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Farmer and retailer knowledge and awareness of the risks from pesticide use: A case study in the Wei River catchment, China

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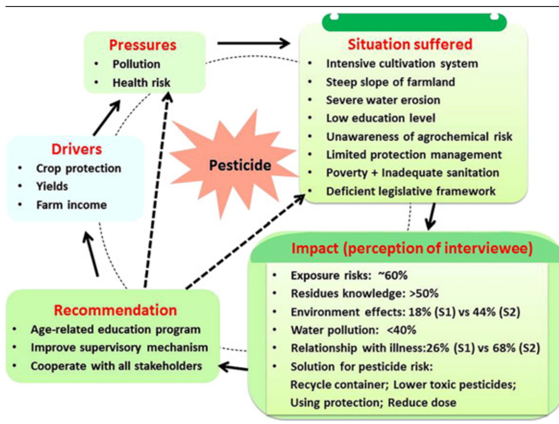
HIGHLIGHTS

- The status of income and expenditure on agriculture cultivation was investigated.
- Knowledge and awareness of risks from pesticide use in different places were estimated.
- The related factors affecting the perception of people on pesticide use was analysed.
- Efficiency programmes on pesticide safety use were recommended.

GRAPHICAL ABSTRACT



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ABSTRACT

Monitoring the educational level of farmers and retailers on pesticide use would be useful to assess the appropriateness of information for reducing or/and avoiding the risks from pesticides in rural regions. The levels of knowledge and awareness of the dangers to the environment and human health were investigated by questionnaires for farmers (209) and retailers (20) in two rural regions (Qianyang County (S1) and Chencang County (S2)) of the Wei River catchment in China where the modes of farming and the state of erosion are very different. The results showed that farmers learned the use and dangers of pesticides mainly by oral communication ($p < 0.01$). Protective measures were inadequate; 65% (S1) and 55% (S2) of farmers never used any protective measures during spraying ($p < 0.05$). Washing hands (>70%) was the most common mode of personal hygiene, relative to wearing masks, showering, and changing clothes, but no significant differences were observed between the selected regions. Most pesticide wastes were dumped directly onto the land or into water, suggesting that educational measures should be taken to address the potential risks from the residues in the wastes. Over 85% of farmers (S1 and S2) claimed to use illegal pesticides, but the reasons for their use varied ($p < 0.01$). Retailers were well-informed and highly conscious of their responsibility for the safe use of pesticides, especially in S2 ($p < 0.01$). A canonical correspondence analysis indicated that educational level and age differed between

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the two regions and contributed greatly to the risks from pesticide use ($p < 0.01$). Educational programmes targeted to age groups, proper disposal of pesticide waste, and sufficient supervision from authorities should consequently be considered for improving the levels of knowledge and awareness of the dangers of pesticides to human health and environmental pollution in the Wei River catchment, China.

1. Introduction

Intensively used pesticides, despite their ability to protect crops, threaten the environment and human health (Damalas, 2009; Damalas et al., 2008; Hvistendahl, 2013; Peshin and Dhawan, 2009; Verger and Boobis, 2013). These "poisons by design" are prevalent and serious occupational hazards faced by agricultural workers and farmers (Gomes et al., 1999; Gunnell and Eddleston, 2003; Hogstedt et al., 1997; Hvistendahl, 2013; Ibitayo, 2006; Yassin et al., 2002). The high levels of occupational exposure to pesticides are correlated with low educational levels, which would preclude the ability of farmers to follow the hazard warnings developed by the chemical industries and agencies (Ibitayo, 2006; Ngowi et al., 2007a,b; Recena and Caldas, 2008). Tragedies such as acute and chronic intoxication, and in some extreme cases, suicide, have frequently been reported, especially in rural regions (Cui, 2009; Gunnell and Eddleston, 2003; Hvistendahl, 2013; Karunamoorthi et al., 2011, 2012; Koh and Jeyaratnam, 1996; Konradsen et al., 2003; Kumar et al., 2012; Phillips et al., 2002; Yassin et al., 2002; Zhou et al., 2011). The lack of a legislative framework regulating the use of pesticides also contributes to the high incidence of poisoning in developing countries (Chen et al., 1998; Hvistendahl, 2013; Salameh, 2004; Yassin et al., 2002). Accountability system, from pesticide registration to supervision mechanism, taking China for instance, is unequipped (Chen et al., 1998; Zhang and Lu, 2007) which leads some big challenges to trace pesticides in market, environmental system and its consequences for human being via food chain(Enserink et al., 2013; Peshin and Dhawan, 2009; Verger and Boobis, 2013). Taking into account the interactions among mixed pesticides, it also increases the risk to human health and the environment (Pedlowski et al., 2012). Poverty, inadequate sanitation, and the standards of medical care are also obstacles to the safe use of pesticides. Those aware of the risks, however, may still misuse pesticides to avoid a lower crop production associated with a significant lower pesticide use (Enserink et al., 2013; Tucker and Napier, 2001). No awareness of alternative systems of production appears to lead to the idea that the use of agrochemicals is unavoidable.

