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Farmers' Behaviors, Perceptions and Determinants of Pesticides Application in China: Evidence from Six Eastern Provincial–level Regions

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Based on a survey to 560 household farms in 6 provincial–level regions of eastern China, this paper studies farmers' application of pesticides, including the amounts of chemical pesticides, use of toxic pesticides and biological pest–control methods. Meanwhile, it summarizes the farmers' perceptions, ranging from pesticides choosing and field application to the awareness on the withdrawal period, possible consequences of overdosing and disposal of the containers. Thereafter, 9 demographic indicators are incorporated as the candidate determinants, including information on the householders, land–using and cropping structure, household income and geographical location. Through the adoption of multivariate OLS and logistic regression models, this paper identifies significant determinants affected farmers' behaviors. Finally, several policy recommendations are put forward, including the countermeasures to increase pesticidal efficiency, decreasing the use of toxic pesticides, improving farmers' capability and awareness on scientific application of pesticides.

Key words: Behavior, Chinese Household Farm, Determinant, Perception, Pesticides

INTRODUCTION

In the latest decades, with the steady increase of agricultural production in China, pesticides have been used extensively to increase crop yields and produce high quality products (J. Zhou, *et al*., 2009). Until end of 2010, the total amount of chemical pesticides produced in China has amounted to 2.34 million tons, maintained an average annual growth rate of 10.32 percent since 1985 (CNSB, 2011). China has become the largest producer, user, and exporter of pesticides in the world (Q. Wei, *et al*., 2011). Meanwhile, the improper use of pesticides has become a major source of food safety incidents, which have resulted in serious threats and losses on ecological environment, human health and economic development. Therefore, safe application of pesticides is drawing unprecedented public concerns, and Chinese government is strengthening regulations on the production, marketing and use of pesticides (X. Song, 2011).

As household farms are the overwhelming managerial units in Chinese agriculture, many scholars tried to accelerate the safe application of pesticides through understanding behaviors and determinants of the farmers. A brief literature review shows that, there are still a variety of topics needs to be researched with further depth. (1) In terms of the survey areas, H. Wang, *et al.* (2004) surveyed 204 farms in Dongtai County, Jiangsu Province; H. Li *et al.* (2007) surveyed 214 farms of Guanghan Prefecture, Sichuan Province; Y. Zhu, *et al.* (2010) sampled 160 farms from 4 villages in Anji County, Zhejiang Province. If more farms from a larger scope of regions be sampled, the findings and conclusions will be more representative to capture important information on pesticides application. (2) Some scholars oriented their studies to the pesticides application on a certain type of agricultural product, including rice (H. Wang, *et al*., 2004), apple (Q. Sun, 2008), vegetables (J. Zhao, *et al*., 2007; J. Zhou, *et al*., 2009), etc. However, most of the farms are growing several agricultural products, on which the pesticide applications are affecting each other, due to limited household budgets, personal preferences, etc. Therefore, inclusion of all the major products grown in a farm will benefit the understanding of their behaviors and determinants of pesticide application. (3) From perspective of the determinants, G. Li, *et al.* (2007) explored impacts from the certification of pollution–free agricultural products; Y. Zhu, *et al.* (2010) compared different types, doses and frequencies of pesticides applied in farms with different scales. As farmers' behaviors are affected by a variety of factors, much comprehensive indicator systems are necessary to specify their natural and social characteristics. (4) In respect to the measurement of the application behaviors, some scholars used the monetary expenses on pesticides (G. Li, *et al*., 2007),

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while in some other studies, the behaviors are represented by the characteristics as toxic or environmentally friendly (Y. Zhang, *et al*., 2004), whether highly toxic pesticides are used (J. Zhao, *et al*., 2007), willingness of applying safe pesticides (H. Li, *et al*., 2007), etc. However, analyses based on physical amount of pesticides, which determines the pesticidal effects in the first place, will provide a better scenario of farmers' behaviors. Furthermore, the integrated analyses on the determinants of farmers' application of chemical pesticides, including the toxic pesticides, and the implementation of biological control methods, etc., will be much beneficial for policy recommending.

Therefore, this study is based on the survey to 560 household farms of eastern China's 6 provincial–level regions, and farmers' behaviors include total amount of chemical pesticides, use of toxic pesticides and biological pest–controls. All the major agricultural products are surveyed and analyzed, including wheat, corn, rice, cotton, oilseed, soy and fruits. The farmers' perceptions cover a variety of concepts from choosing, field application to the withdrawal periods of pesticides, outcomes of overdosing and disposal of the containers. To explore significant determinants behind their behaviors, both quantitative and dummy indicators are used to represent predictor and response variables, through the application of multivariate OLS and logistic regression models. The remainder of the paper is organized as follows: Section 2 briefly describes the field survey and basic statistical summaries; Sections 3 and 4 analyze determinants on farmers' behaviors towards pesticide application; in Section 5, conclusions and policy recommendations are presented, followed by open research topics.

