

## Article

# Is the Environmental Behavior of Farmers Affecting Their Pesticide Practices? A Case Study from Greece

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**Abstract:** Policymakers often assume that farmers with pro-environmental behavior are more likely to follow proper pesticide practices and thus, in order to improve the safety of their pesticide practices, they implement strategies and programs designed to raise environmental awareness among the general public. The aim of this paper is to examine whether pro-environmental behavior can instigate proper pesticide practices among farmers. According to our results, farmers' environmental behavior does not affect their pesticide practices and thus strategies aiming at raising environmental awareness among the general public would not prompt them to follow proper pesticide practices. In addition, the respondents reported following overall proper practices such as wearing masks and appropriate clothes during sprayings as well as rinsing the empty containers by performing the triple-rinse method. However, they did not wear gloves during applications, and many disposed the remaining pesticide concentrate to non-arable land. To conclude, in order to improve farmers' pesticide practices, strategies and programs specifically designed for farmers must be developed because those addressed to the general public would not be effective. Moreover, certain improper practices found in this study ought to be addressed by policymakers and actors involved in the agricultural sector.

**Keywords:** pesticide use; sustainable agriculture; farmers' pesticide practices; sustainable use of pesticides; farmers' behavior; 2009/128/EC Directive on the Sustainable Use of Pesticides (SUP)



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## 1. Introduction

Pesticides can protect crops from pests, pathogens, and weeds, thereby ensuring high yields. Due to these advantages, pesticide use has become widespread both in developed and developing countries [1–3]. If, however, pesticides are not applied properly, they can not only harm non-target organisms but also pose serious risks to human health [4–6]. Over the past years, there have been strong concerns about the impacts of pesticides and policies have been established to mitigate their improper use. In addition, there has been much debate on the sustainability of agriculture and pesticides that can be used at low dose have entered the market in the European Union (EU). Meanwhile, the use of pesticides in EU shows no signs of abating [7] and many voices have been stressing the need to further monitor farmers' pesticide use practices.

In 2009, the European Union adopted the 2009/128/EC Directive on the Sustainable Use of Pesticides (SUP) which foresaw that from 2014 and onwards all farmers must adopt integrated pest management and transition to practices and products which pose the lowest risk to human health and the environment. In addition, the Directive required all Member States to develop and submit National Action Plans in which they would state their

objectives, measures, and timelines aimed at decreasing the dangers and negative effects of pesticide use on human health and the natural environment as well as to promote integrated pest management and alternative methods to reduce the reliance on pesticide use.

In Greece, agriculture is a basic sector of the economy and has always played a key role in the evolution of society. In the second quarter of 2020, the Gross Domestic Product (GDP) from agriculture reached 1736.56 million euros [8]. As a Member State of the European Union and in line with the 2009/128/EC Directive, Greece was bound to reduce pesticide use through the development and adoption of a National Action Plan on the Sustainable Use of Pesticides. According to the Greek National Action Plan (Ministerial Decision Num 8197/90920/22-7-2013), training and certification on the use of pesticides is required for all farmers. Only certified professional farmers can buy and use pesticides and, at the same time, certification implies that farmers have the basic knowledge to protect themselves, consumers and the environment from the harmful effects of improper use of pesticides. However, the certificate can be recalled if infringements are detected during official controls (which are conducted by the Directorate of Crop Production Protection also referred to as the Coordinating National Authority in cooperation with the Regional Centers of Plant Protection and Quality Control). Such infringements involve the use of unauthorized pesticides, the application of higher dosages than the ones that are necessary and the improper disposal of pesticide containers. However, farmers can apply again for the certificate after attending a training program. It should be noted that training programs are free of charge when they are provided during the stewardship program of each company. However, an initial training program provided by certified agricultural training bodies is obligatory before farmers apply for the certification of sustainable use of pesticides. For this training, farmers pay, and the payment usually includes the fees for the participation in the exams and the corresponding certification. Complementary training programs are optional for farmers already having the certificate and need an update.

Moreover, the Greek National Action Plan foresees specific measures to protect the aquatic environment and drinking water. Specifically, farmers are informed by local control authorities and pesticide distributors about the use of low-drift nozzles, as well as measures to reduce the environmental risks related with pesticide application. In addition, they must register their pesticide application equipment and prefer non-hazardous pesticides over other options which are more toxic. Additionally, they are advised to follow efficient application methods such as using low-drift application equipment particularly in vertical crops. Furthermore, they are not allowed to spray pesticides on or along roads, absorptive surfaces, railway lines and any other infrastructure which is located in the proximity of surface waters or groundwater.