China has a long history of cultivation and has the highest application, exportation, and production of pesticides (Zhang et al., 2011b). The annual mean rate of pesticide application in China is 14.8 kg ha^{-1} (DRSE (NBSC), 2013) but the application rate is likely higher in hotspots. Some highly toxic, persistent, and bioaccumulative pesticides such as the chlorinated pesticides have been completely banned since 1983, but some of these are still commercially available (Zhang and Lu, 2007), and high levels of residues are still detected in soils and water (FAO, 2013; Zhang et al., 2011a). Not all regulations and provisions for pesticide management are respected and accepted in rural regions (Li et al., 2002; Zhang et al., 2005). The Wei River catchment is an important region of agricultural development, and the Wei River contributes strongly to the local economy and society. Due to severe anthropogenic activities, however, the water quality in this river has been degraded by over 85% to class IV of the national standards (GHZB 1–1999), indicating that the water cannot be used for either drinking or irrigation (Guo, 2011; Li et al., 2011; Liu et al., 2007; Zhang and Lu, 2007). Many measures and policies, such as the Program of Integrated Management of Pollution in the Wei River [G2005-99], have addressed the direct discharge of pollutants into the Wei River, however, the quality of the water is still deteriorating (Guo, 2011). Li et al. (2011) suggested that agrochemicals (fertilizers) were a source of pollution contributing to the high concentrations of nitrogen and phosphorous in the Wei River. The levels of knowledge and awareness of the stakeholders, especially farmers and retailers, of the hazards of pesticides should be taken into account to enhance the integrated management of agricultural pollution and agrochemical supervision in rural regions. Such studies are unfortunately limited in China (Huang et al., 2000, 2003; Zhang and Lu, 2007) and the poisoning and suicide case from pesticides are reported frequently (Cui, 2009; Zhou et al., 2011). As end users and distributors, farmers and retailers of pesticides are directly exposed to pesticides, and their behaviours for the safe use of pesticides play an important role in reducing point and non-point sources of pollution, hazards, and acute or chronic intoxication to pesticides in agricultural regions. The levels of knowledge and risk awareness and the practices of farmers and retailers are essential elements for increasing the efficiency of devising to protect these stakeholders. The objectives of this study were thus (1) to determine the levels of knowledge and awareness and the practices of farmers and retailers of pesticide use in regions with different modes of farming and terrains, (2) to evaluate the related risks to the environment and human health and to analyse the most relevant factors for the security of pesticide use, and (3) to recommend programmes for reducing pollution and the risks from pesticide use based on the comparative results of a survey in two regions of the Wei River catchment in China.

2. Materials and methods

2.1. Study site

This study was conducted in two typical rural regions in the middle region of the Wei River catchment (107°04′–107°59′E and 34°31′–34°74′N) (Fig. 1). One region (S1) is located in Qianyang County along the Qian River, a branch of the Wei River. S1 has an area of 2290 ha and has approximately 50,000 inhabitants scattered in hilly regions where arable land is terraced and fruit trees are commonly grown. Wheat and maize are also cultivated and irrigated on the limited flat land. The steep slopes of the land and the concentrated rainfall (June to September) have led to serious losses of soil and nutrients and to the degradation of the land. Most of the younger farmers (<40 years of age) also work outside this area due to the difficulty in procuring an adequate income. The other selected region (S2) is located at the junction of the Chencang and Qishan County on the north shore of the Wei River. S2 has an area of 1560 ha and approximately 45,000 inhabitants. The farmland is flat, and the irrigation system is well developed. S2 has a convenient transportation system and good farming conditions. Mushrooms and vegetables are grown in small-scale greenhouses, and traditional crops such as wheat and maize are intensively cultivated. Both study sites are far from large urban areas and are thus not strictly supervised by authorities. The practices of agrochemical use are thus determined by the level of knowledge of the local farmers.

2.2. Survey

A questionnaire was designed to survey the farmers in the selected regions. The local pesticide store was the only direct source of pesticides for the farmers, so a related questionnaire was designed to survey the levels of knowledge of pesticides and the attitudes and practices of the retailers. The questionnaires focused on: 1) basic information about the interviewee, such as gender, age, educational level, and their farming practices (crop types and yields, agrochemical products used, expenditures, and income); 2) the practices of pesticide application and the pesticides commonly used; and 3) the level of awareness of the

