

Article

Analysis in Terms of Environmental Awareness of Farmers' Decisions and Attitudes: Reducing Pesticide Use and Risks

Ismail Bulent Gurbuz 

Department of Agricultural Economics, Faculty of Agriculture, Bursa Uludag University, Nilüfer 16059, Türkiye; bulent@uludag.edu.tr

Abstract: Pesticide residues are a significant problem affecting the quality and safety of agricultural products in Turkey. This study aims to investigate farmers' risk perception regarding pesticide residues, including the primary factors that influence their behavior from the farmers' perspective. In addition, the main characteristics of pesticide residues encountered in the production of agricultural products against the current policy background is investigated to provide decision support to the Turkish government for improving the safe production of agricultural products. This paper uses a binary logistic model to analyze farmers' perceptions of pesticide residues using a cross-sectional dataset of 323 vegetable growers in Bursa, Turkey. Farmer characteristics and pesticide application behavior were more effective in reducing residual risk perceptions than farm characteristics. The effects of membership in a cooperative, average amount of pesticide used, location where the pesticide was purchased, application timing, and adherence to last spraying and harvest timing on the perception of residues were the largest. Farmers receive helpful but limited information from pesticide distributors. However, the primary source of information is not the advisors, which is why these grievances exist. The study results show that policymakers should support cooperatives, expand pesticide training, and make public extension services more effective and that pesticide dealers should conduct more frequent inspections.



Citation: Gurbuz, I.B. Analysis in Terms of Environmental Awareness of Farmers' Decisions and Attitudes: Reducing Pesticide Use and Risks. *Sustainability* **2024**, *16*, 4323. <https://doi.org/10.3390/su16114323>

Academic Editors: Georgios Tsantopoulos, Konstantinos S. Ioannou and Evangelia Karasmanaki

Received: 14 March 2024
Revised: 16 May 2024
Accepted: 16 May 2024
Published: 21 May 2024



Copyright: © 2024 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: sustainable agriculture; pesticide residue; residue perceptions; agricultural pollution; attitudes; behaviors; knowledge

1. Introduction

In today's world, the use of pesticides and its consequences are always on the agenda. This will remain so because, in addition to the intensive use of pesticides in traditional agriculture, the controlled use of pesticides is permitted in good agricultural practice, and natural pesticides are used in organic farming. Unconscious and incorrect use of pesticides leaves residues in the products. Pesticide residues on vegetables and other foods caused by unintentional and erroneous spraying pose a serious risk to consumer health and the environment [1–3]. According to a study by the Environmental Working Group, strawberries were among the foods with the most pesticides in Turkey in 2023. It was found that 20 different pesticides were found in strawberries, which were the most contaminated food in 2023. The second most contaminated food was spinach. It was found that 1.8 times more pesticide residues were found in spinach than in other products. Foods on the list included kale, mustard greens, peaches, pears, nectarines, apples, grapes, peppers and hot peppers, cherries, blueberries, and green beans [4,5].

The residue problem affects not only one country but is also a priority issue among countries that maintain trade relations. Industrialized countries deal meticulously with pesticide residues, and they are systematically monitored. Products that do not meet the specific standards do not find buyers. All countries require pesticide residues to be below the maximum residue levels (MRLs). The Rapid Alert System for Food and Feed (RASFF) of the European Union (E.U.) reports unsuitable products due to pesticide residues

circulating in Europe. The RASFF issues notifications relating to risks deriving from food, food-contacting material, or feed or serious risks to animal health and to the environment derived from feed [6].

In Turkey, as in the rest of the world, the unconscious and, to some extent, uncontrolled use of pesticides can cause many problems regarding food safety and human health. The Non-Toxic Tables of the Civil Society states that there are still 13 active substances used in pesticides in Turkey that have been classified as “extremely hazardous”, “very hazardous”, and “possibly carcinogenic” by the World Health Organization [7].

As mentioned, the European Union Commission publishes non-conformities resulting from border and market controls on food and feed in the RASFF. The Ministry of Agriculture and Forestry also conducts inspections on the domestic market regarding pesticide residues. Information such as all food and feed companies throughout the country, inspections at these companies, samples taken, analysis results of the samples, administrative sanctions imposed on the companies, and import and export records are entered into the Food Safety Information System of the Ministry of Agriculture and Forestry. However, unlike the RASFF system, this information is not publicly accessible, i.e., the audit and analysis results are not shared with the public. Even pressure from non-profit institutions such as the Bugday Ecological Life Support Association and Toxic-Free Tables is insufficient to publicize this data [8].

The state’s declarations show that the contaminated products are not sold in domestic markets. The state confirms that the products in question were burned, buried, or destroyed in various ways. However, the investigations carried out and the images published in the media show that these products are thrown into the sea, into bodies of water such as rivers and stream beds, onto empty fields, or left to rot in the fields. In these cases, the chemical compounds of the pesticides contaminate the water or soil and affect other agricultural products. Furthermore, production and consumption analyses claim that these rejected products have been placed in the domestic market. However, official figures have not been published in this regard. As a result, producers cannot be paid for their work, and the national economy suffers.

The Ministry of Agriculture and Forestry registers and licenses plant protection products (PPPs) in Turkey. The corresponding regulation was first published in 1975 [9]. The latest Regulation No. 32489 on the Licensing and Market Placement of Plant Protection Products came into force on 14 March 2024 [10]. Durmusoglu et al. [11] report that the definitions of biopreparations or biopesticides are not fully defined within the scope of this regulation. Regarding pesticides in Turkish legislation, the Turkish Food Codex Regulation on Maximum Residue Limits of Pesticides was published on 25 November 2016 [12].

Parallel to practices in the world, there is a wide range of legislation from production to storage and application of PPPs. In order for a PPP to be used in agriculture in Turkey, it must be applied in accordance with the licensing legislation and approved by meeting the legal requirements. However, this cannot prevent problems related to the handling of pesticides, especially in regions where agriculture is intensive, and product patterns vary. One of the problems with pesticide management in Turkey is that the active ingredients in the quantities of pesticides used are not adequately recorded. The data kept and shared annually by the District Directorates of Agriculture is based on pesticide groups such as insecticides, fungicides, etc., and not on active substances. This situation makes evaluating the pesticide active substances used according to their hazardous properties difficult. There are PPP database applications and formulation, barcode, and QR code applications. However, the fact that this practice is not applied in many parts of the country by the PPP distributors and thus also by the district agricultural directorates makes it difficult to record the quantities of pesticides used by active ingredient type and to control their use. This situation not only jeopardizes food safety within the country but also poses a residue problem in exported foodstuffs [13].

The collection and disposal of pesticide containers in Turkey are handled under the ‘Hazardous Waste Regulation’. However, this regulation has not been sufficiently

implemented. Although this regulation emphasizes the recycling of waste such as pesticide containers by the manufacturing company, this has not been implemented in practice [14].

The use of pesticides in Turkey is lower than in other countries; nevertheless, the number of notifications for pesticide residues in exported food is relatively high. Of the countries that exported food to the E.U. in 2021, the Netherlands, for example, used 9.4 kg/ha of pesticides, while the number of notifications received by the RASFF was 240. In Turkey, pesticide use was 1.3 kg/ha. Despite this lower use, Turkey was the most notified non-member country, with a total of 630 notifications. The RASFF also issues notifications of non-compliance. These notifications concern non-compliance with food, food-contacting materials, or feed that do not pose a risk, non-serious animal health risks, or plant health or animal welfare risks. The most common pesticide residue issues escalated to the RASFF concerned compliance notifications for the use of pesticides in fruit and vegetables (430). Turkey was followed by India (383), of which 272 were pesticide notifications, and China (331), of which almost half (160) concerned food [15].

Studies show that farmers generally have moderate-to-good knowledge of the harmful effects of pesticides on the environment and human health. However, studies also show that they must know whether pesticides are safe. A study conducted in 2017 in the Gursu and Kestel districts of Bursa province aimed to determine the behavior of growers regarding the use of pesticides in fruit cultivation. The research results showed that 56.2% of the participants believed there would be residues if the interval between the last spraying and the harvest was not observed. In addition, 17.8% of the same growers believed that some pesticides leave residues [16]. In a recent study, pistachio growers were asked about the problem of pesticide residues. One-third of growers (33%) responded “They disappear when the rain washes them”. Those who said “I do not know about residues” were 39%, and “residues” were 16%. The remaining 12% were of the opinion that pesticides leave no residue [17]. Almost half of the tomato growers (43.73%) believed the residues had no harmful effects. The rest of the participants believed that washing could remove residues (15.63%), that there are residues only when the pesticide is overdosed (15.63%), that all pesticides leave residues (15.63%), and that there are no residues when the recommended dose is used (9.38%) [18].