THE FIELD SURVEY

Sample and methods

In order to understand the present situation and farmers' perceptions on agricultural pollution, we designed the survey with questionnaire–based personal interviews to collect first–hand data as used in many previous studies (e.g., J. Zhou, *et al*., 2009; Y. Zhu, *et al*., 2010). In the first section, our questionnaire contains basic characteristics of each household farm, including demographic information of family members, annual incomes, scale and cultivation structure of farmland, production and marketing of aro–products, etc. In the second section of the questionnaire, we enquire the disposal of life garbage, including the wasted glass, plastic, paper, and clothes, kitchen and manure garbage, etc. In succession, farmers' selection and application of fertilizer, pesticides and veterinary drugs are enquired. In the final section, we collect farmers' perceptions on the major sources, routes, responsible parties and countermeasures of agricultural pollution, information and recognition on safe agricultural products. Simultaneously, we designed another questionnaire to capture the general profile of each village, including the demographic information, agricultural production, environmental condition and rural public services, through interviewing the local officials.

In January to March, 2011, we surveyed 560 household farms in 21 villages of eastern China's 6 provincial–level regions, including Beijing, Hebei, Shandong, Shanghai, Jiangsu and Zhejiang (Fig. 1). The sampled area covers 3 major gains–growing provincial–level regions[1], and rural regions affiliating to the top two metropolises in China. The former three regions represent the northern mode of Chinese agricultural production in the Yellow River Basin, while the latter three demonstrate characteristics of agricultural production in south China's Yangtze River Basin. Viewing from topographic types, farms locating in plain, hills and mountainous regions, villages of inlands, seaside and adjoining the metropolises are sampled. In addition to the staple grains crops of wheat, rice and corn, the other major

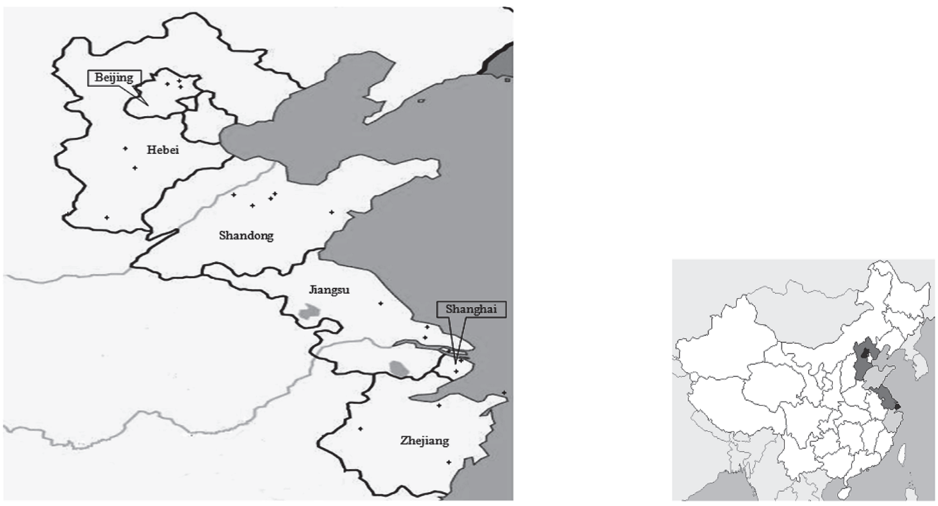

Fig. 1. Location of the sampled areas.

[1] The 13 major gains–growing provincial–level regions include Liaoning, Jilin, Heilongjiang, Inner Mongolia, Hebei, Henan, Hubei, Hunan, Shandong, Jiangsu, Anhui, Jiangxi and Sichuan.

agricultural products, including cotton, vegetables, fruiters, oil crops, etc, and the main livestock, poultry, aquaculture products are being grown and bred in the sampled farms.

