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Original article

Health Risk of Potato Farmers Exposed to Overuse of Chemical Pesticides in Iran

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ABSTRACT

Background: Potato is the main crop of Ardabil Plain (accounting for one-fifth of potato production in Iran). Its health hazard risk to farmers is rising due to the increasing rate of pesticide use. The present study analyzes potato farmers' health hazard risk in the use of chemical pesticides.
Methods: The rate of pesticide use by farmers (n = 370) was first compared with the recommended dosage (on pesticide label). Then, a composite index was employed to estimate the health hazard risk of farmers during pesticide use, and the variables accounting for pesticide overuse and nonoveruse were analyzed. Safety behavior was examined in four steps, namely of pesticide purchase and storage, preparation, application, and postapplication.
Results: It was found that 74.6 percent of potato farmers used pesticides in higher concentrations than the recommended dosage. The higher average rate of pesticide use versus recommendation (label instruction) was related to Chlorpyrifos and Trifluralin, and the highest average health hazard risk among farmers was related to the use of Chlorpyrifos and Metribuzin. Farmers with a higher risk of health hazard displayed much lower safety behavior than the other farmers at all steps of pesticide use.
Conclusion: The most important variables discriminating the health hazard risk of farmers' overuse included health behavior identity, attitude, knowledge and awareness, and cues to action. Therefore, using social media, holding local exhibitions, and engaging local leaders and skilled farmers in the region to improve farmers' attitudes and health behavior identity toward the dangers of chemical pesticides can play a significant role in motivating farmers' display of overuse preventive behaviors.

1. Introduction

Potato is the most important crop of the Ardabil Plain (in northwestern Iran) and is the fourth most important agronomic crop of the world after wheat, rice, and maize [1]. Pests and diseases associated with the crop (such as the Colorado potato beetle (Leptinotarsa decemlineata Say) have shown an increased rate of resistance to pesticides in recent years [2,3]. The success of modern agriculture in recent decades has mainly been at the expense of tremendous consequences for natural capital and the safety of farmers and crops [4,5]. For example, Yildirim et al. [6], Blair et al. [7], and Niyaki et al. [8] attributed the increasing rate of gastrointestinal cancers to the effects of chemical pesticides in parts of Northern Iran and Turkey.

The health hazard risks of pesticides do not depend only on their toxicity but also reflect the likelihood of exposure during excessive overuse. Toxicity is the potential of a compound to cause disease or even death, while health hazard risk refers to a combination of toxicity and exposure to poison during overuse [9]. Therefore, farmers, compared to most occupations, are exposed to higher health hazard risks by contact with pesticide residues. This is more likely to be observed among overuse farmers [10]. The decision by farmers to overuse chemical pesticides can be rooted in their protective and safety measures that are often derived from their context, beliefs (model of health belief), attitudes, and intention (the theory of planned behavior) [11–13]. Based on contextual factors (demographics, knowledge, health value, perceived severity, and perceived susceptibility) and under the influence of health

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behavior identity, the examination of benefits and barriers, and the attitude toward displaying a safety behavior, farmers make an intentional decision at which stage the variables of cues to action, subjective norms, and self-efficacy will be involved to lead to a protective and safe behavior by farmers [10,14]. To practice protective and safe behavior, a farmer should first feel the risk (perceived susceptibility), then he/she should perceive the seriousness of the risk (perceived susceptibility and severity), and in case of a positive assessment (attitude) of benefits, he/she will take protective measures by considering the barriers [15]. In this regard, the variables of attitude, subjective norms, and self-efficacy will finally lead to the accompanying intention to predict an individual's protective behavior [16]. Safety behavior in the use of chemical pesticides by farmers depends on various factors such as personal characteristics such as age, education level, and experience in agriculture [17–20]. In addition, some economic characteristics such as farmer income also affect the safety behavior of farmers in the use of chemical pesticides [17,20,21]. Several studies [10,9,22] report that most farmers tend to overuse pesticides by exceeding the dosage recommended on the labels. Although most farmers usually read instructions on pesticide labels, half of them never use personal protective equipment when working with pesticides and lack a suitable health behavior identity and self-efficacy in taking care of safety and health principles [23]. Strong et al. [24] revealed a positive and significant relationship between farmworkers' attitudes when exposed to pesticides. They found that most local farmworkers believed that unsafe use of chemical pesticides was very harmful to their health, their children's health, and the environment. However, farmworkers, despite their good knowledge of the safety hazards of chemical pesticides, may use less protective equipment in practice due to high costs or lack of access to protective equipment. Similarly, Padmajani et al. [25] stated that toxicity levels and toxin hazards of pesticides are not among most farmers' decision priorities for selecting or overusing them because they believe that these pesticides have faster and more cost-effective results than other pesticides (perceived benefits), so they ignore their toxicity and fatal nature and even feel that it is necessary to overuse pesticides for greater yields (health behavior identity). In addition, the overuse of a pesticide by farmers sometimes emanates from their or other farmers' previous experience of the ineffectiveness of the permissible level recommended on the label (subjective norms), a finding that is evident in the results of Prasadi and Wathugala's [22] study. Knowledge about the harmful effects of chemical pesticides and their health perils, perceived susceptibility, and perceived severity plays a critical role in performing safe and preventive behaviors by farmers when deciding on dosage [10,12].