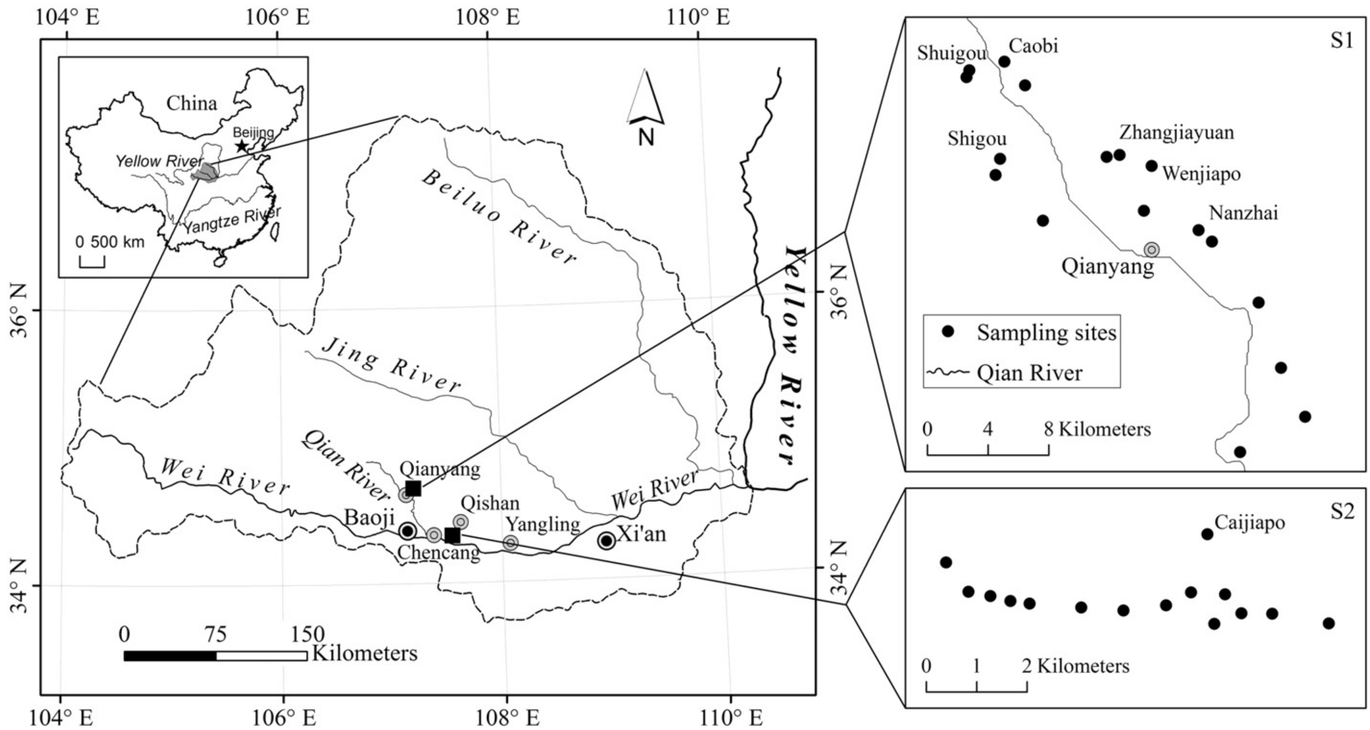

Fig. 1. The geographical location of selected study areas: Qianyang (S1) and Chencang (S2).

dangers of pesticides (Tables 1a, 1b and 1c). To ensure the efficient and economical application of the questionnaires, we first contacted the local leaders or deputies in the villages and talked with them for half of day to obtain basic information, e.g. the number of families and the average areas of the farms. Farmers were completely randomly selected and they were entirely voluntary. The heads of the selected families, i.e. those who purchased and applied the agrochemical products, were interviewed face-to face. The purpose of the survey was clearly explained to minimise the apprehension of the participants or potential bias, and all interviewees remained anonymous. All retailers from the pesticide stores in the two study areas were interviewed as the same way like farmer. The interview lasted around an hour and an economical compensation gift (towels, soaps or detergent) costing $1.5 was supplied to each participant.

2.3. Data analysis

The raw data from the questionnaires were reviewed after the interviews. The answers to each question were then coded and entered into Excel. The statistical analyses, using SPSS 20.0, were based on the relative proportions in each region. Chi-square tests ($p < 0.05$) were used to compare the differences between the two regions. We used Kruskal–Wallis tests for quantitative variables with nonhomogeneous variances or nonnormal distributions and analyses of variance for quantitative variables with normal distributions and homogeneous variances. A canonical correspondence analysis using Canoco 5 was selected to determine the relationship between the backgrounds of the interviewees and their levels of awareness of the dangers of pesticides to the environment and human health.

3. Results

3.1. Social and demographic characteristics

We interviewed 209 farmers and 20 retailers from 23 villages in these two study areas (Table 2). S1 had more farmers (118) than did S2 (91), but each area had 10 retailers. The majority of individuals

Table 1a
The questionnaire on farmers' knowledge, awareness and the risk of pesticides.

Questions
Part 1. Basic information
1. Gender/age/educational level
2. Family members, farmland area, crop types, income from farming and expenditure on pesticides
3. Pesticides names, types and dose for crops
Part 2. Pesticide practice
1. How do you know pesticides?
2. Where do you store pesticides?
3. How do you apply pesticides?
4. Which kinds of protection do you use when you apply pesticides?
5. How do you dispose container of pesticides?
6. Which kinds of measurements you take after applying pesticides?
7. Do you know that some pesticides have already forbidden recent years? If yes, please note them.
8. Do you know the reasons why pesticides were forbidden?

Table 1b
The questionnaire on retailers' knowledge, awareness and the risk of pesticides.

Questions
Part 1. Basic information
1.Gender/age/educational level
2. Working years and permission certificate
3.Commonly used list of pesticides information
Part 2. Pesticide selling
1. Do you give suggestions/guidelines when farmers buy pesticides?
2. Where do you think is a suitable place for pesticides storage?
3. Do you think protective measurements are necessary?
4. How to handle container of pesticides?
5. Do you know that some pesticides have been forbidden in recent years? If yes, please note them.
6. Do you know the reasons why some pesticides were forbidden?

Table 1c
The questionnaire of interviewees' cognition of the awareness and risk of pesticides on environment and human health.

Questions
1. Do you know pesticides residues?
2. Do you think pesticides are harmful for human health?
3. Do you know environment can be impacted by pesticides?
4. Do you think water pollution is related with pesticide application?
5. Do you know the relationship between pesticides and illness?
6. Do you know how to handle the risk of pesticides? If yes, please note.

were males, 68.8% and 57.4% in S1 and S2, respectively. More than half of the participants (66) in S1 were over 50 years of age, and 46 were 40–50 years old, together comprising 86.8% of the interviewees. These two age classes, however, were evenly distributed near 25.0% in S2, with a standard deviation of 6.3% in each age class. Educational levels were significantly different between the two regions. In S1, 35.9% of the respondents were illiterate, a proportion similar to that of people educated at the primary-school level. High-school education was extremely limited, with only 3.1% of the people in S1 having graduated. The majority of the respondents in S2, however, were educated in middle and high schools, comprising 58.4% of the interviewees, and only 20% of the respondents were illiterate.

