On Diffused Pollution Effect of Chemical Fertilizers in Chongqing Municipality

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Abstract Improper use of chemical fertilizers is an essential reason for diffused pollution of agriculture. Therefore, finding out influence factors of farmers in application of chemical fertilizers will play a significant role in controlling the diffused pollution of agriculture. Through field survey, a total of 340 samples in 4 counties of Chongqing Municipality were obtained. On the basis of these samples, an empirical study was carried out. The study results indicate that farmers' application of chemical fertilizers is negatively correlated with farmers' age, education level, male labor proportion, and soil fertility, while the annual family income, agricultural production population proportion, commodity trading characteristics, and scientific fertilizer application ability fail to pass the significance test. These results will provide reference for proper application of chemical fertilizers and controlling diffused pollution.

Key words Chemical fertilizers, Farmers, Diffused pollution, Chongqing Municipality

1 Introduction

A chemical fertilizer is defined as any inorganic material of wholly or partially synthetic origin that is added to the soil to sustain plant growth. China is a country with large population but relatively deficient resources. The per capita farmland area is much lower than the world average level. To increase grain yield and the yield per unit area, application of chemical fertilizers is an essential measure. Monitoring results of national soil fertility indicate that the contribution rate of application of chemical fertilizers to grain yield is 57.8% on average, so chemical fertilizers are the most fundamental and important fertilizers in recent years. However, improper and unscientific fertilizer application technologies will not only influence increase of agricultural yield and income, but also influence quality and safety of agricultural products, and exert adverse influence on environment. Excessive application of chemical will lead to environmental pollution and ecosystem imbalance. Since the 1980s, fertilizer application technologies gradually develop to mainly chemical fertilizers, from less than 30 million tons in 1992 to near 60 million tons in 2011. In the past 20 years, rapid increase of chemical fertilizer application solves food problem of hundreds of millions of farmers, but also brings about serious environmental pollution problem. Diffused pollution of chemical fertilizers threatens quality, safety and health of agricultural products, and also restricts sustainable development of China's agriculture. Therefore, the diffused pollution of chemical fertilizers attracts wide attention. Farmers are basic economic units of agricultural production and also major subjects suffering from diffused pollution of agriculture[1]. In recent years, some scholars start caring about agricultural production act, operation act, and technological acceptance act related to diffused pollution of agriculture[2-4]. They realize that it is required to make clear the relationship between farmer act and diffused pollution, to come up with effective and feasible solutions. Based on samples of farmers in Chongqing Municipality, we studied farmers' application of chemical fertilizers and influence factors, in the hope of providing reference for proper application of chemical fertilizers and controlling diffused pollution resulted from application of chemical fertilizers.

2 Data source and empirical analysis

2.1 Selection of variables Farmers' application of chemical fertilizers is influenced from economic, cultural, technological, labor, and social psychological factors. On the basis of existing research literature[5-9] in combination with experience, we analyzed farmers' application of chemical fertilizers mainly from following factors. (i) Householder characteristics of farmers. This mainly includes age and education level of the householder. The elderly farmers have more experience in agricultural production but not like to accept advanced fertilizer application concept, so they may apply more fertilizers. The education level has negative influence on farmers' application of chemical fertilizers. The higher the education level, the higher willingness of them to adopt scientific fertilizer application methods, and the more likely they are to use less chemical fertilizers. (ii) Family and production characteristics of farmers. This mainly includes annual family income, gender of major labor, the proportion of agricultural production population to total family population, soil fertility, and whether organic fertilizer used. The influence of family income on application of chemical fertilizers is difficult to determine. Families with woman as major labor may adopt simple fertilizer application method due to limitation of physical strength. Families with more members engaged in agricultural production are inclined to use mixed fertiliz-

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ers. Generally, farmers with barren farmland prefer to apply more fertilizers to improve soil fertility. Organic fertilizers can be replaced with nitrogen fertilizers, so farmers applying organic fertilizers may apply less chemical fertilizers. (iii) Characteristics of commodity trading. This mainly refers to commodity rate of crops. The commodity rate of agricultural products is the percentage of crops sold. According to present situation of rural areas, farmers with low commodity rate generally possess less farmland and may carefully manage farmland and apply organic fertilizer, so they may use less chemical fertilizers. Farmers with higher commodity rate generally have large production scale and usually conduct accurate application of fertilizers according to modern agricultural production method, leading to less application of chemical fertilizers. (iv) Characteristics of scientific fertilizer application ability. This mainly refers to whether farmers can understand meanings of instructions for application of chemical fertilizers, whether they have participated in agricultural technological training, and whether they have adopted the technology of testing soil for formulated fertilization. Government should be responsible for guiding and encouraging farmers to apply less chemical fertilizers, provide scientific fertilizer application training and extend the technology of testing soil for formulated fertilization. Here, we suppose farmers who have participated in agricultural technological training and adopted the technology of testing soil for formulated fertilizer have negative influence on application of chemical fertilizers.

