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VEGETABLE FARMERS' USE INTENTION TOWARDS BIOPESTICIDES AND ITS INFLUENCING FACTORS: BASED ON THE SURVEY IN JIANGSU PROVINCE, CHINA

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ABSTRACT

To understand the vegetable farmers' use intention towards biopesticides and its influencing factors, a survey was conducted in Nanjing, Yangzhou, and Xuzhou city, Jiangsu province, China. Penalized logistic regression model was used to analyze. The results showed that the vegetable farmers had low cognitive level of biopesticides, and 68.63% of them would like to use biopesticides if they vary little with chemical pesticides on controlling effect. The farmers with higher education level, higher cognitive level of chemical pesticide residues or biopesticides, smaller vegetable planting area, or vegetable planting years less than 10, as well as under 40 years old, were more willing to use biopesticides. Meanwhile, biopesticide price, government supervision of pesticides, and skill training on biopesticide use significantly influenced the use intention towards biopesticides. Therefore, some suggestions were made, such as developing those biopesticides that take effect promptly and are easy to use, training farmers on biopesticide use and subsidizing those farmers who use biopesticides.

1. Introduction

The planting area of vegetables in China have increased to more than 21 million hm^2, with annual outputs over 700 million tons, occupying the first place in the world (FAO, 2013). Meanwhile, vegetables, with per capita consumption over 500 kg a year (NBSC, 2014), play an important role in food consumption of Chinese. However, using pesticides repeatedly while planting vegetables, combined with short interval between pesticide use and vegetable harvest, may lead to excessive levels of pesticide residues in vegetables. These poisons can enter and accumulate in human body through diet, and pose great threats to human health (Khawaja, 2001).

Biopesticide, a kind of product using living organisms or their preparations to control crop diseases and pests, is characterized by low toxicity and good environmental compatibility. It may be an alternative for chemical pesticide to improve quality safety of agricultural products. To reduce pesticide residues at the source, it is essential to widely use biopesticides in vegetables. Owing to high price, slow efficacy, and high use skill, the application of biopesticides proves to be very difficult. Because the generalization of biopesticides depends on the use intention of vegetable farmers, it is very important to study the use intention and its influencing factors. This may be helpful to provide some policy suggestions on the acceleration of biopesticide application.

2. Materials and methods

2.1. Literature review

Biopesticides have been attracting extensive attention from governments and academic communities. Currently, the focus is mainly on two aspects. One is the introduction of biopesticides from the macro perspective. Ma et al. (2011) introduced application status of various biopesticides in China and Zheng (2006) analyzed competitiveness of biopesticide industry from the perspective of economics. Uri (1998) explored the development and application of biopesticides in America, which remarkably affected consumers' preference for green agricultural products, as well as government's multiple agricultural decision-making in the fields of pesticide supervision, crop planting, and ecosystem protection, etc. However, Skovmand (2007) pointed out that biopesticides in Southeast Asia lacked of competitiveness because of high cost and low efficacy. The other is different types of vegetable farmers' biopesticide-use intention or behavior studied from the micro perspective. Adetonah et al. (2007) analyzed whether cotton farmers in western Africa were willing to apply biopesticides to effectively control cotton bollworm. Doss and Morris (1999) pointed out the striking effect of biopesticide use in corn planting in Ghana. Zhang et al. (2004) concluded that the characteristics of farmer population and cultivated land, and knowledge of farmers on pesticides were obvious factors affecting farmers' use intention towards biopesticides.

2.2. Research hypotheses

In summary, biopesticide use by farmers has been studied systematically, but there is little information on the use intention of Chinese vegetable farmers towards biopesticides. Based on previous findings on biopesticide use, along with actual situation of vegetable planting industry in China, this paper classifies the main factors influencing farmers' use intention towards biopesticides, and then makes some hypotheses as follows.

2.2.1. Individual characteristics of farmers

It mainly includes three factors: gender, age, and education level. When choosing the pesticides, females paid more attention to their own health than males, while males were more normative and rational than females (Wu et al., 2011). Biopesticide is a new type of pesticide. Because younger and higher-educated farmers are more easily to accept new concepts, they were more willing to use biopesticides (Zhu et al., 2012). Based on the above statements, it can be hypothesized that:

[H_1]: Individual characteristics of vegetable farmers will affect their use intention towards biopesticides.