3.2. Farmer income and expenditures for agrochemicals

Socioeconomic variables, including number of people and farm area per family, total income from cultivation, and total expenditure on agrochemical products, differed significantly (Table 3) between regions. According to the survey, more farmland was owned and available for farmers in S1 (0.05–0.1 ha per farmer) than in S2 (0.03–0.05 ha per farmer). Interestingly, the incomes were quite different between the regions. Families in S2 had a mean income of \$10,072.4 ha^{-1} $year^{-1}$ from cultivating vegetables (broccoli, leeks, Chinese cabbage and celery, pepper, eggplant, cucumber, tomato, summer squash, garlic, potato, onion, carrot, mushroom, and other cash crops (watermelon and sweet melon)), compared to a mean income from agriculture in S1 of \$1962.4 ha^{-1} $year^{-1}$ where only crops (maize and wheat) and fruit trees (apple, plum, nuts and pear trees) are planted in limited irrigated land. This significant difference was attributed to the structure of the agriculture, the availability of irrigation, and the long-term management of cultivation. Concerning the intensities of pesticide use in preharvest (vegetable > 5 times; crops ≤ 2 times, fruit trees ≤ 3 times), the expenditures on agrochemical products (fertilizers and pesticides) were similar in both regions, but the proportions for pesticides to the total expenditure were quite different, 0.7% and 2.7% in S1 and S2, respectively.

Table 2
Background of interviewee in two study regions.

Category	Variables	Qianyang		Chencang	
		n	%	*n*	%
Respondent		128	100	101	100
Occupation	Farmer	118	92.2	91	90.1
	Retailer	10	7.8	10	9.9
Gender	Male	88	68.8	58	57.4
	Female	40	31.3	43	42.6
Age	≤30	2	1.6	19	18.8
	30–40	15	11.7	23	22.8
	40–50	45	35.2	25	24.8
	≥50	66	51.6	34	33.7
Educational level	High school	4	3.1	26	25.7
	Middle school	34	26.6	33	32.7
	Primary school	44	34.4	19	18.8
	Illiteracy	46	35.9	23	22.8

3.3. Farmer knowledge of and behaviour towards pesticides

We analysed the level of the knowledge of pesticides of the farmers, including information sources, practices, and protective management (Table 4). Most farmers learned about pesticides by oral communication with retailers or other farmers, and 5-fold fewer farmers in S1 relative to S2 ($p < 0.01$) learned about pesticides via media, e.g. television, the internet, newspapers, or books.

Over 40% of the farmers in these two regions claimed that they seldom store pesticides at home but buy them when needed. In S1, 31.4% of the farmers admitted that they haphazardly stored pesticides, and only 22.9% of the farmers declared storing pesticides in specific storerooms. This latter proportion was similar to that in S2. Nearly half of the farmers in S1 admitted that they trusted their own experience of application rather than following the specifications on the labels of pesticide containers. The frequencies were significantly different in S2: 47.3% of the farmers obeyed the suggestions of the retailer, 30.8% followed the specifications and only 22.9% of farmers use pesticides by their own experience ($p < 0.05$).

Protective measures during and after pesticide application are considered effective means of reducing the risks to farmers. Most farmers, 65.3% and 54.9% in S1 and S2, respectively, stated that they never took any protective precautions during pesticide application because of the good quality of a lever-operated knapsack sprayer. In S1, 26.3% of the farmers used waterproof clothes, similar to the proportion in S2 (29.7%). Few farmers used masks and gloves, especially in S1. A large proportion said that they washed their hands immediately after spraying pesticides (>70%). In S2, 45.1% and 17.6% of the farmers changed their clothes and showered, respectively, but only 28.8% and 8.5%, respectively, of the farmers in S1 took such precautions to avoid the risk of exposure to pesticides. Approximately 20% of all farmers, however, responded that they took no precautions after applying pesticides. A large proportion of the farmers, 84.7% and 79.1% in S1 and S2, respectively, discarded the empty containers near the fields where they prepared the pesticides. The disposal of containers as garbage or burning or burying containers in fields were also reported, but the proportions of these methods of disposal were less than 20%.

The majority of farmers in both regions reported that they knew some kinds of pesticides had already been banned, such as DDT, hexachlorocyclohexanes, parathion, demeton, and thimet, which are all highly toxic and persistent pollutants. A lower proportion paid no attention to such bans, but the proportion was nearly 3-fold higher in S1 than in S2 ($p < 0.05$). A large proportion in S1 (>90%) did not know why these pesticides had been banned, compared to only 1.1% of the farmers in S2. The farmers in S2 believed that commercial unavailability (92.3%), the high toxicity of the pesticide (68.1%), and national control were the critical reasons for the bans, but few of the farmers interviewed in S1 knew of these reasons ($p < 0.01$).