Theoretical model

Drawing upon the rural household models of W. E. Huffman (2001), the farmers are assumed to make consumption, production and labor supply decisions by maximizing utility from a home–produced good Y_1 and leisure L:

$$U = U\ (Y_1, L) \tag{1}$$

subjecting to technology constraints from the production function of Eq. 1–1, human time constraints in Eq. 1–2, and cash income constraints in Eq. 1–3:

$$F\ (Y_1, Y_2, Y_3, H, X, A, E) = 0, \quad Y_3 \geq 0, \mathrm{X} \geq 0 \tag{1–1}$$

$$T = L + H + H_m, \qquad H_m \geq 0 \tag{1–2}$$

$$I = P_2 Y_2 + P_3 Y_3 + W_m H_m + V = W_X X \tag{1–3}$$

where Y_2 and Y_3 are outputs produced for sale, the market prices of which are P_2 and P_3, respectively; total available time per production circle T is allocated among leisure L, farm–household work H, and off–farm wage work H_m with the market wage rate of W_m; X is purchased variable inputs, with the price of W_X; A is technology and agro–climatic conditions; E is an education index of household decision makers; within the cash income of I, V is the household nonfarm–nonlabor income net of any fixed costs associated with farm–household production.

To analyze farmers' application of pesticides (F_p), production decision on a certain variable input (X), four types of variables are included to depict major constraints of household farms in our model:

$$F_p = F\ (HR, LC, HI, GL) \tag{2}$$

As household is the most important member in decision–making, the category of human resources (HR) consists of variables on age, gender and education level (E) of the households. As the production function Eq. 1–1 permits adopting new inputs (W. E. Huffman, 2001) and land in the basic means in agro–production, two variables on land cultivation (LC) are adopted. In the variables on household incomes (HI), total cash income constraint (I) is represented by annual cash incomes, while off–farm wage work H_m is described with the ratio of migrant incomes. Finally, as geographic location (GL) affects the technology and agro–climatic conditions (A), market wage of the off–farm work (W_m) and prices of the inputs (W_X), two variables are included to show farms' affiliation to the metropolises, and location in the north or south. Variables in each type and the modeling mechanism are shown in Fig. 2.

Demographic characteristics

In terms of the analysis about pesticide application, similar with some previous studies (Y. Zhang, *et al*., 2004), only farms answered as used pesticides in 2010 are included in this paper. From this survey, a total sample sized of 220 valid responses is used in this study. We include 9 indicators to represent the demographic characteristics of each farm (Table 1). In the following sections, these indicators will be used as candidate determinants to interpret farmers' behaviors.

(1) Due to the key role of householder in making productive decisions within a family farm, many studies included relevant variables in the analysis of safe agricultural production. In this study, we include three variables to describe characteristics of the householders, i.e., human resources (HR), as *gender* (Q. Song, *et al*., 2010), *age* (H. Li, *et al*., 2007) and education level (*edu*, Y. Zhang, *et al*., 2004). (2) At the same time, to model the impacts of land cultivation (LC) to safe agricultural production as Q. Song, *et al.* (2010), two continuous variables are introduced: the sowing area of total agricultural products (*scale*), rather than total area of farmland is

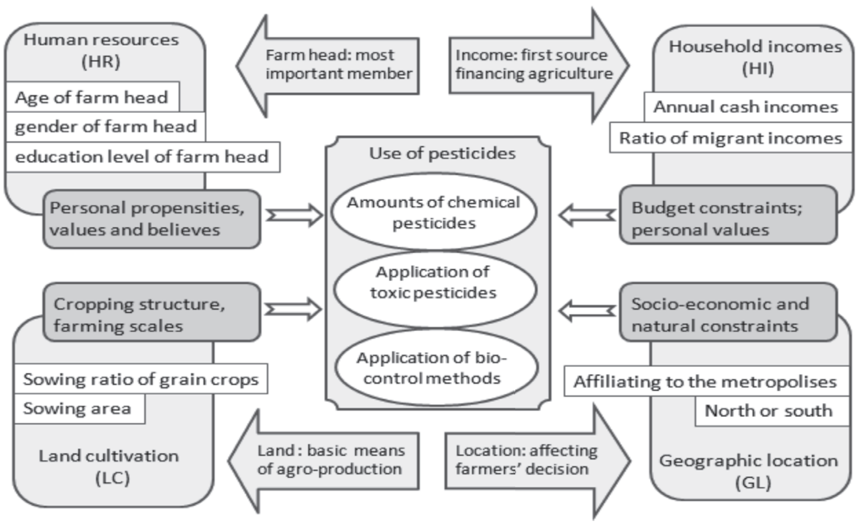

Fig. 2. Mechanism of modeling farmers' use of Pesticides.

adopted with the consideration of multiple cropping (H. Wang, *et al*., 2004); sowing ratio of grain crops (*grainr*) is included to identify the significance of land use structure. (3) Meanwhile, another two variables are used to measure the impacts of discrepancies in household income (*HI*): total annual cash income (*income*) affects household budget and thus the inputs to agricultural production, including those on pesticides and spaying apparatuses (G. Li, *et al*., 2007; Y. Zhu, *et al*., 2010); ratio of income from migrant job (*mir*) shows the main sourcing structure of family income, which affects the relative importance of agriculture and the inputs (H. Dai, 2010). (4) Finally, two dichotomous dummy variables are incorporated to show the importance of geographic location (*GL*) as Y. Zhang, *et al.* (2004), with *north* equal to 1 if a farm is from Beijing, Hebei or Shandong, and *metro* coded as 0 for farms locating in neither Beijing nor Shanghai. The statistical summary of each variable is shown in Table 1.