Farmers should not use pesticides over the doses specified in the technical instructions, should not apply more than the required pesticides, should not mix more than one pesticide, when necessary, should use appropriately calibrated spraying equipment, and should strictly observe the most critical point, i.e., the time between the last spray and harvest. However, there are indeed some things that could be improved in practice. It is important to recognize the potential use of sewage sludge as a pesticide-free fertilizer and to highlight its environmental benefits. Investigating the feasibility of using sewage sludge as a natural fertilizer represents an environmentally sound alternative in agricultural practice that warrants thorough investigation in research [19,20].

This study aimed to investigate farmers’ risk perception of pesticide residues in a multidimensional way. The study and its results will guide young farmers, cooperative managers, food processors, advisors, and policymakers. The study will help them predict and understand farmer behavior and scientifically design and manage appropriate policies and programs.

Theoretical Framework and Research Assumptions

Several studies have extensively addressed extrinsic and intrinsic factors that influence farmers’ behavior about pesticide safety and application. Nevertheless, research on the effects of perceptions of pesticide residues is limited [21–23]. In the present study, it is argued that farmers’ perceptions could be influenced by their characteristics and the characteristics of the farm. In addition, the pesticide training received and previous pesticide use directly affect their perceptions. This study examined twenty-five factors considered antecedents of farmers’ risk perceptions. The complexity of pesticide environmental and health impacts requires a multi-layered analysis of farmers’ risk perceptions through a combined and

in-depth analysis of farmers' personal characteristics, farm-related characteristics, and current behavioral patterns.

The personal characteristics most frequently examined in current studies are farmers' age, education level, number of people in the family (or family labor force), and off-farm income. The empirical study by Sun et al. [24] found that the age of farmers negatively influenced the use of the correct pesticide dose. The authors found that older farmers were less likely to use the correct amount of pesticide. On the other hand, the age of Iranian vegetable farmers had a positive and significant effect on the perception of the risk of pesticide residues [22]. The formal education that farmers receive increases their awareness of environmental and health issues and positively affects their behavior regarding pesticide use and risk perception of pesticides. Farmers' education had a positive effect on the safety behavior of Nepalese farmers [25]. In addition to vegetable cultivation, the number of people in the household and money could influence farmers' risk perception. The study by Sun et al. [24] suggests that family size positively affects the correct use of pesticides by Chinese farmers. Wang and Liu [26] argue that farmers whose main source of income is farming are more resourceful in the dosage of pesticides. They may be better informed about pesticide standards and, therefore, less inclined to overuse pesticides.

In contrast, in another study in China, the regression coefficient for non-agricultural income was negative and significant at the 1% level. This indicates that farmers' willingness to reduce pesticide use decreased with increasing non-agricultural income [27]. Therefore, the first hypothesis is as follows:

H1. *Farmers' characteristics influence their pesticide residue perceptions.*

The effects of farm-related factors have been included in fewer studies. Studies have frequently investigated the effects of farming experience [28], farm size [22], and agricultural income [29] on pesticide usage behavior. On the other hand, land ownership [30] and cooperative membership [29] variables were included in a few studies.

Wang and Liu [26] argued that farmers whose primary source of income was agriculture were more resourceful about pesticide dosage. They might be more informed of pesticide standards and, therefore, less likely to overuse pesticides. Karabat and Atis [31] and Zhao et al. [32] argued that large-scale farms relied on robust vegetable income and were prone to apply pesticides excessively. In contrast, Zhu and Wang [33] research indicated that farm size significantly and negatively impacted pesticide usage intensity. Their research proved that, on average, a 1% increase in farm size leads to a 0.2% reduction in pesticide use per hectare. The probit regression results indicated that farming experience was negatively (and significantly) related to pesticide use intensity among farmers in Kuwait [34].

Joining farmers' cooperatives can help farmers to reduce pesticide use. Cooperatives can reduce pesticide overuse through standard requirements, in-cooperative training, and audit mechanisms. Indeed, the findings of Zhao et al. [29] confirm this argument. Further, Jin et al. [35] note that the lowest pesticide use is achieved when farmers are provided with accurate information and trust this information provider. Cooperative members have a very high level of trust in their retailers. This trust and precise information lead to the lowest pesticide use.

Mehmood et al. [22] and Baharom et al. [30] found that land ownership does not affect farmers' pesticide residue risk perceptions. Additionally, an analysis of Migheli's [36] research with Vietnamese farmers suggests that farmers would use less pesticides if they had higher farming incomes. The author underlines that using chemical products is necessary to reach some income level but emphasizes that once a certain income level is reached, the use of agricultural chemicals does not increase with income. In the study of Uzundumlu et al. [37], however, pesticide usage decreased as the unit income of hazelnut producers and the amount of hazelnut obtained increased. Still, this decrease was statistically significant. Following the above, the second hypothesis is as follows:

H2. Farm characteristics influence farmers' perceptions of pesticide residue.

The demographic and farm characteristics mentioned above are influential in the inappropriate and excessive use of pesticides. However, the farmers' residue perceptions often formed as an extension of their past and current behaviors. Farmers with high-risk perceptions, i.e., those who worry that pesticides will leave residues (on and in the products, depending on their forms), are expected to be more careful in their pesticide handling behavior.

Pesticide use behavior encompasses a multi-stage complex series of behaviors. Although it made the analysis and interpretation difficult, this research attempted to incorporate many of these behavioral features into the model to gain deeper insight. Working more than 6 h a day significantly reduces farmers' use of the correct procedure during application [38]. Numerous studies have shown that pesticide dealers are farmers' primary information sources on pesticides. Jallow et al. [34] observed that farmers were more likely to overuse pesticides if pesticide dealers were their primary information source about pesticide use. The regression results of Jin et al.'s [39] study on the pesticide use of small-scale farmers in China showed that reading the label on the pesticide containers negatively affected pesticide overuse. This finding is predictable and coherent. If farmers read pesticide container labels before usage, they would be more inclined toward using the recommended dose and reducing the probability of pesticide overuse. Wu and Hou's [23] research underlined that considering safety intervals during pesticide application significantly affected farmers' pesticide residue perceptions. Therefore, the third hypothesis is as follows:

H3. Past pesticide application behavior influences farmers' pesticide residue perceptions.

Training and advice, directly and indirectly, impact farmers' perceptions by influencing their specific actions concerning health and environmental safety. Training on pesticides significantly improves farmers' intention to comply with pesticide regulations [30]. Stricter compliance reduces the excessive use of pesticides [34]. Migheli [36] states that poor education and a lack of specific training leads to the overuse of agricultural chemicals. Farmers' awareness of pesticide residues can be improved through training. In fact, IPM training has positively and significantly influenced the risk perception of Pakistani farmers regarding pesticide residues [22]. The fourth and final hypothesis is as follows:

H4. Pesticide training influences farmers' pesticide residue perceptions.

This research provides a theoretical model of the critical factors influencing farmers' perceptions of pesticide residues. The theoretical model considers farmers' perceptions of pesticide residues as the dependent variable and farmers' characteristics, farming characteristics, past pesticide application behavior, and pesticide training as dependent variables.

Personal characteristics included age and years of formal education, family size, and other sources of income besides vegetable farming; farm characteristics included land size, land ownership, farming experience, agricultural income, agricultural expenditure, and membership in a cooperative. Farmers' past pesticide application behavior included pesticide application experience, number of applications per year, average application time per spray day, average application amount per spray day, and meter used. Behavioral variables also included who recommended the dosage used when spraying, where the product was obtained from, whether the pesticide was used at the recommended dosage, when the pesticide was applied, whether the waiting time between two sprays was observed, whether the waiting time between spraying and harvest was observed, what was carried out if it was not effective, whether the label on the pesticide container was read, and whether multiple pesticides were mixed. Finally, pesticide training provided by government agricultural extension services or cooperatives was also included in the model.