3.4. The perception of store owners of the safe use of pesticides

The store owners knew more about pesticide use than the farmers did ($p < 0.01$) (Table 5). Nearly all the retailers in the two regions emphasised that they provided suggestions for the use of the pesticides they sold. They claimed, especially in S2, that protective measures should be taken before and after use and that new and previously purchased pesticides should be stored in storerooms away from children, water, and food. Most retailers in S2 suggested that empty pesticide containers should be recycled and buried (including burned), accounting for, 90% and 80% of interviewed retailers, respectively. Only 70% of the retailers in S1 recommended burying or burning the containers, and 30% suggested disposing of them as garbage ($p < 0.01$). All retailers in S2 admitted that national and other supervisory authorities play dominant roles in their decision to not sell banned pesticides, with toxicity being another important reason. In S1, 60% of the retailers agreed that national controls were important, and half of them thought halted

Table 3
Total income, expenditure and cost for pesticide form agricultural cultivation per family in two study regions.*

Region	Number of people per household	Farmland (ha farmer^{-1})	Total income (\$ ha^{-1} a^{-1})	Total expenditure (\$ ha^{-1} a^{-1})	Pesticides cost (\$ ha^{-1} a^{-1})
Qianyang	5–7	0.05–0.10	1962.4	364.9 (18.6%)	14.3 (0.7%)
Chencang	3–6	0.03–0.05	10,072.4	1855.2 (18.4%)	265.1 (2.7%)

* 1\$ = 6 RMB.

production was also an important reason for the banning or unavailability of pesticides, lower than the proportion in S2 ($p < 0.01$).

The commonly applied pesticides in the study area are listed in Table 6, based on the information and permission of the retailers. Insecticides were used more frequently than fungicides and herbicides at a ratio of 2:1:1. Some organophosphorous pesticides had already been banned, but some such as parathion and phoxim were still available in the stores.

3.5. Farmer and retailer awareness of the dangers of pesticides to human health and the environment

The investigation of the awareness of the dangers of pesticide use to human health and the environment provided interesting results in these two selected regions (Table 7). Over half of the interviewees declared they knew that pesticides left residues. In S2, 92.1% of the interviewed people believed that pesticides were harmful to human health, but 46.9% of the people in S1 held the opposite attitude on this affair ($p < 0.01$). Opinions on the effects of pesticides on the environment were significantly different: 43.6% of the people in S2 thought that pesticides could affect environmental quality, but 49.2% of the interviewees in S1 "had no idea" ($p < 0.01$). More specifically, the similar proportions in these two regions suggested that water pollution was seen to be related to pesticide use, but most farmers did not clearly understand the relationship between them. Furthermore, S1 and S2 differed significantly in the understanding of the relationship between illness and pesticides ($p < 0.01$). The majority of farmers (79.7%) in S1 did not think that illness was related to pesticide use. In contrast, 67.3% of the interviewees in S2 were certain of the relationship, and very few denied it. The proportion of people in S2 who knew nothing about the relationship between illness and pesticides was similar to the proportion of people in S1 who admitted that illness was related to pesticides.

Most of the people in these two regions knew how to deal with the dangers of pesticides, but nearly 40% did not. The methods used to avoid the dangers of pesticides differed between the two areas ($p < 0.01$). In S1, 31.2% and 28.1% of the people assumed that recycling the containers and using protective measures, respectively, would reduce the risks, followed by using less toxic pesticides (19.5%) and reducing the pesticide dosage (12.5%). In S2, 61.4% of the people thought that recycling the containers was the best way to reduce risks, and 39.6% thought that using less toxic pesticides was also an important method. Using protective measures (10.9%) and reducing the dosage of pesticides (11.9%) were only considered as alternative methods.

The dominance tendency of the perception shows overall resemblance among interviewees and doesn't reveal any major influencing factors. For this reason, a statistical method, canonical correspondence analysis (CCA), was used to implement a factorial analysis. CCA analysis was performed on the basis of backgrounds of interviewee (Table 2) and revealed perception of pesticide risks (Table 7). The perception–background relationship is depicted in Fig. 2, an ordination diagram in which the first two canonical axes are in the horizontal and vertical

Table 4
Farmers' knowledge and behaviours with respect to pesticide.

Questions	Variables	Qianyang ($N = 118$)		Chencang ($N = 91$)	
		n	%	*n*	%
How you do you know pesticides (including new products)?					
$\chi^2 = 14.1^{**}$	Retailers	69	58.5	44	48.4
	Other farmers	44	37.3	27	29.7
	TV/Internet/papers/books	5	4.2	20	22.0
Where do you store pesticides?					
$\chi^2 = 1.3$	Specific storeroom	27	22.9	27	29.7
	Random	37	31.4	25	27.5
	Purchase when used	54	45.8	39	42.9
How do you apply pesticides?					
$\chi^2 = 18.6^{**}$	Follow specifications	15	12.7	28	30.8
	By experience	58	49.2	20	22.0
	By retailer	45	38.1	43	47.3
Which kinds of protection do you use when you apply pesticides?					
$\chi^2 = 8.5^{*}$	Mask or respirator	10	8.5	14	15.4
	Water-off clothes	31	26.3	27	29.7
	Wear gloves	7	5.9	16	17.6
	No protection	77	65.3	50	54.9
How do you dispose container of pesticides?					
$\chi^2 = 1.0$	Drop it directly	100	84.7	72	79.1
	Throw it to garbage	16	13.6	17	18.7
	Burning/burying	2	1.7	2	2.2
Which kinds of measurement you take after applying pesticides?					
$\chi^2 = 5.3$	Wash hands	90	76.3	66	72.5
	Showering	10	8.5	16	17.6
	Changing cloths	34	28.8	41	45.1
	Never mind	20	16.9	19	20.9
Do you know some pesticides have been forbidden in recent years? If yes, please note them.					
$\chi^2 = 6.1^{*}$	Yes	102	86.4	87	95.6
	No	16	13.68	4	4.4
Reasons about forbidden pesticides					
$\chi^2 = 272.3^{**}$	Forbidden by nation	1	0.8	46	50.5
	Stop to sell	4	3.4	84	92.3
	High toxic	5	4.2	62	68.1
	Have no idea	108	91.5	1	1.1

Significant difference between the study regions: * $p < 0.05$; ** $p < 0.01$.