Behaviors on pesticide application

To capture the major behaviors of pesticide application in a farm, three aspects are included in our questionnaire. As usually a variety of pesticides, with different pest–control and environmental effects, are used in a farm, weights of pesticides applied in each agricultural product are summed to constitute the total amounts. Meanwhile, as the control of toxic pesticides and promotion of biological pest–controls are of great importance for safe agricultural production, relevant characteristics are included as well. The toxic pesticides incorporate Methamidophos, Furadan (Carbofuran) and Folimat (W. Zhang, 2008). According to the No. 199 Bulletin of China Agricultural Ministry (2002), Methamidophos is prohibited to be applied in agriculture, and Furadan cannot be used on vegetables, fruiters, tea and medicinal herbs. As another major toxic pesticide, Folimat has been banned in some regions including Zhejiang (K. Tao, *et al*., 2005), Jiangsu (SCSC, 2007), etc. The bio–control methods of pests in agriculture are measures to eliminate insects, mites, weeds and plant diseases, etc., relying on certain biological mechanisms of secretion, smell, predation, parasitism, herbivory, etc., thus reduce the use of chemical pesticides. For example, using the smell of onions to kill germs causing black spike of wheat, intercropping beans in corn field to attract beneficial insects and prey upon pests, raising ducks and fish in rice fields to control weeds, etc (W. Zhou, *et al*., 2009). Application of pesticides and bio–control measures in the sampled farms are shown in Table 2.

The agricultural products we surveyed include wheat, corn, rice, cotton, oilseed, soy and fruits, and application

Table 1. Demographic characteristics of the sampled farms applied pesticides

Characteristic	Type [a]	Unit	N	Mean	Min	Max	Std. D.	C. V.
Age of farm head (*age*)	HR	year	211	49.68	26.00	78.00	10.08	0.20
Sowing area (*scale*)	LC	*mu* [b]	220	5.95	0.50	38.00	4.82	0.81
Ratio of grains sowing scale (*grainr*)	LC	%	217	39.20	0.00	100.00	35.40	0.90
Ratio of migrant income (*mir*) [c]	HI	%	216	37.76	0.00	100.00	41.59	1.10
Gender of farm head (*gender*)	HR	dummy	211	1=male (204 [d]); 0=female (7)				
Education level of farm head (*edu*)	HR	dummy	208	1=illiteracy (8); 2=primary (49); 3=middle (106); 4=high (40); 5=advanced (5)				
Total cash income in 2010 (*income*)	HI	dummy	218	1=under 10000 *yuan* (16); 2=10000–30000 *yuan* (86); 3=30000–50000 *yuan* (82); 4=over 50000 *yuan* (34)				
North or south of China (*north*)	GL	dummy	220	1=north (129); 0=south (91)				
Metropolises or not (*metro*)	GL	dummy	220	1=Beijing or Shanghai (55); 0=the other regions (165)				

Note: [a] referring to the four types of variables shown in Fig. 2; [b] as a main unit of land measurement in China, 1 mu=666.67m^2; [c] the income sources contain migrant jobs and sales of agricultural products; [d] the bracketed numerals denote counts of farms.
Source: field survey by the authors

Table 2. Application of pesticides in the sampled farms

	Unit	N	Mean	Min	Max	Std. D.	C. V.
Total amount	*kg/mu*	220	1.05	0.01	11.67	1.92	1.82
Toxic pesticides	*kg/mu*	105	0.51	0.01	7.27	1.25	2.43
Methamidophos	*kg/mu*	47	0.37	0.01	3.33	0.59	1.59
Furadan	*kg/mu*	14	3.74	0.33	13.33	3.88	1.04
Folimat	*kg/mu*	62	0.53	0.00	5.00	1.05	1.98
Bio–control of total farms	dummy	306	1=implemented (46); 0=unimplemented (260)				
Bio–control of farms used pesticides	dummy	168	1=implemented (32); 0=unimplemented (136)				