2.2.2. Planting characteristics of farmers

It mainly includes four factors: planting area, planting years, the purpose of planting vegetables and the proportion of vegetable income to total. Vegetables from farmers with large planting area usually reach high degree of commercialization. If adopting biopesticides, those farmers will take higher risk from technology and market, thus they were more inclined to use chemical pesticides that they were familiar with (Ngowi et al., 2007). In addition, in the study on the use intention of the rice farmers in Sichuan province, China towards biopesticides, Fu and Song (2010) found that planting years and area of rice exerted significant influence on farmers' use intention. Based on the above statements, it can be hypothesized that:

[H_2]: Planting characteristics of vegetable farmers will affect their use intention towards biopesticides.

2.2.3. Farmers' cognition on pesticides

It mainly includes two factors: farmers' cognition on chemical pesticide residues and biopesticides. Wang et al. (2015) studied farmers' choice behavior on pesticide use, and found that the more they knew about the degree of the harm caused by chemical pesticide residues, the more likely they would choose non-polluted pesticides. Meanwhile, the more the farmers knew about biopesticides' friendly features such as safety, low toxicity and free pesticide residue, the higher the use intention towards biopesticides (Fu and Song, 2010). Based on the above statements, it can be hypothesized that:

[H_3]: The cognitive level of vegetable farmers on chemical pesticide residues and biopesticides will affect their use intention towards biopesticides.

2.2.4. Market factors

It mainly includes three factors: pesticide price, vegetable price and safety test. Amaza and Ogundari (2008) researched the intention of the soybean farmers in Nigeria to use new technology, and the result showed that the price of soybean remarkably improved farmers' use intention towards biopesticides. Ma and Yang (2011) suggested that the price of pesticides and rice had great influence on the intention of the farmers in Jiangsu Province, China to use non-polluted pesticides. Ngowi et al. (2007) found that to pass the safety tests on pesticide residues before vegetable sale, the farmers in Tanzania were active in using biopesticides. Based on the above statements, it can be hypothesized that:

[H_4]: Market factors will affect vegetable farmers' use intention towards biopesticides.

2.2.5. Government factors

It mainly includes three factors: pesticide supervision, skill training on pesticide use, and agricultural subsidy. According to Ngowi et al. (2007), strict supervision of Tanzanian government on pesticides and skill training on pesticide use could dramatically enhance farmers' use intention towards biopesticides. Ma and Yang (2011) also suggested that national laws and regulations for agricultural products could restrict farmers' use behavior on pesticides, and improve their use intention towards non-polluted pesticides. Hruska and Corriols (2002) researched corn farmers' use intention towards pesticides in Nicaragua, and the result showed that skill training on pesticide use and agricultural subsidy to farmers who used biopesticides could dramatically stimulate their enthusiasm in using biopesticides. Based on the above statements, it can be hypothesized that:

[H_5]: Government supervision of pesticides, skill training on pesticide use and agricultural subsidy will affect vegetable farmers' use intention towards biopesticides.

2.3. Survey design

Based on the results of previous researches and the purpose of this study, the questionnaire was designed to investigate on the intention and behavior of vegetable farmers to use biopesticides. It mainly included three parts: farmers' basic characteristics, the knowledge of biopesticides as well as use intention and behavior. The questionnaire was modified according to the result of the pre-research, and then sent out.

Formal survey was conducted in April, 2015, and stratified and random sampling was used to select samples. Because the purpose of this study was to investigate vegetable farmers' use intention towards biopesticides, and whether pesticides have been used by farmers or not may directly influence the result of this study, the respondents who have used pesticides were selected.

Jiangsu is a large province of vegetable planting with the area of 1.287 million hm^2, ranking third in China (Fan, 2007). As the three regions, southern, middle, and northern Jiangsu province, have distinct economic development levels, three vegetable planting districts including Liuhe District of Nanjing, Feng County of Xuzhou and Hanjiang District of Yangzhou were chosen to represent the developed, relatively developed and under-developed region, respectively. Then two towns were selected randomly in each district, two villages in each town, and 20 farmers in each village.