Table 5
Retailers' knowledge and behaviours with respect to pesticides.

Questions	Variables	Qianyang ($N = 10$)		Chencang ($N = 10$)	
		n	%	*n*	%
Whether you give suggestions/guides when farmers buy pesticides?					
$\chi^2 = 10.5^{**}$	Yes	9	90	10	100
	No	1	10	0	0
Do you think protective measurements are necessary for pesticides use?					
$\chi^2 = 12.5^{**}$	Necessary	7	70	9	90
	Never mind	3	30	1	10
Where is suitable place to store pesticides?					
$\chi^2 = 22.2^{**}$	Storeroom	8	80	10	100
	Never mind	2	20	0	0
How to handle the container of pesticides?					
$\chi^2 = 84.7^{**}$	Drop directly	3	30	1	10
	Bury/burning	7	70	8	80
	Recycling	0	0	9	90
Reasons about forbidden/unavailable pesticides					
$\chi^2 = 46.1^{**}$	Nation	6	60	10	100
	Stop to produce	5	50	2	20
	High toxic	2	20	8	80

Significant difference between the study regions: **$p < 0.01$.

Table 6
The list of pesticide used in study area.

Registered name[a]	Commercial name[b]	Active ingredient	Type
Carbendazim	Kebaiwei	80% Carbendazim	Fungicide
Cymoxanil	Shuangniaoqin	12% Cymoxanil, 38% Propineb	Fungicide
Mancozeb	Daisenmengxin	80% Mancozeb	Fungicide
Metalaxyl-propamocab	Jiashuanglin	15% Metalaxyl, 10% Propamocab	Fungicide
Thiophanate	Topsin-M	70% Thiophanate-methyl	Fungicide
Triadimefon	Sancuotong	15% Triadimefon	Fungicide
Zineb	Daisenxin	80% Zineb	Fungicide
Carfentrazone	Zuocaotong	14% Tribenuron-methyl 22% carfentrazone	Herbicide
Butylate	Dingcaodi	2,4-D butylate	Herbicide
Glyphosate	Caoganlin	41% Glyphosate isopropylamine salt	Herbicide
Mesosulfuron	Jiajierhuanglong	30 g l^{-1} Mesosulfuron-methyl	Herbicide
Oxyfluorfen	Guo'er	240 g l^{-1} Oxyfluorfen	Herbicide
Paraquat	Baicaoku	200 g l^{-1} Paraquat	Herbicide
Pendimethalin	Xiaocao'an	330 g l^{-1} Pendimethalin	Herbicide
Tribenuron-methyl	Benhuanglong	40% Tribenuron methyl	Herbicide
Chlorpyrifos	Dusibi	40% Chlorpyrifos	Insecticide
Chlorpyrifos-phoxim	Duxin	10% Chlorpyrifos, 30% Phoxim	Insecticide
Decis	Dishasi	25 g l^{-1} Decamethrin	Insecticide
Dichlorvos	DDV	77.5% Dichlorvos	Insecticide
Dimethoate	Leguo	40% Dimethoate	Insecticide
Dipterex	Dibaichong	90% Trichlorphon	Insecticide
Imidacloprid	Pichonglin	50% Imidacloprid	Insecticide
Lambda-cyhalothrin	Kungfu	5% Lambda-cyhalothrin	Insecticide
Matrine	Kusenjian	0.36% Matrine	Insecticide
Omethoate	Yanghualeguo	40% Omethoate	Insecticide
Oxadixyl.mancozeb	Shadufan	6% Oxadixyl 58% Mancozeb	Insecticide
Parathion [c]	Duiliulin	Parathion	Insecticide
Phoxim [c]	Xinliulin	25%/40% Phoxim	Insecticide
Phoxim-phorate	Jiabanlin	10% Phoxim-phorate	insecticide
Pyridaben	Damanlin	15% Pyridaben	Insecticide

[a]The name was registered in China.
[b]The commercial name is used in China.
[c]The pesticide was banned.

Table 7
Awareness of pesticides risk on environment and health of interviewees (farmers and retailers).

Questions	Variables	Qianyang ($N = 128$)		Chencang ($N = 101$)	
		n	%	*n*	%
Do you know pesticide residues?					
$\chi^2 = 0.5$	Yes	69	53.9	54	53.5
	No	29	22.7	27	26.7
	Have no idea	30	23.4	20	19.8
Do you think pesticides are harmful for human health?					
$\chi^2 = 85.9^{**}$	Yes	36	28.1	93	92.1
	No	32	25.0	1	1.0
	Have no idea	60	46.9	7	6.9
Do you think environment can be impacted by pesticides?					
$\chi^2 = 18.0^{**}$	Yes	23	18.0	44	43.6
	No	42	32.8	31	30.7
	Have no idea	63	49.2	26	25.7
Do you think water pollution is related with pesticide application?					
$\chi^2 = 0.9$	Yes	40	31.3	37	36.6
	No	30	23.4	19	18.8
	Have no idea	58	45.3	45	44.6
Do you think illness is related with pesticide application?					
$\chi^2 = 58.9^{**}$	Yes	26	20.3	68	67.3
	No	59	46.1	5	5.0
	Have no idea	43	33.6	28	27.7
Do you know how to handle the risk of pesticides?					
$\chi^2 = 1.0$	Yes	72	56.3	64	63.4
	No	0	0	0	0
	Have no idea	56	43.7	37	36.6
Measurements to reduce the risk of pesticide application					
$\chi^2 = 18.8^{**}$	Reduce dose	16	12.5	11	10.9
	Use protection	36	28.1	12	11.9
	Recycle container	40	31.3	62	61.4
	Low toxic instead	25	19.5	40	39.6

Significant difference between the study regions: $^{**}p < 0.01$.