Note: the bracketed numerals denote counts of farms.
Source: field survey by the authors

of pesticides per *mu* of each product is presented in Table 3. The average pesticides used in the three main grain crops of wheat, corn and rice is 0.51*kg* per *mu*, which is much less than that of the other products as 1.79*kg* per *mu*. Meanwhile, judging from the coefficient of variance (C. V.), amounts of pesticides used in these main grain crops are much discrepant than that of the other products. According to the survey, toxic pesticides are used in all the products except for fruiters, amongst which Methamidophos is used in rice and soy, Folimat is used in wheat, cotton, cole and cotton, while Furadan is used in cotton. Finally, bio–control methods are used in much fewer farms, and coving most of the products other than cotton and soy.

Perceptions on pesticide application

Within this questionnaire, 5 questions are concerning farmers' perceptions on pesticide application, from choosing and field application to the withdrawal periods, and the possible consequences of overdosing. Moreover, as pesticides containers may be toxic and improper disposal may menace environmental safety and human health (H. Li, *et al.*, 2007), another question is adopted in this topic. For each question, the number of valid responses, counts of responses and the corresponding percents to each choice are shown in Table 4.

It shows that for most of the farmers, productive effects are the most determining factors in choosing and using pesticides, less attention is paid upon the environmental effects and sprayers' health. When determine the doses, almost 50 percent farmers are answering as following container instructions, while some one third of them are relying on their own experiences. Although more than 80 percent farmers have heard of the withdrawal period of pesticides, the well known ratio is less than 20 percent. In the disposal of pesticide containers, almost 40 percent farmers answered as littering, thus threat the environment and human health. On the pos-

Table 3. Application of pesticides in each agricultural product

	Application of chemical pesticides							Number of farms used	
	Unit	N	Mean	Min	Max	Std. D.	C. V.	Toxic pesticides	Bio–control
Wheat	*kg/mu*	95	0.37	0.01	3.00	0.56	1.53	48	9
Corn	*kg/mu*	48	0.23	0.02	1.25	0.27	1.21	32	6
Rice	*kg/mu*	46	1.09	0.02	5.00	1.31	1.20	15	2
Cotton	*kg/mu*	28	1.44	0.02	6.00	1.69	1.17	17	0
Fruiter	*kg/mu*	26	5.29	0.40	11.67	2.50	0.47	0	27
Oilseed	*kg/mu*	34	0.58	0.15	2.13	0.43	0.75	33	4
Soy	*kg/mu*	27	0.32	0.10	0.50	0.09	0.28	26	0

Source: field survey by the authors

Table 4. Perceptions concerning pesticide application[a]

1. Determinants on choosing of pesticides (Single–choice with 546 valid responses)					
Price	Productive effects	The sellers	Peer practices	Follow–up services	Environmental effect
103 (18.86%)	380 (69.60%)	16 (2.93%)	31 (5.68%)	1 (0.18%)	15 (2.75%)
2. Determinants of using pesticides (Single–choice with 546 valid responses)					
Costs	Productive effect	Environmental effect	Sprayers' health	Quality of agro–product	
120 (21.98%)	343 (62.82%)	13 (2.38%)	7 (1.28%)	63 (11.54%)	
3. Determinants of pesticides dose (Single–choice with 546 valid responses)					
Container instructions	Private experience	Instruction from the extension staff		Peer practices	
278 (50.92%)	191 (34.98%)	42 (7.69%)		35 (6.41%)	
4. Withdrawal period of pesticides (Single–choice with 557 valid responses)					
Knows very well	Knows fairly well	Knows a little	Unknown		
97 (17.41%)	248 (44.5%)	105 (18.85%)	107 (19.21%)		
5. Disposal of the pesticide containers (Single–choice with 550 valid responses)					
Individual recycling	Burning up	Littering	Collective recycling	Others	
79 (14.36%)	73 (13.27%)	212 (38.55%)	182 (33.09%)	4 (0.73%)	
6. Consequences from overdosing of pesticides (Multiple–choice with 557 valid responses)					
Imperiling sprayers' health	Imperiling food security	Pollution	Effective pests controlling	Unknown	Others
337 (60.50%)	423 (75.94%)	316 (56.73%)	105 (18.85%)	16 (2.87%)	9 (1.62%)

[a] Note: numerals are the counts of valid farm, and the bracketed numbers are the corresponding percents of farms.
Source: field survey by the authors

sible consequences of overdosing, negative effects on sprayers' health, food safety and environment are recognized by more than half of the respondents simultaneously. Hereby the coexistence of the proper and traditional perceptions is shown amongst the farmers.