In view of farmers' low education level, the face-to-face interview was conducted to guarantee sufficient comprehension of the interviewees on the questionnaire, so to ensure authenticity of' the intention and behavior of vegetable farmers to use biopesticides. A total of 240 questionnaires were distributed to the farmers, and finally 204 valid ones were obtained.

2.4. Questionnaire analysis

2.4.1. Sample characteristics

Table 1 shows the basic information of the respondents. The total of 138 males and 66 females participated in this investigation, accounting for 67.65% and 32.35%, respectively. Farmers' age concentrated in 40-49 and 50-59, which accounted for 30.39% and 38.24%, respectively. The education level of the respondents was relatively low. There were 76.96% of farmers with junior high school education level or below, and only 7.84% with junior college degree or above. The proportion of the respondents with vegetable planting area less than 5 mu was 72.55%, and that of the respondents with vegetable income occupied less than 50% of household income was 52.94%, which suggests that vegetable income is not their major income source.

2.4.2. Statistics on vegetable farmers' cognitive level of and use intention towards biopesticides

Vegetable farmers from Jiangsu province mainly used chemical pesticides such as herbicide, microbicide and caricide to control insects and diseases. There were 138 respondents having no knowledge of biopesticides, 26 having a little knowledge and only 8 having rich knowledge, which takes up 67.65%, 12.75% and 3.92%, respectively. In addition, 64.22% (131) of the respondents doubted the efficacy of biopesticides, and only 28.43% (58) suggested that they have ever used or are using the biopesticides. Given that there were little difference in the efficacy on insect and disease controlling between biopesticides and chemical pesticides, 68.63% (140) of the responders showed willingness to use biopesticides.

2.5. Model choice and variable setting

2.5.1. Model choice

Probabilistic model is an ideal estimation approach to discrete choice analysis. When the discrete value of dependent variable belongs to two types, binary probabilistic model should be applied (Lin, 2000). Because the type of the dependent variable is 0-1, and most of the independent variables are also the same type in this paper, the binary logistic model is applied to the regression parameter estimation. Y_i as the dependent variable refers to farmers' use intention towards biopesticides, and if the ith farmers shows willingness to use biopesticides, $Y_i = 1$, otherwise, $Y_i = 0$. Detailed expression is as below:

$$\Pr ob(Y_i = 1 | X_i, B_i) = \Lambda_i = \left\{1 + \exp(-\sum_{r=1}^{n} B_r X_r)\right\}^{-1} \quad (1)$$

Table 1. Basic characteristics of vegetable farmers

Test variable	Grouping variable	Sample size	Percentage
Gender	Male	138	67.65
	Female	66	32.35
Age	20-29	6	2.90
	30-39	18	8.82
	40-49	62	30.39
	50-59	78	38.24
	≥ 60	40	19.61
Education level	Primary school or below	57	27.94
	Junior high school	100	49.02
	Senior high school	31	15.20
	Junior college	14	6.86
	Bachelor or above	2	0.98
Vegetable planting area	< 1 mu	41	20.10
	≥ 1 and < 5 mu	107	52.45
	≥ 5 and < 9 mu	42	20.59
	≥ 9 mu	14	6.86
Vegetable planting years	≤ 5	55	26.96
	6-10	73	35.78
	11-20	45	22.06
	≥ 21	31	15.20
Proportion of vegetable income to total	< 30%	33	16.18
	≥ 30% and < 50%	75	36.76
	≥ 50% and < 70%	42	20.59
	≥ 70%	54	26.47
Purpose of planting vegetable	Self-consumption	62	30.39
	Selling	142	69.61

In formula (1), ***Prob*** refers to the possibility when the dependent variable equals to 1, B_r is the estimated parameter, and X_r is the independent variable. Corresponding log-likelihood function and score equation are as below:

$$lnL = \sum_{i=1}^{n} [Y_i \ln \Lambda_i - (1 - Y_i) \ln(1 - \Lambda_i)] \quad (2)$$

$$U(B_r) = \partial \ln L / \partial B_r = \sum_{i=1}^{n} \left[(Y_i - \Lambda_i) X_{ir} \right] \quad (r = 0,1,2,\cdots,15) \quad (3)$$

