Feder *et al*. (2004b) showed that the diffusion of IPM knowledge among farmers was also not the case and there is no evidence that the expected environmental and health benefits of the programme are significant. This is understandable because non-IPM participating farmers may face different problems from IPM-participating farmers.

The expectation on adoption of the technology by Indonesian farmers is questionable for the target of IPM Programme was not to reach all Indonesian farmers. The strategy of the programme that is not to train a fraction of farmer community, instead of to train all farmers in the community. Thus, the spread of IPM knowledge relies on farmer-to-farmer diffusion. During the introduction of IPM technology, villages where FFSs were carried out and subjectively selected by the project management in collaboration with Agricultural Services official both in provincial and district levels. The selection criteria were easy accessibility and the presence of active farmer groups. Farmers participating in the school were also purposively selected for the programme. Farmers with more prosperous and better informed in the selected villages were encouraged to be participant of the school.

This study aimed to analyse the adoption and diffusion of IPM technology in rice farming. The entry point of introducing IPM technology was plant protection. Farmers facing serious problems of pest infestation were expected to be responsive to adopting the technology. Once the technology has been adopted by some farmers, other farmers having the same problems would adopt the technology.

Material and methods

Source of data and location

Data came from a farm survey conducted in three consecutive seasons of 2000/2001 in two villages. Sixty rice farmers are purposively selected in the survey, which consisted of thirty of them who have been graduated from FFS.

Moyudan sub-district of Jogjakarta province is selected as the study area (see Figure 1 for the location of study). The region constitutes one of the rice production centres in Java where IPM programme has been promoted intensively by local and national government. Every year, a number FFSs have been set up following the introduction of the IPM programme. Importantly, this sub-district is considered an area of endemic pest infestations of rice. This is because this area promote a technical irrigation system to allow farmers to cultivate rice throughout a year. Being an endemic area of pest infestations is expected to stimulate the adoption of IPM technology by IPM-graduate farmers, and enable diffusion of the technology by non-graduate farmers neighbouring the graduates. Rice is of interest in analyzing IPM programme because it is IPM-targeted commodity (World Bank, 1993) (Figure 1).

Figure 1. Location of study.

Underlying theory

A production function explained in the microeconomic theory is used as fundamental analysis. Related to the introduction of new technology, the production function is mathematically expressed as follows:-

$$Y = F(\mathbf{X}, L, T, S) \qquad (1)$$

where Y is output, $\mathbf{X}$ is vector of inputs, L is land, T represent different technology and S represents different states of nature. In Asian developing countries, it has been pointed out by Hayami and Rutan (1985) agricultural production technology exhibits constant returns to scale. This means that output will multiply by a factor λ if all inputs and land are multiplied by the same factor, such that:

$$\lambda Y = F(\lambda \mathbf{X}, \lambda L, T, S) \qquad (2)$$

for any λ>0. If $\lambda = 1/L$, the production function can be expressed as yield function, that is:

$$y = f(\mathbf{x}, T, S) \qquad (3)$$

where $y = Y/L$, and $\mathbf{x} = \mathbf{X}/L$. Variable land, L collapses because it becomes unity and constant.

Economic modelling

Yield function is developed in estimating the functional relationship. Pesticide input is used as independent variable to know the effect of pesticide on rice yield. To detect the impact of the IPM-technology on rice yield, a dummy variable is introduced into the model. A Cobb-Douglas model is used in this study. Soekartawi *et al.* (1986) stated that the Cobb-Douglas model suitable to estimate agricultural production functions. In terms of a log-linear functional form, the Cobb-Douglas model is formulated as:

$$y = \alpha + \sum_i \beta_i \ln \mathbf{x}_i + \gamma T + \sum_j \delta_j S_j + \varepsilon \qquad (4)$$

where y is yield of rice (kg/ha); $\mathbf{x}$ is inputs for i = 1, 2, ... 8; T is dummy variable for IPM-graduate farmers; S_j is dummy variables for j=1, 2 for first and second dry seasons respectively; α, β, γ and δ are coefficients of regression; and ε is error terms.

Having a strong claim about the superiority of the IPM technology, it is assumed that if the all farmers have adopted the technology, there was no difference in productivity between IPM-graduate and non-graduate. The diffusion of IPM technology was indicated by insignificance of γ. Descriptive analyses on pest infestation, pesticide use and micro-economic indicators are primarily used to justify the estimated econometric outcome.