2. Materials and Methods

2.1. Questionnaire Development and Data Collection

Farmers' opinions on the use of pesticides can vary greatly depending on the product. The author focused exclusively on vegetable producers to avoid sampling errors. The preliminary draft of the questionnaire was prepared considering the existing literature [22] and the researchers' previous experiences. A panel of three experts in crop protection, occupational medicine, and public health reviewed the questionnaire to determine content validity. The questionnaire contained closed-ended questions to obtain meaningful information from the vegetable growers. The dependent variable was farmers' risk perception of pesticide residues, assuming that consumer health is at risk from pesticide residues. It was measured as a dummy variable (if the farmer believed that there were no residues when pesticides are used at the recommended dose, the value was 1; otherwise, it was zero). The effects of 25 independent variables were assessed in the survey (Table 1).

Table 1. Description of variables and social and demographic characteristics of the farmers.

Variable	Abbreviation	Definition	Mean ***
Farmers' perception of pesticide residues (Dependent variable)	residue	1 = There will be no residues if the pesticide is used in the recommended dose; 0 = Otherwise	Yes: 166 (51.4%); No: 157 (48.6%)
Age of the farmers	age	Age in years	M = 51.13 SD = 11.06
Educational level	edu	Education in years	M = 6.76 SD = 3.06
Family size	famsize	No. of family members	M = 4.55 SD = 2.00
Income outside crop prod.	noncrop	1 = Yes; 0 = No	N = 249 (77.2%)
Years in farming	farmexp	Years	M = 29.36 SD = 13.42
Cooperative membership	coopmem	1 = Yes; 0 = No	N = 234 (72.4%)
Size of the land	landsize	Hectares	M = 09.12 SD = 213.51
Land ownership	landown	1 = Owned; 0 = Leased	N = 168 (52.0%)
Agricultural income	agriscience	USD **; per year; (000)	M = 84.98 SD = 91.98
Agricultural expenditure	agricexp	USD **; per year; (000)	M = 49.10 SD = 58.05
Spraying experience	pestexp	Years	M = 18.95 SD = 10.95
Number of spraying	numpestapp	Days (per year)	M = 15.94 SD = 33.69
Spraying time	avapptime	Hours (per day)	M = 5.56 SD = 15.94
Pesticide amount used	avpestuse	lt (per day)	M = 5.26 SD = 4.90
Measuring device	mesdevice	1 = Measurement container; 0 = Else	N = 292 (90.4%)
Dosage decision source	dosages	1 = Pesticide dealer; 0 = Else	N = 124 (38.4%)
Pesticide purchase place	purchaseplc	1 = Pesticide dealer; 0 = Cooperative	N = 296 (91.6%)
Application dosage	appdosage	1 = Recommended dosage; 0 = Overdosage	N = 296 (90.1%)
Application time	apptime	1 = When pest presence was observed; 0 = Else	N = 160 (49.5%)
Obey wait time between sprayings	obywaittime	1 = Yes; 0 = No	N = 309 (95.7%)
Obey wait time between last spraying and harvest	obylastspr	1 = Yes; 0 = No	N = 316 (97.8%)
If the pesticide is not effective	pestnotefft	1 = Exchange with stronger pesticide; 0 = Else	N = 201 (62.2%)
Pesticide training	pesttraining	1 = Yes; 0 = No	N = 100 (31.0%)
Reading labels	readlabel	1 = Yes; 0 = No	N = 212 (65.6%)
Mixing products	mixingpest	1 = Yes; 0 = No	N = 219 (67.8%)

M: mean; SD: standard deviation; N: number of respondents. ** Calculated with the Central Bank exchange rate dated 15 July 2019. *** For categorical values, the referenced category is given.

For the pilot survey, ten farmers were interviewed whose results were not included in this study. The questionnaire was modified to reflect farmers' attitudes and behaviors based on the pretest and feedback received. The interviewees were selected from among Bursa Uludag University, Faculty of Agriculture graduate students to collect the required information. Before the interviews, the students were trained and informed about what to pay attention to when communicating with the farmers. The questionnaire consisted of four parts. The first part contained demographic questions. The second part contained

questions aimed at identifying farmers' attitudes and behaviors regarding the impact of pesticides on the environment and the characteristics of pesticide use. The third part contained questions about the products grown, the pests and pesticide types, the amount used, and the frequency of spraying. The fourth part concerned the sprayers' working practices during preparation and spraying and after spraying. The approval of the ethics committee was obtained before the survey was conducted.

The survey was conducted using a multi-stage sampling method. At the first stage, a stratified random sample was used. Four cities in Bursa province where vegetables are mainly grown were selected: Yenisehir, Karacabey, Kemalpasa, and Inegol. These four districts accounted for 67% of the province's vegetable production [40]. At the second stage, one town from each stratum, the villages within the selected towns, and the vegetable producers per village were selected. At the third stage, a random sample was drawn, and a sample of 323 vegetable and fruit farmers was identified. Sixty-two farmers were from Mustafakemalpasa, 33 from Yenisehir, 52 from Karacabey, and 176 from Inegol. The survey was conducted between October 2022 and March 2023. However, care was taken to ensure that the surveys were conducted during the peak spraying season. Before conducting the survey, the heads of the concerned villages and cooperative branches were informed about the nature and purpose of the survey. The farmers were assured that the study was for academic purposes and that their responses would be treated confidentially.

2.2. Data Analysis

All data obtained from the survey questionnaires were coded and analyzed using the SPSS 28.0 package program. Cronbach's alpha (α) was calculated as $\alpha = 0.822$. This conclusion fulfills the criterion of survey reliability. Chi-square and correlation analyses were used to check for possible associations between the survey variables. We used $\alpha \leq 0.05$ as the statistical significance criterion in all the data analyses. Spearman's and point biserial correlation tests were used to determine the level of correlation and significance of the relationship between farmers' risk perceptions of pesticide residues and their socioeconomic farm characteristics and spraying behavior. We conducted a regression analysis using the binary logistic model to identify the factors influencing farmers' risk perceptions of pesticide residues.

Logistic regression is used when the dependent variable is categorical and the independent variables are categorical, continuous, or a combination of both. The dependent variable can be dichotomous or polytomous. The logistic regression used is binary if the dependent variable is binary. Logistic regression analysis is a successful and flexible statistical method for creating models with a categorical dependent variable. The flexibility of the method stems from the fact that it requires far fewer assumptions than similar statistical methods. The logistic regression model has no requirements such as a normal distribution of the explanatory variables, a linear relationship between them, or an equal variance of the different categories. In addition, the explanatory variables can be discrete, continuous, or 0–1 variables. Logistic regression focuses on the probability of a certain expected result occurring for each observation unit.

The logistic regression model is based on the odds ratio. The odds ratio compares the probability of an event occurring with the probability that the event will not occur. The logistic regression model is therefore obtained by taking the natural logarithm of the odds ratio. The maximum likelihood method is often used to estimate the parameters of the logistic regression model obtained [41]. The binary logistic regression model is as follows:

$$\begin{aligned} P_i &= E(Y_i = 1|X_i) = F(I_i) = F(\beta_0 + \beta_1 X_i) \\ &= \frac{1}{1+e^{-I_i}} \\ &= \frac{1}{1+e^{-(\beta_0 + \beta_1 X_i)}} \end{aligned} \quad (1)$$

It takes a value between $-\infty$ and $+\infty$, and P_i takes a value between 0–1, so a non-linear relationship is observed between P_i and I_i .

Equation (1) is non-linear for both X_i and coefficients. In such a case, since an estimation cannot be made with the O.L.S. (ordinary least squares) method, the equation should be converted to a linear form. $e^{-L_i} = \frac{1-P_i}{P_i}$ is obtained by multiplying both sides of the equation by $1 + e^{-L_i}$, dividing P_i , and subtracting 1. Since e^{-L_i} is $\frac{1}{e^{L_i}}$, finally, $e^{L_i} = \frac{P_i}{1-P_i}$ is obtained. This final equation obtained is the odds ratio. By taking the natural logarithm of both sides of this equation:

$$L_i = \ln\left(\frac{P_i}{(1-P_i)}\right) = L_i = \beta_0 + \beta_1 X_i \quad (2)$$

is obtained. Thus, the logarithm of the probability ratio, L_i , is no longer only linear for X_i but also for the coefficients. One unit change in X changes the log probability ratio (L_i) by β_1 .

The odds ratio is expressed as $\text{Exp}(\beta)$ in the logistic regression model. Since the odds ratio is the ratio of the probability of an event occurring to the probability of it not occurring, $\text{Exp}(\beta)$ indicates how often the Y variable is likely to be observed with the effect of the X_i variable or by what percentage [42].