The basic sample size of binary logistic model is 100, and 50 samples should increase with every additional variable (Spicer, 2005); therefore at least 800 samples were needed for 15 variables in this study. If we use formula (3) to estimate parameter under the case of small sample volume, the model would be downward bias and separation could easily occur (Albert and Anderson, 1984). So under such condition, binary logistic regression can not be used alone. To avoid separation of the model and ensure the objectivity and validity of the result, according to Heinze and Schemper's advice (2002), Y_i and $(1 - Y_i)$ were given the weight, and the penalty function was added to the log-likelihood function.

$$lnL^* = lnL + 1/2 ln | I(B) | \quad (4)$$

Wherein, $I(B)$ represents information matrix, $|I(B)|$ represents determinant of information matrix. The formula (3) can be modified as follows:

$$U(B_r)^* = \sum_{i=1}^{n} \left[Y_i - \Lambda_i + h_i (1/2 - \Lambda_i) \right] X_{ir}$$
$$= \sum_{i=1}^{n} \left[(Y_i - \Lambda_i)(1 + h_i / 2) + (1 - Y_i - \Lambda_i) h_i / 2 \right] X_{ir}$$
$$(r = 0,1,2,\cdots,15) \quad (5)$$

Wherein, h_i is the ith element on the principal diagonal of H ($H = W^{1/2}X(X'WX)X'W^{1/2}$, X is independent variable matrix, $W = diag[L_i(1- L_i)]$). The problem of model separation is solved by adding the weight of ***(1 +h_i/2)*** and $h_i/2$ to Y_i and ***(1 - Y_i)***, respectively.

2.5.2. Variable setting

The factors influencing vegetable farmers' use intention towards biopesticides were defined as 15 variables according to preceding hypotheses (see Table 2).

3. Results and discussions

3.1. Results

The formula (5) was dealt with Newton-Raphson iteration method by Matlab. The iterative equation was as follows:

$B^{(S+1)} = B^{(S)} + I^{-1}(B^{(S)})U(B^{(S)})^*$, wherein S means the Sth iteration. Table 3 shows relevant parameter estimation results of penalized logistic regression model.

Table 2. Variable table of hypothetical model

Variable	Symbol	Definition and assignment	Mean value	SD
Use intention	Y	Whether farmers are willing to use biopesticides or not, yes = 1, no = 0	0.6863	0.4491
Characteristics of farmer				
Gender	GEND	Dummy variable, male = 1, female = 0	0.6765	0.4690
Age	AGE	Dummy variable, 40 or older = 1, otherwise = 0	0.8824	0.3230
Education level	EDU	Dummy variable, junior high school or above = 1, otherwise = 0	0.7206	0.4498
Characteristics of planting				
Planting area	AREA	Dummy variable, 5 mu or larger = 1, otherwise = 0	0.2745	0.4474
Planting years	YEAR	Dummy variable, 10 or longer = 1, otherwise = 0	0.3725	0.4847
Purpose of planting	PURP	Dummy variable, for selling = 1, otherwise = 0	0.6961	0.4641
Proportion of vegetable income to total	INC	Dummy variable, 50% or higher = 1, otherwise = 0	0.4706	0.5004
Cognition of pesticides				
Pesticide residue	PESL	Dummy variable, know harm of pesticide residue = 1, otherwise = 0	0.6912	0.4631
Biopesticide	BIPE	Dummy variable, know biopesticide = 1, otherwise = 0	0.3529	0.4791
Market factors				
Biopesticide price	PEPR	Dummy variable, consider high = 1, otherwise = 0	06421	0.4805
Vegetable price	VEPR	Dummy variable, think that vegetable price is higher after using biopesticides = 1, otherwise = 0	0.5294	0.5004
Safety test	SEL	Dummy variable, think that the vegetable is easier to pass the safety test after using biopesticides = 1, otherwise = 0	0.5735	0.4958
Government regulation				
Pesticide supervision	SUP	Dummy variable, strict supervision on pesticides = 1, otherwise = 0	0.6225	0.4859
Training on pesticide use	TRA	Dummy variable, farmer has undergone skill training on pesticide use = 1, otherwise = 0	0.3627	0.4820
Agricultural subsidy	SUB	Dummy variable, government supplies subsidy to farmers for biopesticide use = 1, otherwise = 0	0.8137	0.3903

The education level of farmers, vegetable planting area, purpose of planting vegetables and biopesticide price had significant impact on the use intention towards biopesticides ($P < 0.05$). While, farmers' cognition on pesticide residues had more significant impact ($P < 0.01$) than the former, and other seven variables including farmer age, planting years, proportion of vegetable income to total, farmers' cognition on biopesticides, safety test, government supervision on pesticides and skill training on pesticide use had less significant impact ($P < 0.10$).