The yield and quality of potatoes are very sensitive to weeds [26]. Together with this, pests of this crop have growingly increased in recent years. Consequently, the application of pesticides has risen remarkably, presently making this a major challenge in this plain [24,25].

Taking into account the aforementioned concerns regarding the overuse of pesticides by farmers in recent years, this study investigates the status of farmers' use of pesticides and their protective behavior process, as well as identifies the factors that influence the health hazard risks of farmers when they work with chemical pesticides.

2. Methodology

2.1. Study area

Ardabil Plain is a region with agriculturally fertile land located in the central part of Ardabil Province, Iran. The plain covers an area of approximately 900 km^2 in the northwest of Iran. It encompasses three counties – Ardabil, Namin, and Nir. With 28,000 ha of potato-growing lands and accounting for one-fifth of the total potato-producing of Iran, Ardabil is the leading potato-producing region of Iran.

2.2. The study design and sample selection

A cross-sectional research design was adopted for the study. Data was collected from April to December 2019 in Ardabil Plain (Ardabil Province, Iran). Due to the scattered population of study participants geographically and the need for the presence of researchers in the study districts, a multistage sampling method was used to finalize the sample size [27]. The population under study comprised all active potato farmers using irrigated systems in Ardabil Plain and who themselves used chemical pesticides on their farms ($N = 4786$). The first stage targeted potato farmers residing in the three counties of Ardabil County, Namin, and Nir in the Ardabil Plain. In the second stage, 16 villages were randomly selected from the counties in proportion to their farmer populations and geographical distribution. Accordingly, eight villages from Ardabil County, five from Namin County, and three from Nir County were selected. In each village, with the help of generating random numbers in Excel and based on the list obtained from the agricultural jihad organizations of the counties, agricultural service centers, and village councils, the final respondents were randomly selected. This resulted in 370 farmers being randomly selected from the villages (in proportion to their populations and geographical distribution) using the table of Bartlett et al. [28]. This number included 193 potato farmers from Ardabil County, 104 from Namin County, and 73 from Nir County. Data were collected face-to-face through interviews with potato farmers in Ardabil Plain.

2.3. Survey instrument

The research instrument was a structured four-section questionnaire. The first section requested information on the demographic and occupational characteristics of potato farmers (i.e. age, gender, education, experience in farming, family size, farm size, potato crop yield, annual agricultural income, annual off-farm income, and the number of owned pieces of machinery). The second section included 21 open-ended questions to introduce and ascertain the rate of pesticide use for potato crops per ha. The third section sought data on protective measures (safety behavior) in four steps of chemical pesticide use (including pesticide purchase and storage (six items), preparation (five items), application (nine items), and postapplication (five items)). Items in this section were measured using a Likert-type measurement scale ranging from 0 (never) to 5 (very high). Finally, the fourth section was related to the safety behavior of farmers when using chemical pesticides. It included questions on knowledge and awareness, attitude toward applying pesticides [20,10]; health value [29–31]; perceived susceptibility, perceived severity [30,12,31]; health behavior identity [31,32]; perceived benefits, perceived barriers [13,30,32]; behavioral intention; subjective norms; referring to action; and controlled beliefs (self-efficacy) [31–33]. Likert-type scales were used to measure these variables. The results are presented in Table 1 [13,23]. For ensuring the content and face validity of the questionnaire, it was assessed by a panel of faculty members, as well as experts from the Agricultural Jihad Organization of the Province and Healthcare Center of Ardabil County, whose comments were applied to finalize the questionnaire. Cronbach's alpha was computed to assess the reliability of the questionnaire. This was found to be acceptable (estimated at >0.7 (Pallant)). Descriptions of the main variables of the research are provided in Table 1 with additional details.