The rate of probability change for the independent variable depends not only on the corresponding coefficient (β) but also on the probability level at which the change was measured. Therefore, while the other variables are constant in the logistic regression model, the marginal effects for each variable are obtained with Equation (3). [43].

$$\frac{dP_i}{dX_i} = P_i(1-P_i)\beta_1 \quad (3)$$

The SPSS 28.0 and Stata/SE 15.0 software were used for the data analysis.

3. Results

3.1. Socioeconomic Characteristics of Farmers

The socioeconomic characteristics of the farmers surveyed are listed in Table 1. A whopping 86% of the farmers in the surveyed regions were above 40 years of age, and 23.5% were above 60 years of age. A total of 63.2% of them had primary education or less. The average family size was 4.55. A significant proportion of the participants (77.2%) had an income in addition to vegetable production, and 46.3% of this income was a pension. The average farming experience was 30 years; most participants were cooperative members (72.4%).

The average farm size was 9.12 hectares. Half of the farmers surveyed (52%) farmed their own land, while the other half (48%) were tenants or sharecroppers. While the average annual agricultural income of the farmers was USD 85,000, their average annual agricultural expenditure was USD 49,000. The research results show that most of the participants' socioeconomic characteristics aligned with the average values for Turkey [16,17]. The research sample is, therefore, representative.

3.2. Farmers' Understanding of Risk Perception and Pesticide Residues

Table 2 contains the questions used to assess the farmers' perceptions and attitudes towards pesticide residues. The vegetable growers in the study were highly aware that the use of 'high doses of pesticides increase the possibility of poisoning' (90.1%) and that 'some pesticides can cause fatal poisoning' (91.3%). Pesticide distributors often warn farmers about the toxicity levels, which are indicated on the labels. For this reason, the farmers were highly aware of the need to wear protective clothing when preparing and applying the pesticide (87.6%). However, many studies have repeatedly shown that farmers neglect or only partially use protective equipment [44,45]. A study conducted in Nigeria highlights that 49.3% of cocoa producers were aware that the products they handle are hazardous [46].

However, when asked if they took the necessary precautions, 94% answered 'no'. In Turkey, pesticides are mainly sourced from pesticide dealers, cooperatives, and provincial and district agricultural directorates. These organizations must have a license and be agricultural engineers. Because of this, there can be a misconception in farmers' minds that

the pesticides sold in licensed facilities are safe regardless of their age of use. Although most farmers knew that not every pesticide offered for sale is safe, it is thought-provoking that almost a third (28.7%) were unaware of this. The survey showed that the farmers were aware that the pesticides available for sale have different toxicity levels and that there may be safety issues depending on the application. Around half (46.7%) believed that all pesticides have the same harmful effects on health. Only 58.1% of vegetable and fruit growers in the north of the Delta, Egypt, had general knowledge about the harmful effects of pesticides on human health. The percentage of those who knew that not all compounds have the same harmful effects was 32.6% [47]. Again, half of the farmers (54.2%) believed that the pesticides would disappear in nature over time, and they did not mind walking in the sprayed area a few hours after spraying (42.1%). Similarly, 63.4% of tomato growers in Buea, Cameroon, stated that they saw no harm in re-entering the field less than 48 h after spraying [48]. These results show that farmers have little awareness of the risks of pesticides and that their knowledge of pesticides is very low.

Table 2. Farmers' pesticide risk perception.

Perception	Percentage (%)	
	Yes	No
If the pesticide is on sale, it is safe no matter how it is used.	28.7	71.3
High doses of pesticide use increase the possibility of poisoning.	90.1	9.9
All pesticides have the same adverse effect on health.	46.7	57.3
Some pesticides may cause fatal poisoning.	91.3	8.7
Pesticides decompose in nature over the years	54.2	45.8
Protective clothing is necessary to prevent pesticide poisoning.	87.6	12.4
Entering the field a few hours after applying the pesticide is okay.	42.1	57.9

Source: field survey, 2023.

Table 3 shows the results of the correlation coefficients between the farmers' risk perceptions of pesticide use, personal and farm characteristics, and spraying behavior. The analysis shows that the farmers' risk perceptions correlated significantly and positively with the following variables: age, farming experience, additional income outside vegetable production, experience in pesticide application, and adherence to waiting time between sprays at the 0.01% level of significance, while the average time spent on pesticides per spraying day was significant at the 5% level. In contrast, the farmers' perception of risk showed a negative and significant association with the number of pesticide applications per year and farm size ($p < 0.001$), formal education, and where to seek advice on dosage decisions ($p < 0.05$).

Table 3. Correlation coefficients between farmers' risk perceptions and research variables.

Variables	Correlation Coefficient	<i>p</i> -Value	Correlation Type
age	0.270	0.000	Spearman
edu	−0.137	0.014	Spearman
famsize	−0.302	0.000	Spearman
farmexp	0.367	0.000	Spearman
coopmem	0.168	0.002	Point biserial
landsize	−0.094	0.143	Spearman
landown	−0.005	0.924	Point biserial
agricinc	0.089	0.110	Spearman
agricexp	0.090	0.108	Spearman
noncrop	0.268	0.000	Point biserial
pestexp	0.197	0.000	Spearman
numpestapp	−0.354	0.000	Spearman
avapptime	0.141	0.012	Spearman

Table 3. Cont.

Variables	Correlation Coefficient	p-Value	Correlation Type
avpestuse	0.079	0.284	Spearman
mesdevice	0.056	0.314	Spearman
dosages	−0.112	0.045	Spearman
purchaseplc	−0.061	0.275	Point biserial
appdosage	−0.104	0.063	Point biserial
apptime	0.167	0.003	Spearman
obywaittime	0.262	0.000	Point biserial
obylastspr	0.091	0.104	Point biserial
pestnoteffct	0.143	0.010	Spearman
pesttraining	0.147	0.008	Point biserial
readlabel	0.022	0.698	Point biserial
mixingpest	−0.043	0.436	Point biserial

3.3. Factors Affecting Farmers' Pesticide Residue Risk Perceptions

The results of the binary logistic analysis conducted to estimate the factors influencing farmers' perceptions of pesticide residues are shown in Tables 4 and 5. The explanatory variables were binary and focused on the factors influencing the farmers' perceptions of pesticide residues. Other statistical results, including pseudo R^2 measures (0.53), log-likelihood statistics (−32.51), and L.R. $\chi^2(25)(72.13)$, show the good fit of the binary logistic model.

Table 4. Estimated farmers' risk perception of pesticide residues using a binary logistic model.

Pest Residue	Odds Ratio	Std. Err.	z	p > z	[95% Conf. Interval]	
					Lower Bound	Upper Bound
age	4.787786	4.48442	1.67	0.095	0.7636026	30.0194
edu	0.0228149	0.0327243	−2.64	0.008	0.0013719	0.3794269
famsize	0.6445604	0.1396716	−2.03	0.043	0.4215162	0.9856276
noncropinc	2.90×10^{-10}	1.67×10^{-9}	−3.82	0.000	3.69×10^{-15}	0.0000228
farmexp	0.9311048	0.0339406	−1.96	0.050	0.8669032	1.000061
coopmem	2.224707	0.7982873	2.23	0.026	1.101128	4.494774
landsize	0.9972335	0.0033269	−0.83	0.406	0.9907341	1.003776
landown	1.157374	0.8803755	0.19	0.848	0.2606116	5.139893
agriscience	1.010105	0.0265671	0.38	0.702	0.9593533	1.063541
agricexp	0.8893803	0.0679314	−1.53	0.125	0.7657239	1.033006
pestexp	1.019844	0.0462972	0.43	0.665	0.9330233	1.114744
numpestapp	0.453821	0.1571479	−2.28	0.023	0.2302145	0.8946154
avapptime	0.3457142	0.1436586	−2.56	0.011	0.1531115	0.7805969
avpestuse	2.338539	0.689732	2.88	0.004	1.311868	4.168686
mesdevice	0.557945	0.4295438	−0.76	0.449	0.1233897	2.522922
dosages	0.3235526	0.1706172	−2.14	0.032	0.1151027	0.9095034
purchaseplc	8.603046	6.4021	2.89	0.004	2.000859	3.699032
appdosage	0.0011836	0.0028846	−2.77	0.006	9.97×10^{-6}	0.1404999
apptime	6.131452	4.055154	2.74	0.006	1.677277	22.41413
obywaittime	0.0028453	0.0085194	−1.96	0.050	8.04×10^{-6}	1.006517
obylastspr	4.513748	4.761153	3.09	0.002	1.101128	4.494774
pestnoteffct	0.2834684	0.2130379	−1.68	0.093	0.0649819	1.236564
readlabel	8.833142	13.61492	1.41	0.158	0.4306456	181.18
mixingpest	0.2615257	0.325522	−1.08	0.281	0.0228045	2.999218
pesttraining	0.0070978	0.0162734	−2.16	0.031	0.0000793	0.6349067

The predictors for personal characteristics were age, education level, family size, and whether the family has additional income for vegetable production. The level of education, family size, and additional household income (excluding vegetable production) were negatively related to the likelihood that the farmers would perceive the risk of pesticide residues. When the other factors were held constant, the logarithm of the ratio of the

probability of perceiving residue risk decreased by 0.023 (0.645 and 2.9, respectively) when the education and non-farming variables changed by one unit. The education and non-farming variables were significant at the 1% level, with a marginal effect of -0.390 (and -2.268). Non-farming was significant at the 5% level, with a marginal effect of -0.009 . In general, it is expected that a higher education level, larger family size, and additional money coming to the household should increase farmers' risk perception of arrears. The results show the opposite.