Among those variables, six of them, namely the education level of farmers, farmers' cognition on pesticide residues, farmers' cognition on biopesticides, safety test, government supervision on pesticides and skill training on pesticide use were positively correlated with farmers' use intention towards biopesticides. While planting area, planting years, the purpose of planting vegetables, proportion of vegetable income to total and pesticide price were negatively correlated with the use intention.

3.2. Discussions

Among the variables reflecting farmer's personal characteristics, age exerted a remarkable negative impact on the use intention towards biopesticides ($P < 0.10$). This demonstrates that farmers older than 40 are less likely to use biopesticides than those younger than 40. It is similar to the result of Zhu et al. (2012), but inconsistent with that of Ma and Yang (2011). It is probably because that the elder relies much on his own experience obtained from practice on insect and disease controlling, therefore, the degree of accepting new type of biopesticides is relatively low. However, the education level exerted a remarkable positive impact on the use intention ($P < 0.05$). This demonstrates that farmers with high education level may easily master the skills of biopesticide use, which can help lower the technical risks of biopesticide use and then enhance the farmer's use intention.

Table 3. Results of penalized logistic regression model

Variable	B	Penalized LR	P-value	O.R.
GEND	0.5060	3.3792	0.1435	0.4287
AGE*	-0.9641	4.6103	0.0622	0.6223
EDU**	1.0834	9.0256	0.0375	3.9204
AREA**	-0.5022	5.4453	0.0199	0.9981
YEAR*	-0.9823	2.1581	0.0842	0.3756
PURP**	-0.3297	6.1552	0.0469	1.2174
INC*	-0.5040	3.4912	0.0620	0.4302
PESL***	0.8077	5.0339	0.0003	2.0804
BIPE*	0.6930	7.7141	0.0792	1.5353
PEPR**	-0.8244	2.9783	0.0384	2.3257
VEPR	0.6105	1.0503	0.8239	0.3561
SEL*	0.3038	4.0098	0.0922	1.0392
SUP*	0.5199	3.1882	0.0664	0.8193
TRA*	0.3759	1.4814	0.0724	0.7136
SUB	0.4351	8.5778	0.3448	0.2704
CONT	-0.5290	2.7371	0.3905	-
Omnibus tests: Penalized LR = 208.9960, df = 15				
Goodness of fit: Pseudo $R^2 = 0.4725$				

***$P < 0.01$, **$P < 0.05$, * $P < 0.10$.

Among the variables reflecting farmer's plant features, planting area and years, the purpose of planting vegetables and proportion of vegetable income to total had negative impacts on farmers' use intention towards biopesticides. For farmers who possess large planting area and high income ratio were less likely to use biopesticides than those of opposite counterparts. It is possibly because that the larger area one possesses, the higher commercialization of vegetables, and the farmers will be more dependent on vegetable income. This will give rise to the higher economy and market risks faced by farmers. Because biopesticides itself lack of fast and efficient controlling on insect and disease, farmers with large planting area and high income ratio are more likely to use better chemical pesticide that they are familiar with, which is out of pursuing economic interest. Therefore, their use intention towards biopesticides decreased. It is consistent with the conclusion of Amaza and Ogundari (2008) and Ngowi et al. (2007). Meanwhile, farmers with less 10-year-planting experience were more likely to use biopesticides. It is probably because that farmers with less experience are much younger and more willing to try new technology. This enhances their use intention towards biopesticides.

Vegetable farmers' cognition on pesticide residues significantly influenced farmers' use intention towards biopesticides ($P < 0.01$). The use of chemical pesticides not only damages farmers' own health but also jeopardizes badly vegetable eaters' health and ecological environment. Consequently, the more clearly vegetable farmers know about the hazard caused by chemical pesticides, the higher the use intention towards biopesticides they express. However, the cognition on biopesticides had no such significant influence on the use intention ($P < 0.10$). The reasons may lie in that vegetable farmers need to promptly and effectively resolve the problems of plant diseases and insect pests, but the biopesticides take effects slowly and their working range is relatively narrow, bringing great damage to the growth of vegetables, which leads to the economic loss for farmers. Compared with chemical pesticides, biopesticides are featured by higher safety and environmental compatibility. But, driven by economic interests, vegetable farmers are unwilling to use biopesticides, which is contrary to the results of Fu and Song (2010).