Table 1 Definition and explanation of variables

Name of variable	Definition of variable
Explained variables	
Application of chemical fertilizers (ACF)	Total application of chemical fertilizers in unit area
Explanatory variables	
1. Basic characteristics of farmer householder (Char)	
Age of head of householder (Char1)	Young adult = 1; Middle aged and old = 0
Education level (Char2)	Primary school = 1; Junior middle school = 2; Senior middle school = 3
2. Farmer family and production operation characteristics (Oper)	
Farmer family income (Oper 1)	Total annual family income
Gender of major labor (Oper 2)	Male = 1; Others = 0
Size of agricultural production population (Oper 3)	Agricultural production population / total population of farmer household
Soil fertility (Oper 4)	Low fertility = 1; Others = 0
Whether organic fertilizer used or not (Oper 5)	Yes = 1; No = 0
3. Characteristics of agricultural product trading (CTC)	Ratio of agricultural products sold to total yield of agricultural products
4. Scientific fertilizer application ability (SFA)	
Whether they can understand instructions for application of chemical fertilizers (SFA 1)	Fully understanding = 1; Others = 0
Whether they have participated in agricultural technological training (SFA 2)	Yes = 1; Others = 0
Whether they have adopted technology of testing soil for formulated fertilization (SFA 3)	Yes = 1; No = 0

2.2 Data source In view of diffused pollution of chemical fertilizers, we carried out a field survey in Beibei District, Hechuan District, Fengdu County, and Shizhu County in Chongqing Municipality. The survey objects are local farmers engaged in agricultural production. In the form of questionnaire, we asked farmers about agricultural production, fertilizer application, attitude and ideas about environmental situation, environmental pollution, and pollution control. We collected 340 valid samples (120 samples, 98 samples, 65 samples, and 57 samples respectively in Beibei District, Hechuan District, Fengdu County, and Shizhu County in Chongqing Municipality).

2.3 Model design Due to diversity of agricultural production and planting varieties of farmers, it is impossible to survey all agricultural production acts of every farmer. Therefore, we mainly selected some planting varieties of farmers to make survey and statistics. Besides, considering quantification of empirical analysis data and relevant requirements of econometrics for analysis data, it is impossible to incorporate all influence variables into the analysis system. We only selected representative variables to make regression analysis. Suppose farmers take maximum net income as code of conduct, for certain crop, farmers can freely decide the application of fertilizer, and their acts are restricted by rational men. In other words, the purpose of applying fertilizer is to maximize net income. The maximum expected net income of farmers will be influenced by basic characteristics of farmer householder, farmer family and production characteristics, agricultural product trading characteristics, and farmers' scientific fertilizer application ability. Therefore, the influence model for application of chemical fertilizers in unit area is as follows:

$$ACF = f(Char, Oper, CTC, SFA) + \varepsilon$$

where ACF stands for application of chemical fertilizers in unit area, Char refers to basic characteristics of farmer householder, Oper refers to farmer family and production characteristics, CTC means commodity trading characteristics, SFA stands for scientific fertilizer application ability, ε is random disturbance term reflecting other factors impossible to concern.

3 Model estimation results and analysis

3.1 Descriptive statistics of major sample data

3.1.1 Education level of farmer householder. In the survey of 340 farmer families, we found that the education level of farmer householder is mainly junior middle school, followed by primary school, and the least is senior middle school and above. Such cultural structure reflects that most farmers have low education level.

Therefore, it is difficult to popularize and practice concept of environmental protection and scientific fertilizer application.

Table 2 Education level of farmer householder

	Primary school	Junior middle school	Senior middle school and above	Total
Beibei	40(33.33%)	52(43.33%)	28(23.33%)	120
Hechuan	39(39.80%)	43(43.88%)	16(16.32%)	98
Fengdu	28(43.08%)	30(46.15%)	7(10.77%)	65
Shizhu	26(45.61%)	24(42.11%)	7(12.28%)	57

3.1.2 Descriptive statistics and analysis of major dummy variables. In dummy variables, people engaged in agricultural production are mainly middle aged and old, which is consistent with the reality of China's labor migrating to cities. In gender of major labor, it is women that are mainly engaged in agricultural production. Most farmers surveyed thought their farmland has low fertility, which may be partly because of their conservative answer, and partly because of hills and mountains in Chongqing. In the use of organic fertilizer, about 43.82% farmers have applied organic fertilizer, indicating that farmers are mainly applying chemical fertilizers at present. As for the characteristics of scientific fertilizer application ability, majority farmers can fully understand instructions for application of chemical fertilizers. However, they take few agricultural technological training. This is partly because of farmers themselves, and partly because of lack of agricultural technological extension personnel and unreasonable agricultural technological training organization. Therefore, government should enhance agricultural technological training and extend latest agricultural sci-tech achievements to farmers. In addition, technology of testing soil for formulated fertilization is a new fertilizer application technology. It determines type and quantity of fertilizers according to soil properties and crop demands, so as to maximally use fertilizers and avoid damage of chemical fertilizers to soil environment and water body. However, this technology is not widely applied yet.