Table 5. Marginal effects of farmers' risk perceptions of pesticide residues.

Pestresidue	dy/dx	Std. Err.	z	$p > z $	[95% Conf. Interval]	
					Lower Bound	Upper Bound
age	0.1617578	0.0920387	1.76	0.079	−0.0186347	0.3421502
edu	−0.3904681	0.1276442	−3.06	0.002	−0.6406461	−0.1402902
famsize	−0.0453632	0.0209554	−2.16	0.030	−0.0864351	−0.0042913
nonfarminc	−2.268447	0.4242665	−5.35	0.000	−3.099994	−1.4369
farmexp	−0.0126703	0.0060379	−2.10	0.036	−0.0245044	−0.0008362
coopmem	0.1863095	0.0801636	2.32	0.020	0.0291917	0.3434273
landsize	−0.0002861	0.0003403	−0.84	0.400	−0.000953	0.0003807
landown	0.0150961	0.0785583	0.19	0.848	−0.1388754	0.1690676
agricinc	0.0010385	0.0027123	0.38	0.702	−0.0042775	0.0063544
agricexp	−0.0121086	0.0075969	−1.59	0.111	−0.0269982	0.002781
pestexp	0.0034878	0.0080351	0.43	0.664	−0.0122608	0.0192363
numpestapp	−0.0816038	0.0322524	−2.53	0.011	−0.1448173	−0.0183904
avapptime	−0.1097078	0.037837	−2.90	0.004	−0.1838669	−0.0355487
avpestuse	0.0877468	0.0258462	3.39	0.001	0.0370893	0.1384044
mesdevice	−0.0602687	0.0786899	−0.77	0.444	−0.2144979	0.0939606
dosages	−0.1165508	0.0492759	−2.37	0.018	−0.2131298	−0.0199717
purchaseplc	0.4673314	0.1476689	3.16	0.002	0.1779058	0.7567571
appdosage	−0.6960851	0.2135264	−3.26	0.001	−1.114589	−0.2775811
apptime	0.1873078	0.0582298	3.22	0.001	0.0731794	0.3014362
obywaittime	−0.6054904	0.289222	−2.09	0.036	−1.172355	−0.0386257
obylastspr	1.453427	0.3881154	3.74	0.000	0.6927348	2.214119
pestnotefft	−0.1302119	0.072237	−1.80	0.071	−0.2717937	0.0113699
pesttraining	−0.5110716	0.2209726	−2.31	0.021	−0.94417	−0.0779733
readlabel	0.2250165	0.153895	1.46	0.144	−0.0766122	0.5266451
mixingpest	−0.1385337	0.1251002	−1.11	0.268	−0.3837255	0.1066581

Membership in a cooperative, farmland ownership, and agricultural income increased farmers' perceptions of residual risk. In contrast, farming experience, acreage size, and farming expenses decreased farmers' perceptions of residual risk. However, only cooperative membership and farming experience were not statistically significant at the 5% level. For a one-year increase in farming experience, the logarithm of the probability of residual risk perception decreased by 0.0911. If the farmer was a cooperative member, the logarithm of the ratio of the probability of residual risk perception increased by 2.224.

Research has shown that farmers' behavior when applying pesticides influences their risk perceptions. Most of the variables included in the model had a statistically significant effect on the dependent variable. The number of sprays carried out during the year and the average duration of spraying on each spraying day significantly affected the farmers' perceptions of residual risk at the level. As the number and duration of pesticide applications increased during the year, the farmers' perception of pesticide risk increased, i.e., their perceptions that the pesticides applied will leave residues. When the variables numpestapp and numpestapp increased by one unit, the logarithm of the ratio of the probability of the perception of the residue risk decreased by 0.023 (or 0.345). Farmers who consulted the pesticide dealer when deciding on the pesticide dose, used the recommended dose, and followed the recommended waiting time between sprays had a lower perception of pesticide risk, i.e., the perception that pesticides leave less residue in these situations was

higher. When the variables dosage, application, and waiting time were increased by one unit, the logarithm of the ratio of the probability of perceiving the risk of residue decreased by 0.32, 0.001, and 0.002, respectively.

Farmers who bought pesticides from dealers, used the recommended dosage, and observed the waiting period between the last spraying and harvest were less concerned that pesticides may contain residues. For a one-unit change in the purchase/plc (or app time and oblasts) variables, the logarithm of the odds ratio of pesticides containing residues increased by 8.603 (or 6.131 and 4.513). These variables also had the highest marginal effects (0.467, 0.187, and 1.45, respectively). Most of these variables were significant at the 5% and 1% levels, suggesting that the farmers' behavioral habits directly and significantly impacted the farmers' risk perception.

Specialized pesticide handling training was inversely related to the farmers' risk perceptions of residues. Farmers who had participated in pesticide training were more likely to believe that there will be no residues if the recommended amount is not exceeded. For a one-unit change in the variable pesticide training, the logarithm of the ratio of the probability of perceiving the risk of residues decreased by 0.007. Training was significant at the 5% level, with a marginal effect of -0.511 .

4. Discussion

Farmers' risk perception of pesticides is one of the most important factors in promoting the safe use of pesticides and ensuring food safety. Studies conducted in Turkey have frequently investigated farmers' pesticide use habits, their mistakes in pesticide use, and their reckless attitude towards personal protection. These studies have emphasized the role of cooperatives, label reading, and proper training to improve farmers' risk perception.

This study aimed to investigate the risk perceptions of vegetable farmers in Bursa province regarding pesticide residues, and further research data are needed from the literature. The research findings will provide new perspectives on the factors influencing farmers' risk perceptions of pesticide residues. The author first discusses the relationship between farmers' personal and farm characteristics and pesticide application behavior, as well as the role of education in understanding pesticide residue risk perceptions. Several valuable guidelines for local and national policymakers, farmers, advisors, and cooperatives are then presented.

The coefficients of the binary logistic model represent the farmers' characteristics (family size, additional income outside vegetable production) and had a positive and significant influence on the risk perceptions of pesticide residues. However, formal education had a significant but negative influence on risk perceptions, confirming Hypothesis 1.

Studies have shown that a higher level of education increases the likelihood that farmers will apply the correct dose [25] and comply with pesticide regulations [30]. It was expected that higher levels of education would also increase the farmers' knowledge that pesticides do not leave residues (above MRLs) on crops. However, our results showed the opposite; the farmers' risk perception decreased as their level of education increased. Mehmood et al. [22] came to the same conclusion. With increasing formal education, farmers' risk perception regarding pesticide residues in Pakistan decreased. The reason for this is that as the level of education increases, farmers become more confident in production and aim to increase yield, for which they use more pesticides and ignore the residue problem in the short term.

As the family grows, so does the number of dependents. Consequently, farmers will try to secure the yield, so they will use more pesticides. Therefore, their risk perception will decrease. Wang and Liu [26] also came to a similar conclusion in their research in China. The risk perception of farmers decreased with increasing family size.

This study shows that the risk perception of pesticides increases as farmers' income increases. On the contrary, the literature emphasizes that farmers with a high non-agricultural income are less dependent on agricultural income. Our results may seem contradictory, yet 56.3% of the farmers in this study were 51 years old and older, and 23.5% were 61 years

old and older. Furthermore, 46.2% of their non-farm income was a pension. Farmers who relied only on pensions still took care of their produce and had a higher perception of risk.