Table 1
Description, frequency distribution, and examples of items for the main research variables

Variables	Explanation	Cronbach's alpha	Median	Range	Examples of items
Age	- The age of each farmer (years)	—	46	20–78	—
Education	- The number of years of formal education (years)	—	13	0–18	—
Experience in agriculture	- The number of years of experience in agriculture (years)	—	23	3–64	—
Farm income	- Average annual income of the farmer from on-farm activities (million IRR*)	—	1,700	500–6200	—
Knowledge	- This is measured as the sum of eight items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.73	19	8–31	- "Continued and abundant use of chemical pesticides makes pests resistant to toxins. "; "Excessive use of chemical pesticides causes pollution of surface and groundwater." And …
Perceived severity	- This is measured as the sum of seven items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.78	15.5	8–29	- "It scares me to think about the side effects of unsafe pesticides. "; "If I suffer from the effects of chemical pesticides, it will be more serious than other diseases." And …
Perceived susceptibility	- This is measured as the sum of five items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.70	20	7–50	- "I have a chance of being poisoned by chemical pesticides"; "My physical condition makes me more likely to suffer from the effects of chemical pesticides." And …
Health value	- This is measured as the sum of sex items ranging from 1 (very low) to 5 (very high).	0.82	17	7–26	- "I pay attention to health content on public media (radio, television, social media, etc.)." "I participate in health education programs." And …
Health behavior identity	- This is measured as the sum of five items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.69	15	5–25	- "Using safety equipment in the use of pesticides is the right behavior," "Safe disposal of pesticide residues is valuable work to protect the environment." And …
Attitude	- This is measured as the sum of seven items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.72	28	7–66	- "Unsafe use of chemical pesticides in agriculture endangers human health;" "Excessive use of chemical pesticides does not increase crop yield." And …
Perceived benefits	- This is measured as the sum of five items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.72	16	5–35	- "I can save more money by reducing the use of chemical pesticides;" "Observing safety principles in the use of chemical toxins prevents harm to my health and that of my family members." And …
Perceived barriers	- This is measured as the sum of sex items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.74	15	6–25	- "Observing safety tips for using pesticides is costly;" "Studying pesticides labels is difficult to determine the appropriate dose of pesticides."

(continued on next page)

Table 1 (*continued*)

Variables	Explanation	Cronbach's alpha	Median	Range	Examples of items
Intention	- This is measured as the sum of sex items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.78	28.5	6–56	- "I plan to reduce the use of pesticides on my farm in the future;" "I plan to read the full label of the pesticide before using it in the future." And …
Cues to action	- This is measured as the sum of five items ranging from 1 (very low) to 5 (very high).	0.69	23	5–41	- "I follow the advice of experts on the observance of safety principles in the use of pesticides;" "I watch TV and radio shows about the dangers of chemical pesticides." And …
Self-efficacy	- This is measured as the sum of eight items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.70	31	8–65	- "I can produce the same amount of current product with less pesticide consumption;" "I can use alternative methods of pesticides in the production of products." And …
Subjective norms	- This is measured as sum of sex items ranging from 1 (strongly disagree) to 5 (strongly agree).	0.69	24	6–49	- "In the use of pesticides, the opinions of friends and acquaintances are important to me;" "Farmers who used more pesticides also harvested more." And …
Supply and storage	- This is measured as sum of sex items ranging from 0 (never) to 5 (very high).	0.72	20	2–29	- "Following the recommendations of agricultural experts in selecting chemical pesticides;" "Acquiring adequate knowledge of correct storage of pesticides." And …
Preparation of pesticides	- This is measured as the sum of five items ranging from 0 (never) to 5 (very high).	0.70	16	2–25	- "Using protective equipment when mixing pesticides;" "Reading instructions on the label of pesticides carefully before use." And …
Using of pesticides	- This is measured as the sum of nine items ranging from 0 (never) to 5 (very high).	0.73	28	3–43	- "Using mask"; "Wearing safety glasses" And …
After using of pesticides	- This is measured as the sum of five items ranging from 0 (never) to 5 (very high).	0.74	14	2–25	- "Washing hands, face, and body after pesticide application"; "Disposing cans and pesticide residues safety" And …

2.4. Data analysis

Data were analyzed in two phases – the phase of data description and the phase of their inferential analysis. Frequency, percentage, mean and standard deviation were used in the descriptive phase, while the inferential phase made use of coefficients of correlation, binary logistic regression, and discriminant analysis.