Results and discussion

The impact of IPM on rice yield

The impact of IPM-training on yield of rice is given in Table 1. Even though the coefficient determination is relatively low, overall test showed high level of significance. Low coefficient determination was a common case in estimating yield function, because land, which highly correlated with production, disappears in the model. We can see that KCl and labour inputs significantly increased in yield of rice. On the other hand, pest infestation significantly reduced in yield. It is logical because pesticides have no impact on yield. An interesting phenomenon was that yield of rice in second dry season showed the highest. Referring to the system irrigation in this area, this case was understandable.

Table 1. Regression results of yield function.

Variables	Estimated results	
	Coefficients	**t-value**
Intercept	7.6131	14.73***
Urea	0.0158	0.21[ns]
TSP	-0.0046	-0.07[ns]
KCl	0.0037	1.51*
Seed	0.0411	0.60[ns]
Non-liquid pesticides	-0.0042	-1.37[ns]
Liquid pesticides	0.0203	0.96[ns]
Labour	0.1001	2.11**
Pest infestation	-0.0683	-2.43***
IIPM graduate	0.0253	0.79[ns]
First dry season	0.0154	0.46[ns]
Second dry season	0.0497	1.45*
R^2	0.1518	
F-test	2.732***	

Note: *** = Significant at 1 %   ** = Significant at 5 %   * = Significant at 10 %

IPM graduate has no impact on yield of rice. Assuming that IPM technology can increase productivity, there are two possible cases explaining the finding. First, IPM graduates do not adopt IPM principles, such that there was no difference in yield of rice between IPM graduate and non-graduate. Second, non-graduates have adopted IPM technology because the technology diffused among farmers in the villages through informal forums. It seems that the second case was acceptable because at aggregate provincial level, IPM technology has escalated rice production (Mariyono and Irham, 2001; Mariyono *et al*. 2002). Farmers adopted IPM technology because of the fact that pesticides are no longer useful in controlling pest infestation. This indicated in the yield function. As mentioned by Lichtenberg and Zilberman (1986), pesticides have positive impact on yield or production if susceptible pest infestation exists. When pesticides are not effective, farmers needed to choose alternative pest controls. IPM has been introduced as an alternative.

Note that the farmers in the study area still use pesticide. Although both groups apply pesticides for their crop protection, their philosophy of using them was different. (Table 2)

Table 2. Philosophy of using pesticides (%).

Types Reason	IPM-graduate farmer	Non-graduate farmer
Pest infestation exist	66.7	40.0
Preventive motive	16.7	50.0
High yield motive	10.0	16.7
Neighbours' influence	6.7	10.0

Source: Farm Survey, 2001

Table 2 shows that most of IPM-graduates used pesticides only when pest infestation exists, and only few of them used pesticides for preventive motive. This is understandable as they received the IPM principle during training. On the other hand, most of IPM-graduates regarded pesticide as a preventive measure regardless the level of seriousness of pest infestation although some of them apply pesticides only when severe pest infestation exist.

Adoption and diffusion of IPM technology

It is necessary to understand the implementation of the IPM technology by the farmers after analyzing the impacts of IPM programme on pesticide use and yield of rice. (Table 3)

Table 3 shows that resistant variety has been adopted by both IPM-trained and non IPM-trained farmers. Both different groups of farmers have applied recommended technical culture concept for fertilizer application particularly for potassium fertilizer. Only a few of non IPM-trained farmers used this fertilizer. One of the applicable reasons is that the non IPM-trained farmers still think the necessity of this fertilizer while its price is little bit higher compared to other types of fertilizer.

It is important to note that none of groups applied crop rotation. This became the main reason of high possibility of pest and disease infestations to exist in this area. The study also found that IPM-trained farmers applied more mechanical pest control compared to that of non IPM-trained farmers particularly for rat control by using trapping tools and sulphured-smoke. IPM-trained farmers also applied non-pesticide material such as salt and ashes regardless the effectiveness of such measures. One of the distinct different between both different groups was that the IPM-trained farmers gave better observation on their crops condition compared to that of non IPM-trained farmers. Overall, the gap in adopting the components of IPM technology was not wide a lot. This is an indication that the principle of IPM has been widely known by both groups of farmers in the study area. One important factor is that all farmers face the same problems of massive pest infestation. The farmers get incentives in adopting the IPM technology in coping with the risk of crop loss.

Table 3. Implementation of components of IPM technology.