ANALYSIS ON DETERMINANTS OF THE BEHAVIORS

On the total amount of pesticides

In the prior studies, multivariate OLS regression models are used to identify the significant determinants of pesticide application, as H. Wang, *et al.* (2004), G. Li, *et al.* (2007), etc. In this study, the model used to find the important factors of total chemical pesticides amount is formulated as:

$$Y = \beta_0 + BX + u \tag{3}$$

where Y is the total amount of pesticides applied per mu, $X=(x_1, x_2, \ldots, x_9)^{\mathrm{T}}$ is a vector contains the 9 variables listed in Table 1, β_0 and $B=(\beta_1, \beta_2, \ldots, \beta_9)$ are coefficients need to be estimated, while u is the random error. Through the multivariate linear regression process, with the independent variable selection method of Backward in the statistical software of SPSS 13.0, four significant determinants are chosen in the final model. Concerning statistics of the model are shown in Table 5. The significant values of F and t (p–value < 0.1) indicate a good fitness of this model[2].

The results show that, farms affiliating to the two metropolises of Beijing and Shanghai (*metro*=1), or headed by males (*gender*=1) are positive, while ratios of income from migrant jobs (*mir*) and grains sowing scales (*grainr*) are negative with the amount of chemical pesticides applied per mu. (1) The coefficient of *metro* can be explained by the comparison of average pesticides used per mu and other indicators of the farms. Within the 199 farms included in this model, farms affiliating to the metropolises applied 2.64kg of pesticides per mu with the sowing area of 3.84mu in average, while the corresponding indicators in non–metropolises farm are 0.38kg per mu and 6.70mu respectively, thus the formers may have to maintain high yields through more application of pesticides. Simultaneously, the higher annual cash incomes in farms affiliating to the metropolises[3] enable them to input more in pesticides. However, we should notice that this discrepancy may threat the environmental and food safety of the metropolises. (2) As to the finding that male headed farms are applying more pesticides, it indicates that males are more concerning about the productive effects of farming activities and suitable to spray large volume of pesticides in physical power, as investigated by H. Li, *et al.* (2007). (3) The negative effect of income ratio of migrant job is in line with G. Li, *et al.* (2007). The more non–agricultural income usually result in less farming time and attention in agricultural yields, thus the application of pesticides may be decreased. (4) As analyzed above, the three types of staple grain crops are supplied with less pesticide than the other agricultural products. Therefore, their sowing ratio goes negatively with the total amount of pesticides.

On the application of toxic pesticides

To model factors significant for application of the toxic pesticides defined above, the dependent variable is a dichotomous indicator being coded 1 if applied and 0 if not. As the OLS modes like Eq. 3 is inappropriate for discrete and limited dependent variables (Jack J., *et al.*, 1997), a Binary Logit Regression model is adopted (J. Zhao, *et al.*, 2007; H. Dai, 2010) and defined as (H. R. Seddighi, *et al.*, 2000):

$$Log\left[\frac{P(Y_1)}{P(Y_0)}\right] = \beta_0 + \sum_{i=1}^{9}\beta_i x_i + \varepsilon \tag{4}$$

where Y is the application of toxic pesticides with $P(Y_1)$

Table 5. Statistics of the significant determinants on total pesticides used per mu

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.107	0.493		0.217	0.829
Metropolis or not (*metro*)	2.355***	0.219	0.605	10.747	0.000
Gender of farm head (*gender*)	0.846*	0.481	0.099	1.759	0.080
Income ratio of migrant job (*mir*)	–0.004**	0.002	–0.109	–1.975	0.050
Ratio of grain sowing scale (*grainr*)	–0.010***	0.003	–0.222	–3.996	0.000
Valid N=199; F=33.13, Sig=0.000***; R^2=0.406					

Note: Dependent Variable: pesticides used per mu; ***, **and *represent statistical significance in the level of 1%, 5% and 10%, respectively.
Software: SPSS 13.0

[2] Although a not very high R^2 value of 0.406 is given in the table, it should not be used to judge the fitness of a model. The fact that R^2 never decreases when any variable is added to a regression makes it a poor tool for deciding whether one or several variables should be added to a model. Low R^2s in regression equations are not uncommon, especially for cross–sectional analysis. Thus using R^2 as the main gauge of success for an econometric analysis can lead to trouble (J. M. Wooldridge, 2003).

[3] Using the codes of 1, 2, 3, 4 to denote the ascending income levels of Table 1, within the 199 farms included in this model, the mean in farms affiliating to the metropolises is 3.02, while that in the other farms is 2.48.