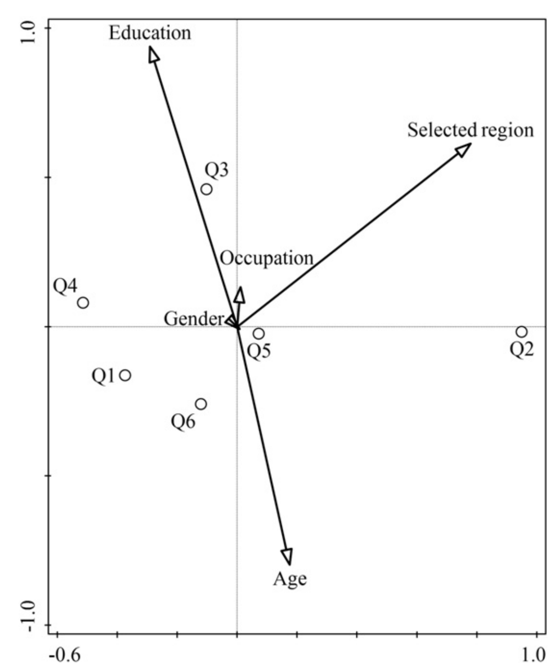

Fig. 2. Biplot of perception of pesticide risks and backgrounds of interviewees under CCA as constructed according to data collected. Full questions are presented in Table 1c. Q1: Do you know pesticide residues? Q2: Do you think pesticides are harmful for human health? Q3: Do you know environment can be impacted by pesticides? Q4: Do you think water pollution is related with pesticide application? Q5: Do you know the relationship between pesticides and illness? Q6: Do you know how to handle the risk of pesticides?

direction, respectively, and the arrows represent the different background variables. The direction of the arrows represents the correlation between each variable and the canonical axes, and each other, whereas the length of the arrows represents the relative a contribution of the variables to the axes and the perception–background relationship. Generally, the first canonical axes represent an estimated 71.6% of the variation in the perception–background of pesticide risk and the first two represent an estimated 86.9%. Selected region, education, and age were significantly correlated with the responses to the dangers of pesticides (permutation test, $p < 0.01$) (Table 7), but occupation and gender were not (Fig. 2). The opposite directions of the arrows for education and age in Fig. 2 indicated that these two factors had opposite influences on the awareness of the dangers of pesticides. The location of gender and occupation near the origin of the coordinates indicated that the effects of these two factors on the understanding of the dangers of pesticides were similar and could not vary the percentage of the explanation of understanding on the canonical axis. Consequently, selected region, education, and age were important factors in promoting the understanding of the dangers of pesticides to the environment and human health.

4. Discussion

The level of knowledge of pesticides of the stakeholders is vital for providing sound strategies for reducing environmental and health risks. As the end sellers and users, retailers and farmers play important roles in the safety of pesticide use, especially in rural areas. This study was intended to evaluate the attitudes and levels of awareness of pesticide safety to address reasonable measures for avoiding the dangers of pesticides and for reducing potential pollution to agricultural systems. Men appeared to take more responsibility than did women to purchase and spray pesticides which is related the roles acted in the family. The gender-specific knowledge of pesticide use seems to be a precaution to the dangers of exposure (Atreya, 2007), especially for women living in rural regions (Cui, 2009). Age and educational level differed significantly in our study between the two regions. The levels of knowledge of pesticide safety were insufficient in older and less educated interviewees. Recena et al. (2006) and Ibitayo (2006) reported that a low level of education among farmers hampered their ability to follow the hazard warnings provided by the chemical industry and regulatory agencies. The lack of education has been associated with poisonings, suicides, exposure risks, and high mortality rates in many rural areas of developing countries (Phillips et al., 2002; Zhou et al., 2011; Zyoud et al., 2010).

Salameh (2004) claimed that adequate and reliable sources of information seemed to induce the perception of risk and the adoption of preventive measures, despite the low general level of education of the subjects involved. Oral communication with retailers and among farmers played a dominant role in learning about pesticides and their functions. Although some media channels provide information about the control of pests and diseases in cultivation, media advertising seems an inadequate mean to provide information about pesticides. Participants said that information provided by television was difficult to apply because of differences from the real conditions of cultivation. The distrust of pesticide advertisements led to a strong reliance on the information provided by distributors and neighbours and on the personal experience of the farmers. Accordingly, based on their own experiences, farmers would likely overuse or mix pesticides unaware of the negative interactions among the various active ingredients. Mixed pesticides not only lose efficacy but may also enhance the hazards to the sprayer and the environment (Karunamoorthi et al., 2011).

Correct application, proper protective measures, and good personal hygiene are considered to be good practices for the safe spraying of pesticides (Matthews, 2008). Dasgupta et al. (2007) reported that increasing the use of protective measures could decrease the probability of poisoning by 44.3%. The lack of protective measures can lead to unpredictable hazards when farmers load their sprayers and walk through their treated crops (Recena et al., 2006). The high incidence of adverse symptoms (intoxication) such as cephalea, dizziness, vomiting, and skin problems have been reported after pesticide use (Ngowi et al., 2007a,b; Recena et al., 2006; Yassin et al., 2002). Most respondents in our study said that they applied pesticides without taking any protective measures. They also claimed that special protective gear, such as waterproof clothes or masks, were uncomfortable to wear in summer and even, in some cases, unnecessary during the limited time of spraying. In addition, personal hygiene, e.g. washing hands, changing clothes, and showering, is another way to avoid poisoning after pesticide application (Dasgupta et al., 2007). Unfortunately, some farmers ignore such measures, which is circumstantial evidence that the danger of poisoning is higher when no precautions are taken when using pesticides (Ngowi et al., 2007a).