Important components of IPM Technology	IPM-graduate farmer (%)	Non-graduate farmer (%)	Gap
Pest-resistant variety	100	100	0
Technical culture			
a. Land preparation	100	00	100
b. Sanitation	100	66.7	33.3
c. Land idling	100	100	0
d. Crop rotation	0	0	0
e. Planting period	100	100	0
f. Crop density	100	100	0
g. Recommended fertilizers	83.3	10	77.3
Mechanical rat control			
a. Mass killing	100	100	0
b. Trapping	56.7	20	30.7
c. Sulphured smoking	66.7	23.3	43.4
Chemical			
insect control	100	100	0
a. Pesticides	53.3	0	53.3
b. Non pesticides			
Observation	80	53.3	26.7
a. Every 1-3 days	20	33.3	-13.3
b. Every 4-7 days	0	13.3	-13.3
c. Every > 7 days	72	53	19
Average			

Source: Farm Survey, 2001

Conclusion

The Indonesian government has institutionalized IPM technology to replace the previous chemical intensive technology, which has been introduced during the green revolution. However, it was doubted whether the IPM technology can be adopted by farmers directly participating in the IPM training and diffused among non-participating farmers. This because Farmers have been accustomed with chemical intensive technology for long period and the number of IPM-participating farmers were very small compared with total number of Indonesian farmers. IPM-participating and non-IPM-participating farmers in area were compared where serious and chronic pest infestation existed, this study showed that there was no different productivity of rice. Both groups of farmers have applied the important components of IPM technology. This was an adequate indication that in an area where farmers faced serious problems of pest infestation, IPM technology has been responsively adopted by both IPM-participating and non-IPM-participating farmers. It is the case that the technology has diffused to other neighbouring farmers.

References

Agro-Chemical Report (2002). Pesticide and policy: the impact of integrated pest management (IPM) on the Indonesian economy. Agro-Chemical Report 2(2): 18-20.

Antle, J.M. and Capalbo, S.M. (1994). Pesticides, productivity, and farmer health: implication for regulatory policy and agricultural research. American Journal of Agricultural Economics 76: 598-602.

Antle, J.M. and Pingali, P.L. (1994). Pesticides, productivity, and farmer health: a Philippines case study. American Journal of Agricultural Economics 73: 418-430.

Barbier, E.B. (1989). Cash crops, food crops, and sustainability: the case of Indonesia. World Development 17(6): 879-895.

Bond, J.W. (1996). How EC and World Bank Policies Are Destroying Agriculture and the Environment. AgBé Publishing, Singapore.

Conway, R. G. and Barbier, B. E. (1990). After the Green Revolution: Sustainable Agriculture for Development. Earthscan Publication, London.

Feder, G., Murgai, R. and Quizon, J. B. (2004a). Sending farmers back to schools: the impact of farmer field school in Indonesia. Review of Agricultural Economics 26(1): 45-62.

Feder, G., Murgai, R. and Quizon J. B. (2004b). The acquisition and diffusion of knowledge: the case of pest management training in farmer field schools, Indonesia. Journal of Agricultural Economics 55(2): 221-243.

Hayami, Y. and Rutan, V.W. (1985). Agricultural Development: an International Perspective. John Hopkins Univ. Press. Baltimore.

Irham (2001). Impact of ipm program on rice production and income. In Toward the Harmonization between Development and Environmental Conservation in Biological Production, Proceeding of the International Workshop, The University of Tokyo, Japan, Feb. pp. 21-23.

Irham (2002). Integrated pest management program, pesticide use and rice productivity: a case study in Yogyakarta, Indonesia. In: Proc. Int. Workshop on Environmental Risk Assessment of Pesticides and Integrated Pesticide Management in Developing Countries 6-9 Nov. 2001 Kathmandu, Nepal. Landschaftsökologie und Umweltforschung 38, (eds. A. Herrmann, A. and S. Schumann) Braunschweig: 73-81.

Irham and Mariyono, J. (2002). The impact of Integrated Pest Management on pesticide demand for soybean farming in Yogyakarta, Indonesia. In: Proc. Int. Workshop on Environmental Risk Assessment of Pesticides and Integrated Pesticide Management in Developing Countries 6-9 Nov. 2001 Kathmandu, Nepal. Landschaftsökologie und Umweltforschung 38, (eds. A. Herrmann, and S. Schumann) Braunschweig: 62-72.

Kishi, M., Hirschorn, N., Djayadisastra, M., Satterlee N. L., Strowman, S. and Dilts, R. (1995). Relationship of pesticide spraying to signs and symptoms in Indonesian farmers. Scandinavian Journal of Work and Environmental Health 21: 124-133.