Research often claims that farm characteristics influence farmers' pesticide use behavior. However, Table 5 shows that only farming experience (negative) and membership in a cooperative (positive) significantly influenced the farmers' risk perceptions regarding residues. The results only weakly support Hypothesis 2. More experienced farmers are generally older and less educated. They are less open to new developments and rely more on their experience than on advisors; therefore, their risk perceptions are lower. This finding is supported by recent research. Experienced farmers are more inclined to overuse pesticides [35], focus more on the benefits of pesticide use, and, therefore, have a lower perception of risk.

Membership in a cooperative increases risk perception by helping farmers reduce the overuse of pesticides. Cooperatives encourage farmers through training and effective communication to practice proper pesticide management to meet the cooperative's standards. Research in China [29], Turkey [37], and Oman [49] has also found an inverse relationship between joining cooperatives and farmers' behavior in excessive pesticide use.

Pesticide application involves a series of complicated behaviors, from choosing the right pesticide to preparation and application. The choices made at each stage have an impact on residue levels. Numerous studies have independently examined these behaviors and reported problems. The current research included as many variables as possible in the model to predict these complicated behaviors. Each behavior is interconnected, and the effects of a single behavior should be considered together with others. Nine of the fourteen variables in the model had a statistically significant impact on the growers' perceptions of pesticide residue risk. Thus, Hypothesis 3 is confirmed.

Spraying experience is often related to farming experience. In this study, the average farming experience of the farmers was 29 years, and their experience with spraying was 19 years. Theoretically, it can be assumed that farmers can spray better with increasing experience. In this study, experience in the use of pesticides increased the farmers' perception of risk. However, this increase was not statistically significant.

The number of spraying operations per year, the duration of the spraying operations on each working day, and the quantity used influence the amount of residue. This study showed that the participating farmers sprayed for an average of more than five hours per working day. This result is consistent with a study that found that most (67%) cocoa farmers in southwestern Nigeria worked for 6–8 h per day [46]. Such a long spraying time increases the risk of residues as farmers are distracted and ignore the spraying instructions.

A Chinese study reported that only 1.1% of wheat farmers were sufficiently informed about pesticide residues; 33.8% had never heard of pesticide residues, and the remaining respondents (63%) had some knowledge [21]. When Egyptian growers were asked if pesticides leave residues on crops, 27.7% answered yes, and a worrying 61.7% said they were unsure if pesticides leave residues [50]. About half of Iranian farmers (47.9%) had never heard of pesticides leaving residues, while the other half had no idea (41.8%). When asked whether pesticides harm agricultural products, 64.0% of Iranian farmers answered no, and 21.5% said they did not know [51].

Farmers obtain the necessary information on crop protection from various sources, including dealers, cooperatives, extension agents, neighboring farmers, and the media. Research shows that licensed dealers also act as agricultural extension agents. In a study conducted in the Wei River basin in China, 90 traders answered 'yes' when asked if they advised farmers on purchasing crop protection products [52]. In Turkey, 80% answered 'yes' [53]. Pesticide dealers are a convenient source of information in many regions, as the number of agricultural advisors is insufficient, and not all farmers know the scope of their services. It is feared that traders may be biased in recommending their products rather than encouraging farmers to make independent decisions about pest control methods. Concerns have also been raised that some distributors may encourage farmers to buy their products instead of using chemical products or products from other companies. However,

dealers in Turkey must have a college degree and be agricultural engineers. This is the most encouraging factor that motivates farmers to use distributors.

For this reason, the risk perception of farmers who bought pesticides from distributors was eight times higher. Pesticide distributors are also trusted sources worldwide. For example, 75% of farmers in Kuwait [34], 59% of farmers in Cameroon [54], 56.5% of farmers in the Wei River basin, China [52], and 52.6% of farmers in south India [55] trusted distributors to obtain information about pesticides.

Farmers not only buy from dealers but also apply the dose they recommended. As explained earlier, without effective extension services, dealers become the first and most reliable qualified source for farmers. Research shows that 38.4% of farmers determine application doses according to the vendor's recommendation. The managers of pesticide dealers in Turkey were asked about the people and institutions that affect farmers' pesticide selection choices. Like the current study's findings, 31.15% of the participants stated that the producers chose pesticides with the dealers' suggestions [56].

The pesticide label and usage instructions are critical information sources for correct application. Reading the label on the container negatively affects pesticide overuse and positively affects risk perceptions. If farmers read the label and instruction manual, they will be more likely to use the recommended dose, reducing the likelihood of pesticide overuse and residue [39]. Although reading the instructions for use in the current study also increased the pesticide risk perception eightfold, the fact that this effect was not statistically significant may be because the farmers also referred to the dealers' opinions simultaneously.

Most pesticides are extremely dangerous or somewhat toxic, and a short interval between pesticide applications and sales can put public health at risk. Many products have more than one active substance against the same disease. The time between the last spraying and harvesting of the licensed pesticides is hugely variable. This creates problems, especially in products with frequent harvesting processes, such as vegetables. In the current study, 95.7% of the participants stated that they respected the time between spraying, and 97.8% observed the time between the last spraying and harvest. These high compliance rates positively and significantly affected the farmers' residual risk perceptions. Contradictory findings were obtained in the literature. For example, none of the vegetable and fruit farmers in the north of the Delta, Egypt, followed the recommended pre-harvest no-spray interval [47]. More worryingly, 98% of Vietnamese farmers said they were aware of the pre-harvest interval but admitted that they did not always observe it [57].

Pest control must be carried out on a predetermined schedule. Waiting to observe pests and even damage before starting spraying increases residue risk. In the current study, half of the farmers (49.5%) sprayed after they observed pests or pest damage. Only 16.7% administered control strategies according to a predetermined schedule. Recent research presented consistent findings. Kuwaiti farm owners commonly applied pesticides when they observed pests or pest damage (40%), and 36% followed a predetermined schedule [34]. Pesticides are generally imported. Increases in exchange rates directly affect pesticide prices and constitute a substantial item in farmers' costs.

When dealers in Turkey were asked about the factors that farmers prioritize when selecting pesticides, the dealers stated that half of the farmers (51%) paid attention to the cheapness [56]. Consequently, almost all (90.1%) respondents used the recommended dose. Similarly, 87.5% of Lebanese farmers [58] and 82% of Algerian farmers claimed to always follow the recommended dose [59]. Although applying the pesticide at the recommended dose significantly reduces the likelihood of residue release, several pesticides are often mixed in practice. When farmers think the pesticide does not affect them, they prefer pesticides containing a more toxic active ingredient. More than two-thirds (67.8%) of Turkish farmers mixed several pesticides. When the pesticide was ineffective, 62.2% replaced it with a more toxic alternative, and 19.2% used more of the same pesticide. In the research conducted in West Java, Indonesia, 66.25% of the farmers mixed pesticides, and 50% carried this out because they believed the pesticides would be more effective [60]. Farmers claim that mixing chemicals saves time and labor. They also predict higher pest

control efficiency. Mixing pesticides increases pest resistance and increases the risk of residues in foods. This study showed that applying pesticides by mixing increased the likelihood of residues in the products.

The research results from this study showed that as farmers were trained, their risk perception increased, and their perception of residue in the products increased. Thus, Hypothesis 4 was confirmed. Farmers' low education level is one of the most fundamental problems in farming practices. This gap can only be closed with dedicated training. Although cooperatives, various non-governmental organizations, and state institutions organize occasional training, it is seen from the research results that this training needs to be sufficient in quantity, and the participation needs to be higher. Less than a third (31%) of farmers in Turkey have received training. These results coincide with undeveloped countries; 31% of Ugandan farmers, 30% of Nepali farmers [25], and 33% of southwestern Nigerian farmers [46] had received pesticide training.

5. Conclusions and Future Directions

Excessive and inaccurate pesticide use in Turkey has had a detrimental effect on farmers' health and the environment, and it indirectly harms human health by resulting in intolerable residue levels. Numerous studies have investigated the inappropriate and excessive use of pesticides. However, only a handful of studies have examined farmers' knowledge of pesticide residues and focused on understanding the factors that influence their residue risk perceptions. The results of this study show that the farmers' overall pesticide risk perception was low. The results also show that farmer characteristics and pesticide application behaviors significantly positively affected pesticide residue risk perception. The pesticide purchase place, adherence to the period between the last spraying and the harvest, the dosage used, and membership in a cooperative were the factors that most affected the residual risk perceptions of the farmers.