2.5. Farmers' health hazard risk (a composite index of chemical pesticide dosage)

The health hazard risk of potato farmers' exposure to chemical pesticides (based on the toxicity degree of pesticides) was estimated by a composite index (CI) [17]:

$$CI_f = \sum (I_p \cdot W_p) = \sum \left(\frac{X'_p}{X_p} \cdot W_p\right) = \left(\frac{X'_1}{X_1} \cdot W_1\right) + \left(\frac{X'_2}{X_2} \cdot W_2\right) + \left(\frac{X'_3}{X_3} \cdot W_3\right) + \ldots + \left(\frac{X'_s}{X_s} \cdot W_S\right)$$

CI_f = Composite index: the number of pesticides used based on health hazard and f (farmer) = 1, 2, 3 …, 370.

X'_p = The amount of standard dosage of pesticide per unit ha (% active ingredient) and p (pesticide) = 1,2,3 …,8.

Xp = The amount of pesticide used by the farmer per unit ha (% active ingredient) and p (pesticide) = 1,2, 3 …,8.

W_p = Index weight based on WHO toxicity class of pesticide (1,2,3 …,5); and p (pesticide) = 1,2, 3 …,8.

To determine CI_f, one should first calculate the main index, which is obtained from dividing the pesticide application rate by farmers

Table 2
Mean and standard deviations of the demographic characteristics

Variables	Mean	SD	Min	Max
Age (years)	46.53	1.371	20	78
Education (years)	9.39	5.760	0	18
Agricultural experience (years)	23.63	11.625	3	64
Household size (members)	4.03	1.584	2	11
Farm size (ha)	5.02	3.488	1.0	30
Potato yield (t/ha)	35.44	7.332	15	46
Annual farm income (million IRR*)	1606.49	923.06	500.00	6200
Annual off-farm income (million IRR)	179.35	100.778	10	620
Ownership of agricultural machinery (no.)	2.03	1.335	0	5

* 1 US dollar ≈ 130 000 Iranian Rials (IRR) at 2018.

(per unit ha) in the permissible (standard) rate. Therefore, we first determined the rate of pesticide use (based on % active ingredient) per ha (X_p). Then, the main index was determined for each farmer for the standard rate of use (X'_p) as per the instruction on the label [35]. In the third step, we needed to conclude the health hazard of the pesticides (W_p), for which we used the weights of 1, 2, and 3 for chemical pesticides as per their toxicity and dangers for farmers' health (mentioned in Table 3) [35–41]. Consequently, it calculated the ratio of farmers' use of pesticides to the recommended dosage (as per the instruction on the label) and obtained the final indices using the weights for the coefficient of their health hazard. This showed the level of health hazard risk for each farmer versus other farmers. Finally, the indices obtained for the pesticides were summed up to provide the total composite index. To avoid the error of nonuniform measurement units (g and mL of the active ingredient) in calculating the total composite index, the measurement unit of ml was considered to be roughly equal to 1 g. Therefore, the measurement units of pesticide use indicators were considered to be equivalent when calculating CI_f in order to make it possible, to sum up the indices to give the total composite index.

For analyzing the variables underpinning health hazard risk, overuse farmers were divided in terms of percentage ratio into three groups – low health hazard risk (the first 1–33% of CI_f), moderate health hazard risk (the second 34–67% of CI_f), and high health hazard risk (the third 68–100% of CI_f) [34]. It should be noted that farmers from the study area used four herbicides (Paraquat (Gramaxon, 20% SL), Metribuzin (Sencor, 70% WP), Glyphosate (Roundup, 41% SL), and Trifluralin (Treflan, 48% EC)), three insecticides (Imidacloprid (Confidor, 35% SC), Diazinon (Basudin, 10% G) and Chlorpyrifos (Dursban, 40.8% EC)), and one fungicide (Chlorothalonil (Daconil, 72% SC–75% WP)). Furthermore, 69% of farmers used only boots, gloves, and face masks as personal protective equipment when using pesticides. However, the uses of safety glasses (12%) and respirators (9%) were the last priorities, respectively.

3. Results

3.1. Demographic characteristics

Table 2 provides the mean values of variables, which are as follows: age (46.53 years); education (9.39 years); agricultural experience (23.63 years); average annual farm income (1606.49 million IRR); household size (4.03 persons); farm size (5.02 hectares); average potato yield (35.44 t/ha), average annual off-farm income (179.35 million IRR); and the number of agricultural machinery owned (2.03).