The methods of storing and disposing of pesticide containers are also critical points of intervention to enhance the awareness of safety during the application of pesticides (Matthews, 2008). Storing pesticides in the home can easily contaminate drinking water and food and can threaten the health of children. Matthews (2008) reported that 62% of 8500 smallholders in 26 countries stored pesticides, and 68% of this group stored the pesticides in locked locations. Similarly, over 50% of the farmers in our survey stored pesticides, but approximately half of this group stored them in their homes. The interesting point is that about 40% of the farmers had never stored pesticides, which is a good option for reducing the dangers of pesticides. Some larger countries recycle pesticide containers despite having contained dangerous chemicals (Matthews, 2008; Salameh, 2004). We often observed farmers discarding empty plastic bags and bottles in wells or ditches where the pesticide solutions were prepared. This observation was supported by the responses of the interviewed farmers. Pesticide residues in empty containers may be released or washed into the surroundings by rain and/or irrigation. This uncontrolled discharge of pesticide pollutants can easily contaminate agricultural soil and water and also threaten human health and ecosystem quality (Hvistendahl, 2013; Ibitayo, 2006). The responses and practices of the farmers suggested that S1, a hilly area with severe soil erosion, was at a greater risk than S2 to the dangers of pesticide use.

Since the publication of Rachel Carson's *Silent Spring*, more attention has been paid to the problems triggered by pesticides. Several pesticides have been banned in the last three decades due to their ecotoxicities and long half-lives. The reasons for these bans were not clear to the farmers. Some environmentally friendly pesticides are produced, but a few banned pesticides are still commercially available (Table 6). Effective legislation and strict supervision should be improved to monitor the production and circulation of pesticides. Admittedly, economics is another factor why farmers ignore the dangers of pesticides (Uri, 1998). Farmers claimed that expenditure was an important factor in the purchase of pesticides. Our survey and calculations, however, indicated that expenditures on pesticides were less than 3% of the total agricultural income, so farmers were not likely to reduce pesticide use for economic reasons. Furthermore, pesticide consumption and use involves several stakeholders, such as authorities, producers, retailers, and farmers. The owners of local pesticide stores, as the final links in the economic chain, play an important role in disseminating pesticides and guiding their use for farmers and agricultural workers. In this study, most retailers provided guidance to farmers on the use of pesticides and on the protective measures available for their application. The retailers, however, revealed that farmers were reluctant to adopt these measures, preferring to rely on their own experience and the influence of their neighbours and ancestors (Matthews, 2008; Yassin et al., 2002; Zyoud et al., 2010). Compared to farmers, retailers were either more familiar with the products or were more aware of the reasons why some pesticides had been banned, implying that the retailers in the study areas have the ability to interpret and provide advice on the active ingredients, functions, and application dosages of pesticides.

The perception of risk is an important element in developing effective campaigns of education and communication (Damalas et al., 2008). The prevalence of pesticide poisoning decreased from 1.05% to 0.25% after a safety educational programme (Chen et al., 1998). An awareness of the dangers of pesticides to the environment and human health reflects a consciousness of self-protection and a responsibility to the surroundings (Ibitayo, 2006). In our study, only some of the basic information on pesticide residues was known, and the levels of awareness of the dangers of pesticides to human health were significantly different between the selected areas. Some aspects of the relationships between pesticides and environmental factors and human health were unclear and sometimes unknown. Gender, age, educational experience, and even location were all correlated with vague responses (Fig. 2). These correlations suggest that educational programmes should be specifically targeted to improve the self-protective consciousness of farmers to the use of pesticides, especially in the rural regions of developing countries.

5. Conclusions

This study indicated that farmers are exposed to the dangers of pesticides in the Wei River catchment, especially in S1, a hilly region. Even though some protective measures are taken, the farmers seem to be unaware of the true risks from the use of pesticides. Retailers are well-informed and have a strong understanding of, and sense of responsibility towards, pesticide application. The awareness of the dangers of pesticides to human health and the environment, however, is still limited in these two study areas. The canonical coordination analysis indicated that older and poorly educated people are most at risk. Therefore, measures to reduce pesticides risks can be grouped into three categories:

1. Those related to applying pesticides (farmers and retailers).
2. Those related to producing pesticides (factories).
3. Those related to supervising pesticides (authorities).

According to this survey, the steps for reducing pesticide effects on farmers would be considered. The pressing step, supposedly, is to implement some educational programmes for farmers in non-harvesting time (normally in winter). Understandable activities, such as lectures, pictures, videos and some interesting shows which reflect the pesticide risk on health and environment, can be held based on farmers' age in rural regions. At the same time, many strict procedures on pesticide registration should be concerned and the detail information of pesticides should be labelled especially marking the level of toxicity for human health. The supervisory mechanism and environmental monitoring systems for pesticides should be strengthened and the nation scale survey on safety use of pesticide and its risk on environment and human health should also be evaluated. The large agricultural population in China suggests that all stakeholders, including governmental agencies, producers, retailers, and farmers, should unite to address the risks from the use of pesticides for farmers and the environment.

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