Biopesticide price ($P < 0.05$) and safety tests on biopesticides ($P < 0.10$) exerted significant influence on farmers' use intention towards biopesticides. Biopesticide price was significant negatively correlated to the use intention. This illustrates that the larger price gap between biopesticides and chemical pesticides may cause the higher cost farmers have to pay for pesticides, which finally leads to lower use intention towards biopesticides. In addition, safety test positively influenced farmers' use intention towards biopesticides ($P < 0.10$). The low residue property of biopesticides enables vegetables to pass the pesticide residues inspection more easily. Due to the unsound traceability system, vegetables produced by using biopesticides can not be sold at relatively high price. Therefore, the influence of vegetable price on farmers' use intention towards biopesticides is insignificant, which is contrary to the result of Ma and Yang (2011).

Both government supervision and skill training on pesticide use exerted influence on farmers' use intention towards biopesticides. Government supervision over pesticides positively influenced the use intention ($P < 0.10$), which indicates that more strictly the use of highly toxic and pestilent pesticides is supervised, more capable farmers become of regulating their behavior and enhancing their use intention towards biopesticides. Due to the complexity of biopesticide use, government training for farmers will reduce the risk from biopesticides and thus strengthen farmers' use intention towards biopesticides. Government policy of agricultural subsidy for farmers to use biopesticides exerted insignificant influence on the use intention, inconsistent with the findings of Hruska and Corriols (2002). One reason for it may lie in low or even entirely no subsidy, which can not motivate farmers to use biopesticides.

4. Conclusions

4.1. Main conclusions

This study conducted a survey on vegetable farmers from Nanjing, Yangzhou, and Xuzhou city in Jiangsu Province, China, to investigate the farmers' cognitive level of and use intention towards biopesticides. By employing penalized logistic regression model, the major factors affecting the use intention were analyzed. The main conclusions are as follows:

Vegetable farmers mainly use chemical pesticides to control plant diseases and insect pests. The farmers have low cognitive level of biopesticides. Up to 67.65% of the investigated farmers know nothing about biopesticides and have doubts about the controlling effects. Only 28.43% used to apply or are now applying biopesticides. Under the assumption that biopesticides vary little with chemical pesticides on the controlling effects, 68.63% show their willingness to use biopesticides.

Several factors, namely farmer age, vegetable planting area and years, the purpose of planting vegetables, the proportion of vegetable income to total, and biopesticide price, negatively influence farmers' use intention towards biopesticides at different significant levels. Whereas, farmers' education level and cognitive level of chemical pesticide residues, government supervision over chemical pesticide use, safety test of vegetables, and skill training on biopesticide use positively influence the use intention at different significant levels.

4.2. Policy suggestions

First, related research institutions should develop those biopesticides that take effect promptly and are used easily. They should lower the difficulty of using biopesticides as well as the cost of biopesticides' production and marketing, thus enhancing market competitiveness of biopesticides.

Second, with support of vegetable production cooperative organization, the government should choose farmers under 40 years old, with high education level and small planting area as pilot objects to gradually promote biopesticides throughout the country.

Third, effective measures should be made to control pesticide residues in vegetables, to improve vegetable safety test system, and to strengthen supervision over pesticide use. Government should also establish a marketing network to sell high-quality agricultural products and ensure a relatively high price of vegetables used biopesticides, thus effectively encouraging farmers to use biopesticides.

Fourth, currently, biopesticide use by vegetable farmers in Jiangsu Province is motivated mainly by their internal willingness, while the external driving force from the government is not powerful enough. There is a necessity for the government to increase the propaganda of biopesticides, thus improving farmers' cognitive level of biopesticides. Meanwhile, it is essential for the government to reward for biopesticide use, and conduct skill training for farmers on biopesticide use, which may be helpful to promote the prompt application of biopesticides in vegetable-planting industry.

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