3.2. Health hazard risk of farmers (a composite index of pesticide application dosage)

Table 3 indicates that the average rate of pesticide use was higher than recommended for all farmers, implying that farmers overused pesticides. The highest rate of pesticide use versus recommendation (label) was related to Chlorpyrifos (2.838) and Trifluralin (2.190). With respect to toxicity class, the pesticides that farmers used on their potato farms belonged to toxicity class U (weight factor of 1) and toxicity class II (weight factor of 3). Additionally, the highest average health hazard risk factor among farmers was related to Chlorpyrifos (8.514) and Metribuzin (5.223) (Fig. 1). Looking at the application of the individual pesticides by farmers, it was revealed that 74.6 percent of farmers (279 persons) overused pesticides, and only 24.6 percent (91 persons) used them within the permissible levels or less than recommended.

3.3. The safety behavior steps of pesticide use (protective measures) and correlation of farmers' health hazard risk (the composite index) with them

At this phase, the safety behavior steps of pesticide use were defined as purchase and storage, preparation, application, and postapplication. Table 4 reveals that the main protective measures used by the participants were "determining appropriate pesticide type for the pest and disease and checking its production and expiring dates," "preparing pesticides outside the house," "using boots," and "changing the suit after pesticide application," respectively. Furthermore, there is a negative, significant correlation

Table 3
Indices determining health hazard risk of farmers

Applied pesticides (X)	Number of farmers using pesticides	Recommended dosage on label (X'p)	Average rate of pesticide use per ha (Xp)	Average ratio of pesticide use to recommended rate on label	Index weight in terms of WHO toxicity class* (Wp)	Average health hazard risk index
Paraquat (X1)	370 (100%)	3 l/ha	3.540 l/ha	1.180	II = 3	3.540
Metribuzin (X2)	370 (100%)	1 kg/ha	1.741 kg/ha	1.741	II = 3	5.223
Chlorothalonil (X3)	370 (100%)	2.5 kg/ha	2.797 kg/ha	1.119	U = 1	1.199
Imidacloprid (X4)	370 (100%)	0.250 l/ha	0.304 l/ha	1.215	II = 3	3.645
Diazinon (X5)	370 (100%)	15 kg/ha	19.635 kg/ha	1.309	II = 3	3.927
Chlorpyrifos (X6)	144 (39%)	2 l/ha	5.676 l/ha	2.838	II = 3	8.514
Glyphosate (X7)	129 (35%)	6 l/ha	10.146 l/ha	1.691	U = 2	3.382
Trifluralin (X8)	96 (26%)	2 l/ha	4.380 l/ha	2.190	U = 1	2.190

* WHO toxicity class [45,17]: 1 = Unlikely to present an acute hazard (U), 2 = Slightly hazardous (III), 3 = Moderately hazardous (II), 4 = Highly hazardous (Ib), and 5 = Extremely hazardous (Ia)).

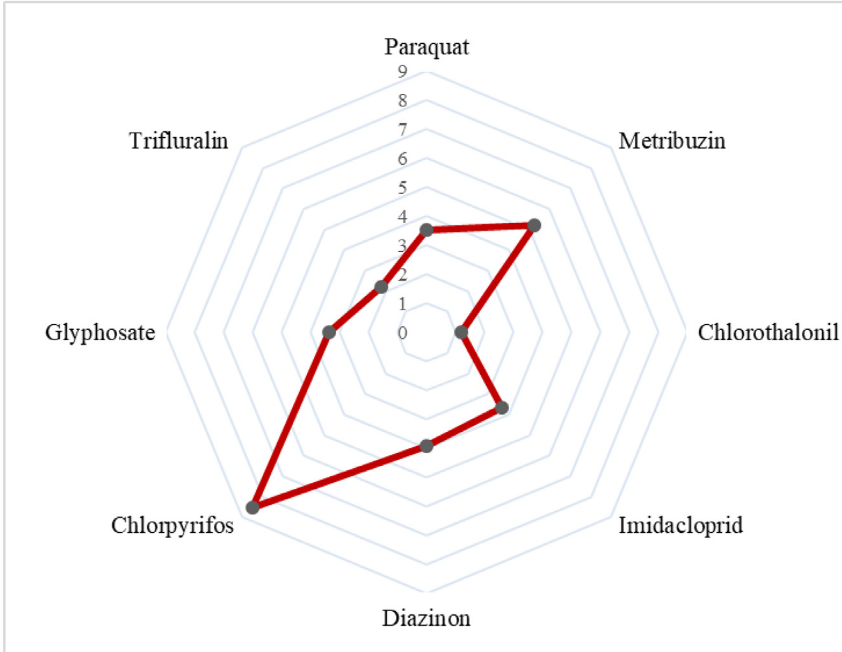

Fig. 1. The average health hazard risk indices for the pesticides used by farmers.

between the health hazard risk composite index and all stages of pesticide use (lower values of coefficients were related to the sample size). In other words, potato farmers with higher health hazard risk displayed much lower safety behavior than other farmers at all stages of pesticide use.