Although the state provides fertilizer and diesel support to farmers, farmers need more support in the current economic climate in Turkey. The state should also add agricultural pesticide support to farmer support. The Ministry should regularly disclose the results of residue analyses for domestic consumption and make them available to universities, non-governmental organizations, and other organizations related to public health. The inspections carried out by the Ministry should be improved, and more food and agricultural engineers should be employed for this purpose.

The research results show that only a few members benefit from this training, but it is effective. This training within cooperatives should not only be limited to selecting and using pesticides but also include residue and health risks.

Pesticide dealers in Turkey are generally agricultural engineers. However, agricultural engineers are also trained primarily by vendor companies. The pesticide market is highly competitive. Pesticide retailers may lead farmers to choose pesticides with high profit margins for retailers, even though they are not effective in fighting targeted insects or diseases or their active ingredients are not allowed to be used in producing certain products. Therefore, dealers should be regularly trained and inspected by the relevant agricultural organizations rather than manufacturers.

There are many more information sources for farmers than before. Nevertheless, this information needs to be more cohesive. In addition, a large amount of data from different sources can be misleading. Improving public agricultural extension services to improve farmers' pesticide application behavior is essential. In Turkey, pesticide retailers have overtaken the agricultural extension system as the most prominent external information source on pesticide use for farmers. However, Turkey's agricultural extension services are not at the desired level, and farmers need to be made aware of independent agents. Therefore, increasing the visibility and effectiveness of extension agents is vital.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. Sener, S.; Turemis, N.F.; Tanir, F. Agrochemical usage for sustainable fruit production and human health. In *Agrochemicals Detection, Treatment and Remediation*; Prasad, M.N.V., Ed.; Butterworth-Heinemann: Oxford, UK, 2020; pp. 291–305.
2. Erdil, M.; Tiryaki, O. Investigaton of the knowledge level and awareness of farmers about pesticide usage in Manisa. *Çanakkale Onsekiz Mart Univ. J. Grad. Sch. Nat. Appl. Sci.* **2020**, *6*, 81–92. [CrossRef]
3. Gun, S.; Kann, M. Pesticide use in Turkish greenhouses: Health and environmental consciousness. *Pol. J. Environ. Stud.* **2009**, *18*, 607–615.
4. Pesticide Atlas 2022. In *Facts and Figures about Toxic Chemicals in Agriculture*; Heinrich-Böll-Stiftung, European Union: Brussels, Belgium, 2022. Available online: <https://eu.boell.org/en/PesticideAtlas> (accessed on 1 March 2024).
5. Gurbuz, I.B.; Abdullahı, A.M.; Ozkan, G. Integrated pest management practices in Somalia to reduce pesticide use in banana production. *Erwerbs-Obstbau* **2023**, *65*, 1793–1801. [CrossRef]
6. EFSA (European Food Safety Authority); Carrasco Cabrera, L.; Medina Pastor, P. The 2020 European Union report on pesticide residues in food. *EFSA J.* **2022**, *20*, e07215. [CrossRef] [PubMed]
7. Sade, G. *Civil Society in Turkey Came Together against Pesticides: Toxic-Free Tables Project*; Euronews: Lyon, France, 2020. Available online: <https://tr.euronews.com/2020/02/19/turkiye-de-sivil-toplum-pestisite-karsi-bir-araya-geldi-zehirsiz-sofralar-projesi> (accessed on 1 March 2024).
8. Karahan, S. Turkey's Food Security and GMO: Current Status and Future Strategies. MISAK-National Strategy Research Board. 2017. Available online: <https://millidusunce.com/misak/turkiyenin-gida-guvenligi-ve-gdo-mevcut-durum-ve-gelecek-stratejileri/> (accessed on 1 March 2024).
9. Balci, H.; Durmusoglu, E. Biopesticides as plant protection products: A review of their definitions, classifications, legislation and markets. *Turk. J. Biol. Control.* **2020**, *11*, 261–274. [CrossRef]
10. Official Gazette, Licensing and Market Placement of Plant Protection Products Regulation No. 32489. 14 March 2024. Available online: <https://www.resmigazete.gov.tr/eskiler/2024/03/20240314-5.htm> (accessed on 1 March 2024).
11. Durmusoglu, E.; Tiryaki, O.; Kumral, N.A.; Aydin, A.; Gungor, O. Legislation on plant protection products, 47–72. In Proceedings of the Turkish Agricultural Engineering IX. Technical Congress, Ankara, Turkey, 13–17 January 2020. Proceedings Volume 2, TMMOB Chamber of Agricultural Engineers; 895p.
12. Official Gazette, Turkish Food Codex Regulation on Maximum Residue Limits of Pesticides. Regulation No. 29899. 25 November 2016. Available online: <https://www.resmigazete.gov.tr/eskiler/2016/11/20161125M1-1.htm> (accessed on 1 March 2024).
13. Hanedar, A.; Tanık, A.; Girgin, E. Pesticide management within the context of green deal and Türkiye. *ITU Environ. Clim. Sustain.* **2023**, *24*, 87–96.
14. Uysal, F.F.; Yildirim, C. Keskin, Management of empty pesticide containers in Turkey and in the World. In Proceedings of the 1st International Conference on Environment, Technology and Management ICETEM, Niğde, Turkey, 27–29 June 2019; pp. 204–210.
15. European Union. *2021 Annual Report, Alert and Cooperation Network*; European Union: Luxembourg, 2021.
16. Erberk, E.; Ozyoruk, A.; Arslan, U. Determination of attitudes and behaviors of fruit producers towards pesticide use in Gursu and Kestel districts of Bursa province. *J. Agric. Fac. Bursa Uludag Univ.* **2018**, *32*, 69–76.
17. Dilmen, H.; Pala, F.; Ozer Dilmen, M. Determination of knowledge level of pistachio (*Pistacia vera* L.) growers on agricultural pest control: The case of province Siirt, Turkey. *Turk. J. Agric. Res.* **2020**, *7*, 1–8. [CrossRef]
18. Gozener, B.; Sayili, M.; Caglar, A. Agricultural chemical use in tomato farming in Kazova region of Tokat province. *Turk. J. Agric. Food Sci. Technol.* **2017**, *5*, 451–458. [CrossRef]
19. Kowalik, R.; Widlak, M.; Widlak, A. Sorption of heavy metals by sewage sludge and its mixtures with soil from wastewater treatment plants operating in MBR and INR technology. *Membranes* **2021**, *11*, 706. [CrossRef]
20. Janaszek, A.; Kowalik, R. Analysis of heavy metal contaminants and mobility in sewage sludge-soil mixtures for sustainable agricultural practices. *Water* **2023**, *15*, 3992. [CrossRef]
21. Hou, B.; Wang, Z.-w.; Ying, R. Pesticide residues and wheat farmer's cognition: A China scenario. *Agric. Res.* **2016**, *5*, 51–63. [CrossRef]
22. Mehmood, Y.; Arshad, M.; Kaechele, H.; Mahmood, N.; Kong, R. Pesticide residues, health risks, and vegetable farmers' risk perceptions in Punjab, Pakistan. *Hum. Ecol. Risk Assess.* **2021**, *27*, 846–864. [CrossRef]
23. Wu, L.; Hou, B. China's farmer perception of pesticide residues and the impact factors. The case of Jiangsu province. *China Agric. Econ. Rev.* **2012**, *4*, 84–104. [CrossRef]
24. Bhandari, G.; Atreya, K.; Yang, X.; Fan, L.; Geissen, V. Factors affecting pesticide safety behavior: The perceptions of Nepalese farmers and retailers. *Sci. Total Environ.* **2018**, *631–632*, 1560–1571. [CrossRef] [PubMed]
25. Sun, S.; Hu, R.; Zhang, C. Pest control practices, information sources, and correct pesticide use: Evidence from rice production in China. *Ecol. Indic.* **2021**, *129*, 107895. [CrossRef]