Table 6. Binary logistic regression on whether toxic pesticides used

Variables	B	S. E.	Wald	df	Sig.	odds ratio
Metropolis or not (*metro*)	–2.507***	0.607	17.051	1	0.000	0.082
Income ratio of migrant job (*mir*)	0.018***	0.005	11.975	1	0.001	1.081
Total cash income in 2010 (*income*)	–0.755***	0.251	9.019	1	0.003	0.470
Ratio of grain sowing scale (*grainr*)	–0.027***	0.006	18.828	1	0.000	0.974
(Constant)	2.515	0.640	15.458	1	0.000	12.363

Cases included in analysis: 199; Missing cases: 21; Total cases selected: 220
Dependent variable: whether toxic pesticides are used, with 93 cases = 1, and 106 cases = 0
Omnibus tests of model coefficients: *Chi*–square (4)=71.642, Sig.=0.000***

Note: *** represents statistical significance in the level of 1%.
Software: SPSS 13.0

denotes the probability of being applied, while $P(Y_0)$ means that of being unapplied; x_i (i=1, 2, …, 9) are the 9 variables listed in Table 1; β_0 and β_i (i=1, 2, …, 9) are coefficients need to be estimated;$\varepsilon$is the random error.

Estimation of this model is carried out through the application of Binary Logistic Regression procedure in SPSS 13.0. The Backward approach is adopted to remove the statistically insignificant variables (p–value$\geq$ 0.1), from the initial model with all the candidate determinants as independent variables. The final model includes four predictors, all of which embrace p–values less than 0.01 (Table 6). The column B estimates log–odds coefficients of β_i in Eq. 4, for predicting the dependent variable by the independent variables. The last column lists the exponentiation of B, the ratio of $P(Y_1)$ and $P(Y_0)$, thus be called *odds ratios* simultaneously. In this case, an *odds ratio* over 1 denotes that the toxic pesticides are more probably be used, while an *odds ratio* less than 1 implies that the toxic pesticides are easier not be used (Bruin J., 2006).

Within the four significant variables listed in Table 6, *mir* is positive to the odds of toxic pesticides be applied, while the other three variables are negative with the application probability of toxic pesticides in a farm. (1) Being the Capital and largest city in China, respectively, especially thanks to the hosting of Olympic Games and World Expo, Beijing and Shanghai have adopted stringent regulations to prevent using of highly toxic pesticides (X. Song, *et al*., 2008; X. Bo, 2009). Therefore, the less probability of applying toxic pesticides there, hence the negative effect of *metro* can be interpreted. (2) For a farmer, the more income from migrant jobs means less time and attention for farming in general. However, due to the instable conditions and high living expenditure outside of homeland, most of the migrant farmers have to leave their families at home and engage in agriculture (Y. Zhang, *et al*., 2004). As most of the left family members are women, children, and the elderly, they are prone to control the pests through the more efficient toxic pesticides. The positive effect of *mir* may reveals that the more they get from migrant jobs, the more they will be afford to buy and use the toxic pesticides. (3) However, when observe farms' cash *income* with units of dozens of thousand yuan as shown in Table 1, farms with upper level of income are tend to use less toxic pesticides as their major income come from non–agricultural sectors[4]. Through the tradeoff with the probable efficient pest–control by toxic pesticides, most of them may prefer to conserve the environment and food security. (4) Finally, as the three types of staple grain crops need less pesticide in general, the application of toxic pesticides is negative with the *grainr* simultaneously.

On the adoption of biological pest–controls

With the same Binary Logistic Regression procedure in SPSS 13.0 and the 9 variables as the candidate determinants, we measure the significant factors for the implementation of biological pest–control in the sampled farms.

As shown in Table 7, through the predictor selection method of Backward, three variables are included in the final model. Judging from the *odds ratio* of each variable, (1) farms from the north (*north*=1) or (2) affiliating to the two metropolises (*metro*=1) are more probably to adopt biological measures. Within the 46 farms answered as conducted biological pest–controls, 36 are from the north and 31 are from the two metropolises, the ratios are 78.26percent and 67.39percent, respectively. To the positive significance of *metro*, it may because that as aforementioned, being the Capital and largest city in China respectively, Beijing and Shanghai are taking full use of their solid industrial foundation and advantages in technology, trade, information, making greater efforts to promote the research and production of low toxicity and environmentally friendly pesticides (D. Gu, 2004; W. Zhou, *et al*., 2009). As to the difference between the north and south, further investigations are necessary to explore the possible reasons in cropping structure, farming habits, the degree of pest damages, etc. (Y. Zhang, *et al*., 2004), hence searching for suitable countermeasures to extend biological pest–controls in different regions. Meanwhile, (3) income ratio of migrant job (*mir*) is found negative with the introduction of biological pest–con-

[4] Within the 199 farms included in this model, no migrant income occurred in the farms with annual cash income less than 10000 *yuan*, while this ratio in the other three income levels of Table 1 are 22.70%, 54.58% and 60.56%, respectively.