3.4. Variables determining overuse and nonoveruse farmers

To check the variables discriminating these two groups of farmers, we first divided the dependent variable into pesticide nonoveruse (24.6 % of farmers with code: 0) and overuse farmers (75.4% of farmers with code: 1). Then, discriminant analysis was performed using the Wilks' Lambda test. This test is used to determine the significance of the variables included in discriminant functions [42]. In total, the results of the Wilks' Lambda test for function fit ($p < 0.01$; 0.634) showed that the first discriminant function could discriminate between the two groups acceptably and significantly. Additionally, the canonical correlation, variance percentage, and χ^2 were found to be 0.631, 104.5, and 171.465, respectively, showing the good discriminating power of the function. In total, 21 variables were included in the research. According to Table 5, 15 variables, i.e. education, farm income, knowledge, perceived susceptibility, perceived severity, health behavior identity, attitude, perceived benefits, perceived barriers, intention, cues to action, controlled beliefs (self-efficacy), and subjective norms contributed to the discrimination of the two groups of farmers at the $p < 0.01$ level and the variables of experience in agriculture contributed to it at the $p < 0.05$ level. The values of the structure matrix indicate the linear correlation of individual independent variables with the discriminant function. In other words, these values show the amount of variance accounted for by each independent variable with respect to the discriminant performance [43]. Therefore, the structure matrix shows that the strongest discriminant variables were knowledge (0.697), attitude (0.568), perceived severity (0.565), intention (0.560), and cues to action (0.473), respectively. In addition, the correctness of predicting the group to which a farmer would be assigned was estimated to be 83.2 percent.

3.5. Variables affecting pesticide overuse farmers

To better describe the results of the composite index for overuse of pesticides (279 farmers), it was encoded (Table 6). Potato farmers were assigned to three groups in terms of their health hazard risk: low health hazard risk (the first 1–33 percent of the composite index values); moderate health hazard risk (the second 34–67 percent of the composite index values); and high health hazard risk (the final 68–100 percent of the composite index values) [34]. Table 6 shows that most respondents (39.43 percent) belonged to the group of potato farmers who were exposed to high health hazard risk, while 30.82 and 29.75 percent of the groups were exposed to moderate and low health hazard risk, respectively.

The results of discriminant analysis and the Wilks' Lambda test for function fit ($p < 0.01$; 0.457) showed that the first discriminant function could discriminate between the three groups acceptably and the canonical correlation, variance percentage, and χ^2 were found to be 0.703, 89.4, and 212.465, respectively, showing the good discriminating power of the function. In addition, the correctness of predicting the group to which a farmer would be assigned was estimated to be 63.2 percent. According to Table 6, 13 variables (age, farm income, knowledge and awareness, perceived severity, health behavior identity, attitude, perceived benefits, perceived barriers, intention, cues to action, controlled beliefs (self-efficacy), and subjective norms contributed to the discrimination of the three groups of farmers at the $p < 0.01$ level; similarly, the structure matrix shows that the strongest discriminant variables were health behavior identity (0.708), attitude (0.659), knowledge (0.542), and cues to action (0.528), respectively. The correctness of predicting the group to which a farmer would be assigned was estimated to be 63.2 percent.

4. Discussion

The present study, while examining the safety behavior of potato farmers in the use of chemical pesticides, with the help of a health hazard risk index assessment, analyzes the variables affecting farmers' overuse. The study results revealed the diversity of herbicides used by potato farmers in Ardabil Plain (4 types of pesticides), suggesting the extensive diversity of weeds and pests in this plain. In addition, according to the results of Damalas and Koutroubas [9], Jallow et al. [10], and Prasadi and Wathugala [22], the farmers, on average, used higher dosages of pesticides than recommended. Similar to the results of Prasadi and Wathugala's [22], Glanz et al. [11], and Bhandari et al. [13], this behavioral output may be due to their or other farmers' perceptions and previous experiences of the ineffectiveness of the permissible level recommended on the label or to their background, beliefs, attitudes, and intentions. The health hazard risks of pesticides, in addition to the degree of their toxicity, also depend on the degree of exposure to the pesticides during overuse [9]. Therefore, among the pesticides used by farmers, the highest average health hazard risk index among the farmers was related to Chlorpyrifos and Metribuzin.