26. Wang, C.; Liu, W. Farmers' attitudes vs government supervision: Which one has a more significant impact on farmers' pesticide use in China? *Int. J. Agric. Sustain.* **2021**, *19*, 213–226. [\[CrossRef\]](#)
27. Zhang, L.; Li, X.; Yu, J.; Yao, X. Toward cleaner production: What drives farmers to adopt eco-friendly agricultural production? *J. Clean. Prod.* **2018**, *184*, 550–558. [\[CrossRef\]](#)
28. Qin, S.; Lu, X. Do large-scale farmers use more pesticides? Empirical evidence from rice farmers in five Chinese provinces. *J. Integr. Agric.* **2020**, *19*, 590–599. [\[CrossRef\]](#)
29. Zhao, Q.; Pan, Y.; Xia, X. Internet can do help in the reduction of pesticide use by farmers: Evidence from rural China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 2063–2073. [\[CrossRef\]](#)
30. Baharom, N.; Ali, J.; Aziz, F.S. Factors influencing intention to comply with the pesticide regulation among rice farmers. *Int. J. Soc. Sci. Humanit. Res.* **2018**, *6*, 101–107.
31. Karabat, S.; Atis, E. An analysis of effects on food safety of pesticide usages with contingent valuation method in Manisa vineyard areas. *J. Agric. Fac. Ege Univ.* **2012**, *49*, 17–25.
32. Zhao, L.; Wang, C.; Gu, H.; Yue, C. Market incentive, government regulation and the behavior of pesticide application of vegetable farmers in China. *Food Control* **2018**, *85*, 308–317. [\[CrossRef\]](#)
33. Zhu, W.; Wang, R. Impact of farm size on intensity of pesticide use: Evidence from China. *Sci. Total Environ.* **2021**, *753*, 141696. [\[CrossRef\]](#)
34. Jallow, M.F.; Awadh, D.G.; Albaho, M.S.; Devi, V.Y.; Thomas, B.M. Pesticide risk behaviors and factors influencing pesticide use among farmers in Kuwait. *Sci. Total Environ.* **2017**, *574*, 490–498. [\[CrossRef\]](#)
35. Jin, S.; Bluemling, B.; Mol, A.P. Information, trust and pesticide overuse: Interactions between retailers and cotton farmers in China. *NJAS Wagening. J. Life Sci.* **2015**, *72–73*, 23–32. [\[CrossRef\]](#)
36. Migheli, M. Land ownership and use of pesticides. Evidence from the Mekong Delta. *J. Clean. Prod.* **2017**, *145*, 188–198. [\[CrossRef\]](#)
37. Uzundumlu, A.S.; Kilic, B.; Tozlu, G. Analysis of factors affecting pesticide use in hazelnut production: The case study of Giresun. *Gumushane Univ. J. Sci. Technol.* **2017**, *7*, 1–9. [\[CrossRef\]](#)
38. Camur, D.; Vaizoglu, S.A.; Guler, Ç. Are pesticide applicators in Turkey able to protect themselves? *Cukurova Med. J.* **2017**, *42*, 254–263. [\[CrossRef\]](#)
39. Jin, J.; Wang, W.; He, R.; Gong, H. Pesticide use and risk perceptions among small-scale farmers in Anqiu County, China. *Int. J. Environ. Res. Public Health* **2017**, *14*, 29. [\[CrossRef\]](#)
40. U.I.B. *Fresh Fruit and Vegetable Sector Report*; Uludag Exporters Union: Bursa, Turkey, 2019. Available online: <https://uib.org.tr/tr/kbfile/yas-meyve-sebze-sektor-raporu> (accessed on 1 March 2024).
41. Benson, M.L.; Levine, D.M.; Krehbiel, T.C. *Basic Business Statistics: Concepts and Applications*, 8th ed.; Prentice Hall: Hoboken, NJ, USA, 2002.
42. Park, H.-A. An introduction to logistic regression: From basic concepts to interpretation with particular attention to nursing domain. *J. Korean Acad. Nurs.* **2013**, *43*, 154–164. [\[CrossRef\]](#)
43. Fernihough, A. Simple Logit and Probit Marginal Effects. In *R. Working Papers 2011*; School of Economics, University College Dublin: Dublin, Ireland, 2011.
44. Sapbamrer, R.; Thammachai, A. Factors affecting use of personal protective equipment and pesticide safety practices: A systematic review. *Environ. Res.* **2020**, *185*, 109444. [\[CrossRef\]](#)
45. Garrigou, A.; Laurent, C.; Berthet, A.; Colosio, C.; Jas, N.; Daubas-Letourneux, V.; Judon, N. Critical review of the role of P.P.E. in the prevention of risks related to agricultural pesticide use. *Saf. Sci.* **2020**, *123*, 104527. [\[CrossRef\]](#)
46. Sosan, M.B.; Akingbohunge, A.E. Occupational insecticide exposure and perception of safety measures among Cacao farmers in Southwestern Nigeria. *Arch. of Environ. Occup. Health* **2009**, *64*, 185–193. [\[CrossRef\]](#)
47. Abbassy, M.M. Farmer's knowledge, attitudes and practices, and their exposure to pesticide residues after application on the vegetable and fruit crops. Case study: North of Delta, Egypt. *J. Environ. Anal. Toxicol.* **2017**, *7*, 1–6. [\[CrossRef\]](#)
48. Tandi, T.E.; Wook, C.J.; Shendeh, T.T.; Eko, E.A.; Afoh, C.O. Small-scale tomato cultivators' perception of pesticide usage and practices in Buea Cameroon. *Health* **2014**, *6*, 2945–2958. [\[CrossRef\]](#)
49. Al Zadjali, S.; Morse, S.; Chenoweth, J.; Deadman, M. Factors determining pesticide use practices by farmers in the Sultanate of Oman. *Sci. Total Environ.* **2014**, *476–477*, 505–512. [\[CrossRef\]](#)
50. Ibitayo, O.O. Egyptian farmers' attitudes and behaviors regarding agricultural pesticides: Implications for pesticide risk communication. *Risk Anal.* **2006**, *26*, 989–995. [\[CrossRef\]](#)
51. Sharafi, K.; Pirsaeheb, M.; Maleki, S.; Arfaeinia, H.; Karimyan, K.; Moradi, M.; Safari, Y. Knowledge, attitude and practices of farmers about pesticide use, risks, and wastes; a cross-sectional study (Kermanshah, Iran). *Sci. Total Environ.* **2018**, *645*, 509–517. [\[CrossRef\]](#)
52. Yang, X.; Wang, F.; Meng, L.; Zhang, W.; Fan, L.; Geissen, V.; Ritsema, C.J. Farmer and retailer knowledge and awareness of the risks from pesticide use: A case study in the Wei River Catchment, China. *Sci. Total Environ.* **2014**, *497–498*, 172–179. [\[CrossRef\]](#)
53. Tezcan, H.; Ozahiskali, H.; Toktay, S.; Gunaltay, S.; Kilinc, I.; Akbas, L.; Yildirim, I. Changes in education and education of agricultural pharmaceutical dealers. In *Proceedings of the Agricultural Engineering VII. Technical Congress*, Ankara, Turkiye, 1–4 January 2010; pp. 645–650.
54. Jean, S.; Emmanuel, F.; Edouard, A.N. Brownlinda, Farmers' knowledge, attitude and practices on pesticide safety: A case study of vegetable farmers in Mount-Bamboutos agricultural area, Cameroon. *Agric. Sci.* **2019**, *10*, 1039–1055. [\[CrossRef\]](#)

55. Satya Sai, M.V.; Revati, G.D.; Ramya, R.; Swaroop, A.M.; Maheswari, E.; Kumar, M.M. Knowledge and perception of farmers regarding pesticide usage in a rural farming village, Southern India. *Indian J. Occup. Environ. Med.* **2019**, *23*, 32–36. [[CrossRef](#)] [[PubMed](#)]
56. Saglam Altinkoy, H.D.; Akan, K.; Kan, A.; Korkmaz, A. Evaluation of plant protection products dealers' current situation and their problems in Kirsehir province. *Mediterr. Agric. Sci.* **2020**, *33*, 351–359. [[CrossRef](#)]
57. Nguyen, M.T.; Le, N.T.; Havukainen, J.; Hannaway, D. Pesticide use in vegetable production: A survey of Vietnamese farmers' knowledge. *Plant Prot. Sci.* **2017**, *54*, 203–214. [[CrossRef](#)]
58. Mardigian, P.; Chalak, A.; Fares, S.; Parpia, A.; El Asmar, K.; Habib, R.R. Pesticide practices in coastal agricultural farms of Lebanon. *Int. J. Environ. Health Res.* **2021**, *31*, 132–147. [[CrossRef](#)]
59. Soudani, N.; Belhamra, M.; Toumi, K. Pesticide use and risk perceptions for human health and the environment: A case study of Algerian farmers. *Ponte* **2020**, *76*, 10–28. [[CrossRef](#)]
60. Munif, A.; Rachmawati, V. Knowledge, attitude and action of farmers in controlling plant pest and disease of potato in Garut, West Java. In Proceedings of the Southeast Asia Plant Protection Conference, Bogor, Indonesia, 14 August 2019; Volume 468, p. 012053.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.