Table 7. Binary logistic regression on implementation of biological pest–control

Variables	B	S. E.	Wald	df	Sig.	*odds ratio*
North or south of China (*north*)	0.980**	0.572	2.929	1	0.087	2.664
Metropolis or not (*metro*)	3.403***	0.571	35.490	1	0.000	30.056
Income ratio of migrant job (*mir*)	–0.011	0.007	2.574	1	0.109	0.989
(Constant)	–3.239	0.570	32.273	1	0.000	0.039

Cases included in analysis: 274; Missing cases: 286; Total cases selected: 560
Dependent variable: whether biological pest–controls are implemented, with 27 cases = 1, and 247 cases = 0
Omnibus tests of model coefficients: *Chi*–square (3)=47.607, Sig.=0.000***

Note: ***, **and *represent statistical significance in the level of 1%, 5% and 10%, respectively.
Software: SPSS 13.0

trols. It may be because that farms lying more on the non–agricultural incomes, usually have less time and attention to farming, much less controlling pests through biological methods.

CONCLUSIONS AND RECOMMENDATIONS

Major conclusions

This study explores farmers' behaviors, perceptions and determinants of pesticides application, based on a survey to 560household farms from 6eastern provincial–level regions of China. The behaviors involve total amount of chemical pesticides, application of toxic pesticides and adoption of biological pest–controls. Farmers' perceptions consist of 6 facets, ranging from choosing and field application, the withdrawal periods, possible consequences of overdosing, to disposal of the containers. Multivariate OLS and logistic regression models are used to identify significant determinants of the farmers' behaviors.

The survey shows that pesticides used in the three staple grain crops are less than that of the other products, but more discrepant amongst the farms. The toxic pesticides are applied in most of the products and some 50 percent of the sampled farms, while bio–control methods are used in only about one sixth of the farms. Perceptions on proper application of pesticides exist amongst some of the farmers, including applying by instructions on the containers, awareness on the withdrawal periods, collective recycling of the containers, concerning upon sprayers' health and food security. Simultaneously, traditional conceptions still influence many of them, such as the over emphasized importance of productive effects and private experiences, littering the pesticide containers, etc.

According to the empirical analyses, farms in the two metropolises and headed by males are positive, while ratios of income from migrant jobs and grains sowing scales are negative with the amounts of pesticides applied. With respect to the application probability of toxic pesticides, income ratio of migrant job is positive, while the other 3 variables of *metro*, *income* and *grainr* embrace negative effects. Farms' location of whether north or affiliating to the metropolises are measured as positive, while ratio of migrant income is negative to the odds of adopting biological pest–controls.

Policy recommendations

(1) Extending advanced techniques to improve pesticidal efficiency and guarantee safe application of pesticides. In addition to the alternative techniques and products of toxic pesticides, biological pest–controlling techniques, techniques on efficient pesticide spraying, monitoring the residues, decomposing garbage including pesticides containers, etc., are being highly needed by the farmers.

(2) Severe inspection on the production, circulation and use of highly toxic pesticides, including the improvement of the licensing, registration and classification systems of pesticide production, establishing the tracing back systems and cracking down the illegal production and trafficking of highly toxic pesticides.

(3) According to the foregoing analysis, income ratio of migrant job is negative to amount of pesticides; total income is negative to use of toxic pesticides. Therefore, continuing transfer of surplus labors from agriculture to the other sectors is still urgent obligation for the government, which can improve the total income of rural households simultaneously. The main tasks include promoting the vocational training, perfecting the employment information networks, and protecting the legal rights of migrant workers.

(4) This survey reveals that behaviors like littering the containers, spraying pesticides by private practice still exist amongst many farmers, and their perceptions on safe application of pesticides need to be improved. Hence education on scientific application of pesticides, which is poor in traditional education, is in high necessary to be strengthened (Q. Wei, *et al*., 2011).

Open research topics

In terms of pesticide application amongst the sampled farms, there are still some relationships not being well interpreted, e.g., why farms from the north are much easier to adopt biological pest–controls? Moreover, much more questions can be included, such as the determinants out of the farms like the price changes of pesticide, motivation for using toxic pesticides and biological pest–controls, pesticide–related technologies in most needs, etc., hence are referential for policy recommending.

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