Table 4
Ranking of items pertaining to farmers' protective measures at different stages of pesticide use

Application steps	Items	Rank	Correlation with health hazard risk
Pesticide purchase and storage	- Determining appropriate pesticide type for the pest and disease and checking its production and expiring dates.	1	−0.362**
	- Storing out of the reach of children and animals.	2	
	- Selecting and purchasing pesticides with lower risk hazards and more environmentally friendly.	3	
	- Following the recommendations of agricultural experts in selecting chemical pesticides.	4	
	- Acquiring adequate knowledge of correct storage of pesticides	5	
	- Purchasing from reliable pesticide stores.	6	
Pesticide preparation	- Preparing pesticide outside the house.	1	−0.390**
	- Learning how to prepare a solution of pesticide correctly.	2	
	- Attending the quality of soluble (water) or mixture in pesticide preparation.	3	
	- Using protective equipment when mixing pesticides.	4	
	- Reading instructions on the label of pesticides carefully before use.	5	
Pesticide application	- Using boots.	1	−0.370**
	- Ensuring that the pesticide sprayer is well adjusted.	2	
	- Avoiding pesticide spraying in adverse weather or in the opposite direction of the wind.	3	
	- Using mask.	4	
	- Wearing gloves.	5	
	- Wearing protective gown.	6	
	- Wearing safety glasses.	7	
	- Wearing protective hat and respirator.	8	
	- Selecting the appropriate pesticide sprayer that is compatible with pesticide type and crop.	9	
Post-application	- Changing the suit after pesticide application.	1	−−0.297**
	- Announcing the application of pesticides on the farm and not letting others enter the farm.	2	
	- Washing hands, face, and body after pesticide application.	3	
	- Disinfecting protective equipment after pesticide application.	4	
	- Disposing of cans and pesticide residues safely	5	

**P < 0.01 level.

Table 5
Tests of equality of group means and canonical discriminant function coefficients

Independent variables	Wilks' Lambda	F	*p*-value	Standard coefficients	Structure matrix
Age	.990	3.845	.051	.099	−.134
Education	.966	12.926	.000	.159	.246
Experience in agriculture	.984	5.930	.015	−.018	−.167
Farm income	.890	45.450	.000	.154	.384
Knowledge	.780	103.984	.000	.543	.697
Health value	.985	5.417	.060	−.004	.159
Perceived susceptibility	.966	12.845	.000	.101	.245
Perceived severity	.844	68.218	.000	.455	.565
Health behavior identity	.885	47.908	.000	−.301	.465
Attitude	.842	68.893	.000	.429	.568
Perceived benefits	.880	50.401	.000	.092	.485
Perceived barriers	.961	14.861	.000	−.132	.264
Intention	.846	67.141	.000	.291	.560
Cues to action	.871	54.648	.000	−.128	.473
Subjective norms	.978	8.174	.004	−.095	.196
Self-efficacy	.947	20.476	.000	.040	.309

Eigenvalue = 0.639; Canonical correlation = 0.631; Wilks' Lambda = 0.634 and $p < 0.01$; Chi-square: 171.465and df: 16; % of variance = 104.5.
Note: 83.2% of original grouped cases correctly classified.

Table 6
Tests of equality of group means and canonical discriminant function coefficients

Independent variables	Wilks' Lambda	F	*p*-value	Standard coefficient	Structure matrix
Age	.913	13.171	.000	−.048	−.319
Education	.989	1.507	.223	−.012	.204
Experience in agriculture	.996	.610	.544	−.019	−.287
Farm income	.927	10.788	.000	−.171	.095
Knowledge	.776	39.930	.000	.336	.542
Health value	.982	2.601	.076	.052	.142
Perceived susceptibility	.987	1.873	.156	−.064	.095
Perceived severity	.951	7.071	.001	.101	.229
Health behavior identity	.673	67.101	.000	.203	.708
Attitude	.703	58.229	.000	.397	.659
Perceived benefits	.806	33.280	.000	.135	.499
Perceived barriers	.882	18.539	.000	−.029	.372
Intention	.709	56.554	.000	.304	.526
Cues to action	.785	37.812	.000	.227	.528
Subjective norms	.916	12.673	.000	.067	.284
Self-efficacy	.950	7.255	.001	−.101	.208

Eigenvalue = 0.928; Canonical correlation = 0.703; Wilks' Lambda = 0.457 and *p*-value: 0.000; Chi-square: 212.465 and df: 34; % of variance = 89.4.
Note: 63.2% of original grouped cases correctly classified.