Kuswara, E. (1998a). IPM in Marga Sub-District, Tabanan District, Bali. In: Community IPM: Six Cases from Indonesia. Semi-annual FAO IPM Technical Assistance Progress Report, Jakarta Indonesia: 100-137.

Kuswara, E. (1998b). IPM in Tulang Bawang Udik Sub-District, Lampung. In: Community IPM: Six Cases from Indonesia. Semi-annual FAO IPM Technical Assistance Progress Report, Jakarta Indonesia: 221-248.

Lichtenberg, E. and Zilberman, D. (1986). The econometrics of damage control: why specification matters. American Journal of Agricultural Economics 68(2): 261-273.

Mariyono, J. and Irham (2001). Usaha mengurangi penggunaan pestisida dengan program PHT. Jurnal Manusia dan Lingkungan 8(1): 30-36.

Mariyono, J., Irham and Suratiyah, K. (2002). Dampak teknologi pengendalian hama terpadu pada permintaan pestisida pada padi di Yogyakarta. Agrosains 15(1): 141-149.

Nhachi, C. F. B. (1999). Toxicology of Pesticides and the Occupational Hazards of Pesticide Use and Handling in Zimbabwe. In: Pesticide Policies in Zimbabwe, Status and Implications for Change (eds., Mudimu, G. D., Waibel, H. and Fleischer, G.). Pesticide Policy Project Publication Series, Special Issue: 125-140.

Paiman (1998a). An IPM Case Study in Gerung Sub-District, West Lombok District, West Nusa Tenggara. In: Community IPM: Six Cases from Indonesia. Semi-annual FAO IPM Technical Assistance Progress Report, Jakarta Indonesia: 138-166.

Paiman (1998b). An IPM Case Study in Ngantang Sub-District, Malang District, East Java. In: Community IPM: Six Cases from Indonesia. Semi-annual FAO IPM Technical Assistance Progress Report, Jakarta Indonesia: 168-189.

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J., Lipner, V., Giordano, S., Horowitz, A., D'Amore, M. (1993). Assessment of environmental and economic impacts of chemical pesticides use. In: The Chemical Pesticides Question - Environment, Economics and Ethics (eds., Pimentel, D. and Lehmann H), Chapman & Hall, New York: 47-84.

Pincus, J. (1991). farmer field school survey: impact of IPM training on farmer's pest control behavior. IPM National Program: Jakarta.

Rola, A.C. and Pingali, P.L. (1993). Pesticides, Rice Productivity, and Farmer's Health. International Rice Research Institute and World Resource Institute, Philippines. Washington D.C.

Rolling, N. and van de Fliert, E. (1994). Transforming extension for sustainable agriculture: the case of integrated pest management in rice in Indonesia. Agriculture and Human Value 11 (2/3): 96-108.

Saha, A., Shumway, C.R. and Havenner, A. (1997). The economics and econometrics of damage control. American Journal of Agricultural Economics 79: 773-785.

Soekartawi, Soehardjo, A., Dillon, J., L., and Hardaker, B. J., (1986). Ilmu Usahatani dan Penelitian untuk Pengembangan Petani Kecil. UI Press, Jakarta.

Susianto, A., Purwadi, D., and Pincus, J. (1998). Kaligondang Sub-District: a case history of IPM Sub-District. In: Community IPM: Six Cases from Indonesia. Semi-annual FAO IPM Technical Assistance Progress Report, Jakarta Indonesia:. 15-99.

Untung, K. (1996). Institutional constraints on ipm implementation in Indonesia. Publication of the Pesticide Policy Project, Publication Series 3A: 37-47.

Useem, M., Setti, L. and Pincus, J. (1992). the science of javanese management: organizational alignment in an indonesian development programme. Public Administration and Development 12: 447-471.

Wilkinson, C.F. (1988). Introduction and overview. In: The effects of Pesticides on Human Health. (eds., Baker, S.R. and Wilkinson, C.F.) Princeton Scientific Publishing Co. Inc. Princeton: 5-33.

Winarto, Y.T. (1995). State intervention and farmer creativity integrated pest management among rice farmers in Subang, West Java. Agriculture and Human Value 12(4): 47-57.

World Bank (1993). Staff Appraisal Report. Indonesia Integrated Pest Management Training Project. The World Bank, Washington DC.
Zilberman, D. and Castillo, F. (1994). Economic and health consequences of pesticide use in developing country agriculture: discussion. American Journal of Agricultural Economics 76: 603-604.

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