Table 3 Basic characteristics of major related dummy variables

Name of variable	Classification	Frequency	Percentage//%
Age of farmer householder	Young adult = 1	26	7.65
	Middle aged and old = 0	314	92.35
Gender of major labor	Male = 1	37	10.88
	Others = 0	303	89.12
Soil fertility	Low fertility = 1	304	89.41
	High fertility = 0	36	10.59
Organic fertilizer used or not	Yes = 1	149	43.82
	No = 0	191	56.18
Understanding application of chemical fertilizer or not	Yes = 1	317	93.24
	No = 0	23	6.76
Participated in agricultural technological training or not	Yes = 1	99	29.12
	No = 0	241	70.88
Technology of testing soil for formulated fertilization adopted or not	Yes = 1	53	15.59
	No = 0	287	84.41

3.2 Model regression results and analysis

3.2.1 Basic characteristics of farmer householder. Regression results indicate that the symbol of age of farmer householder (Char1) is negative, indicating the older the age, the larger the application of chemical fertilizers. Middle aged and old agricultural producers, due to limited physical strength, are unable to handle heavy organic fertilizers, so they usually apply chemical fertilizers. Besides, old people are not easy to accept new ideas and concepts, and usually do agricultural production activities according to their habits and experience. Therefore, it is unlikely for them to adopt new fertilizer application technology or improve the fertilizer application structure. The influence of education level of farmer householder (Char2) on fertilizer application is significantly negative at 5% level, indicating that the higher the education level, the higher possibility of using less chemical fertilizers, possibly because they are easy to accept new things, and partly because they have higher awareness of environmental protection.

3.2.2 Farmer family and production operation characteristics. The influence of family annual income (Oper1) on application of chemical fertilizers in Chongqing is not significant. This is possibly because Chongqing is poor and backward. In some areas, especially mountain areas, farmers rely excessively on farmland, so it is required to ensure certain farmland output and high yield of grain crops. The influence of gender of major labor (Oper2) on application of chemical fertilizers is negatively significant, indicating families with female as major labor may use more chemical fertilizers. The influence of soil fertility (Oper4) on application of chemical fertilizers is positively significant, indicating that the lower the soil fertility, the more application of chemical fertilizers. Thus, it easily leads to excessive application of chemical fertilizers, consequently leads to soil hardening, lower fertility, and falling into a vicious circle. The influence of proportion of agricultural population (Oper3) and whether using organic fertilizer (Oper5) is not significant, possibly because of not grasping scientific fertilizer application technology and relying on application of chemical fertilizers.

3.3.3 Commodity trading characteristics. The regression coefficient of commodity trading characteristics is negative but fails to pass the significance test. This is possibly because farmers with low commodity rate of agricultural products generally have small operation scale, products are mainly self consumption. Farmers generally will realize the crops relying on chemical fertilizers are

detrimental to health, and will consider mixed application of chemical and organic fertilizers.

Table 4 Model regression results

Variables	Regression coefficient	t value
Constant	337.752***	3.49
Char1	-130.194**	2.28
Char2	-112.326***	-5.26
Oper1	0.001	-0.31
Oper 2	-101.425**	-2.21
Oper 3	64.053	0.88
Oper 4	152.515***	3.01
Oper 5	-14.523	-0.50
CTC	-9.622	-0.26
SFA1	17.878	0.32
SFA2	3.325	0.10
SFA3	-59.477	-1.19
Number of samples	340	
A-R2	0.12	
F value	4.13	

Note: ***, ** and * signify that variable is significant at 1%, 5% and 10% respectively.

3.3.4 Scientific fertilizer application ability. All three variables of scientific fertilizer application ability, SFA1, SFA2 and SFA3, fail to pass the significance test. This is possibly because farmers seldom participate in agricultural technological training and extension of scientific fertilizer application technologies, and professional level of agricultural technological personnel is to be improved.

4 Conclusions

Improper use of chemical fertilizers is an essential reason for diffused pollution of agriculture. Therefore, finding out influence factors of farmers in application of chemical fertilizers will play a significant role in controlling the diffused pollution of agriculture. Based on survey data of 340 farmers in Chongqing, we made empirical analysis on influence factors of farmers' application of chemical fertilizers, including basic characteristics of farmer householder, farmer family and production characteristics, agricultural product trading characteristics, and farmers' scientific fertilizer application ability. Results show that application of chemical fertilizers is negatively correlated with age and education level of farmer householder, while women labors are more likely to apply more chemical fertilizers. Besides, low soil fertility will lead to more application of chemical fertilizers. Family annual income, proportion of agricultural production population, commodity trading characteristics, and whether organic fertilizers used or not fail to pass the significance test. Finally, the influence of scientific fertilizer application ability on farmers' application of chemical fertilizers is not significant.

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