Therefore, it seems that Integrated Pest Management (IPM) programs should focus on extending alternative methods for these pesticides and developing biological methods to control agricultural pests in the study area.

By using the results of correlating the composite health hazard risk index and safety behaviors (significant and negative correlation with all steps of safety behavior), the safety behaviors that were the most dangerous to farmers' health could be identified. In this regard, the results indicate that purchasing from unreliable pesticide stores, not carefully reading instructions on pesticide labels [21]), inattention to the selection of a suitable sprayer that is compatible with pesticide and crop, and unsafe disposal of cans and pesticide residue (burying, burning, etc.) were most dangerous to farmers' health at different stages. Purchasing pesticides from unreliable centers may result in the use of substandard, outdated, or ineffective pesticides. As a result, it may increase the use of pesticides to its permissible level for the farmer; therefore, while further monitoring chemical pesticide sales centers, promotional and educational programs, and public media in the region should focus on all steps of pesticide application. However, it should not be forgotten that safety behavior in pesticide use comprises four steps, namely purchase and storage, preparation, application, and postapplication.

The variables accounting for pesticide overuse and nonoveruse farmers revealed that the most effective variables were perceived severity, attitude toward pesticide use, and knowledge of pesticide use (According to the results of Jallow et al. [10] and Sun et al. [12]). In addition, the results of analyzing the variables underpinning pesticide overuse farmers revealed the positive role of health behavior identity, attitude, knowledge, and cues to action in alleviating the health hazard risk of farmers. In line with the results of Sookhtanlou and Allahyari [17] and Sharifzadeh et al. [20], among the demographic variables, farm income and age variables affect the overuse of pesticides. Older farmers seem to be less inclined to reduce the use of chemical pesticides on the farm. In addition, farmers with higher incomes often have larger and better-quality farms; therefore, the ratio of pesticide consumption per hectare is reduced, and consequently, the risk of health risk is reduced. However, the possibility of optimal access and financing of personal protective equipment for small and low-income farmers is less, and this may increase their health risk in the application of chemical pesticides.

Promoting farmers' knowledge of unsafe usage consequences of chemical pesticides and attracting local leaders' cooperation to motivate farmers to consider the hazards of unsafe behaviors and pesticide overuse (with reliance on their religious background) can contribute to improving farmers' health behaviors. Of course, audio and social media and public media (the improvement of cues to action) can play a significant role in motivating farmers' display of overuse preventive behaviors and will lead to farmers developing higher levels of perceived severity about the dangers of unsafe usage of pesticides. It seems that proper management in providing better quality pesticides for farmers and providing government subsidies for personal protective equipment can reduce the level of health risk of farmers in the application of chemical pesticides. Furthermore, similar to the results of Rezaei et al. [44], local educational and promotional programs should place emphasis on informing farmers about the side-effects of unsafe use and overuse of pesticides on health (through different media) so that they realize that they need to pay attention to the perils of unsafe use of pesticides.

5. Conclusion

According to the results, since most farmers use more than the recommended dosage of chemical pesticides, this indicates a high health risk among farmers for the use of chemical pesticides in the study area. It was also found that potato farmers with higher health hazard risk (those overused pesticides more frequently) had much lower safety behavior than the other farmers at all steps of chemical pesticide application (pesticide purchase and storage, preparation, application, and postapplication). Therefore, reducing government subsidies for hazardous pesticides obtained in this study or biologically alternative methods of pest control along with training programs on the management of chemical pesticide use should be a priority in the safety-health and educational planning of farmers in the study area. In addition, the labels of pesticides do capture the attention of farmers to read them. It is therefore recommended that the labels and alert signals on pesticide containers be in a language that is understood by farmers. In addition, monitoring pesticide shops, obliging retailers to get valid certificates, or introducing valid pesticide retailers to farmers can play a positive role in improving farmers' safety behaviors. Identity of health behavior, attitude, knowledge, and reference to action were the most effective variables on reducing the health risk of farmers in the use of chemical pesticides. In this regard, by holding consultative meetings with local trustees, local leaders, and skilled farmers in the area, their participation can be raised to improve the health behavior identity and farmers' attitudes about the dangers of chemical pesticides and the need for safe behaviors. Holding local exhibitions on safer pesticides or alternative methods of chemical pesticides, and introducing the dangers of pesticides, preparing printed brochures in the region, and local media programs on the dangers of pesticide overuse can improve knowledge and attitudes.

Conflicts of interest

The authors declare they have no conflict of interest.

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