The Greek National Plan foresees that farmers must adopt certain practices in order to handle pesticides properly. As such, farmers must wear protective equipment (e.g., chemical protection suits, nitrile chemical resistant gloves) before they start preparing the spraying solution and keep on wearing it during pesticide application. After application, they must wash thoroughly the spraying equipment away from surface waters and check it for any leakages. Farmers can harvest their crops no sooner than the legal pre-harvest interval defined for each formulation and must never use higher dosage than the one that is stated in the directions on the pesticide's label. However, if there is still some remaining pesticide in the container, the users can keep it for the next application but ensure that the container is tightly closed. If the pesticide container is empty, the farmers must wash it by performing a triple rinse either by hand or using pressure machinery and pour the rinse water into the spray tank. Empty containers must not be placed in with regular garbage because if there is any pesticide left in the container, it may pollute regular waste. Hence, farmers must collect containers in specific basins which are used explicitly for containers. When an appreciable number of empty containers is collected, farmers must take them to licensed companies which are responsible for managing the containers in terms of energy recovery or recycling.

Pesticides can be dangerous to farmers who apply them and thus necessitate the adoption of protective measures. However, the literature examining farmers' practices during pesticide application shows that farmers are often somewhat reluctant to take protective measures. For instance, 76% of farmers in Thailand sprayed pesticides without taking any form of protective measures such as wearing gloves or masks during application [9]. A similar disinclination to protective measures was observed among Indian farmers who remained barefooted during pesticide application [10] but also among Bangladeshi farmers who reported not using protective equipment or wearing protective clothing during sprayings [11]. However, a remarkable commitment to protection measures was indicated in the study of Houbraken et al. [12] who indicated that the majority of farmers in Vietnam wore gloves, face shields, masks, or goggles during pesticide application. It is interesting to note that most farmers had attended training on pesticide use [12].

Moreover, the relevant literature has examined the factors affecting farmers' adoption or non-adoption of protective measures. In developing countries, factors such as low educational level, false views, lack of regulations on protective measures, sufficient information about pesticides, the increased interest in ensuring high yields to obtain greater profits and the lack of training on farming practices have a negative effect on farmers' practices and explain their reluctance to adopt protective measures in pesticide application [10,11,13,14]. Moreover, age appears to play a negative role in the adoption of protective measures as older farmers were found to be significantly less willing to adopt them [11].

Another significant topic in the relevant literature is how farmers dispose empty pesticide containers which, if not managed properly, can be hazardous to human health and the environment. In specific, empty pesticide containers used for storing food and water could lead in poisoning and, if they are abandoned in the environment, they can result in soil and groundwater pollution [15]. For this reason, empty pesticide containers must be subjected to a triple rinse process to become "non-hazardous waste" and then be recycled. It is therefore up to farmers' will to dispose containers safely or allow them to threaten the environment and human health. The relevant literature has examined farmers' attitudes towards the disposal of empty pesticide containers. Houbraken et al. [12] found that most of the Vietnamese farmers, who participated in their study, stored the empty containers for incineration and 37% of them threw them in the garbage or disposed of them to landfills, while very few respondents buried them and threw them in rivers. Perilous disposal practices were observed by Yang et al. who indicated that an appreciable percentage of Chinese farmers threw the empty containers near the fields where they prepared the pesticide solution [16]. Moreover, the surveyed Bangladeshi farmers reported not disposing the empty containers according to the guidelines on the pesticide label [11]. What is more, Wang et al. found that significant shares of Chinese female and male farmers disposed the empty containers without performing any type of treatment, while very few farmers sold the containers to recycling collectors [17].

Farmers are the end-users of pesticides and thus their practices for using pesticides are critical to addressing the environmental contamination caused by pesticides and preventing health issues associated with the improper use of pesticides. At the same time, farmers who are members of agricultural cooperatives present an interesting case because the cooperatives can be a significant source of information about the safety and the proper use of pesticides as well as the disposal of pesticide containers. In this regard, agricultural cooperatives are very important stakeholders and are able to affect the practices of their members. In addition to the role of cooperatives, farmers' pesticide use practices may be affected by their environmental behavior. Although a considerable number of studies has examined the factors affecting farmers' practices [10,11,13,14] there is a paucity of studies when it comes to the effect of farmers' environmental behavior on pesticide use practices. To fill this gap, the aim of this study is to examine the pesticide use practices of farmers and to investigate whether pesticide use practices are affected by their environmental behavior. The findings contribute to the growing literature devoted to understanding farmers' pesticide practices and may be particularly useful to policymakers and guide

them to improve the existing legal framework as well as the strategies and programs which aim to improve the practices the farmers follow when they apply pesticides.

## 2. Materials and Methods

The population under study was farmers who live and work in the Municipal Unit of Zagora, which in terms of administration belongs to the Municipality of Zagora-Mouresi and is located in Thessaly, Greece. According to the last national population census conducted in 2011, the population is 2074 residents. The study area has important agricultural production and involves several agricultural cooperatives with the most important being the renowned cooperative “Zagorin” that produces apples which have been recognized as “Protected Designation of Origin” products. The findings presented in this paper are part of a larger research which was conducted from June 2019 to September 2019 and analyzed farmers’ views on various agricultural topics as well as their farming practices. However, in this paper we focused explicitly on farmers who are members of agricultural cooperatives.

To achieve the research objectives, a questionnaire was developed. All items drew on the findings of former relevant studies and were specifically designed to capture farmers’ environmental behavior and their practices in pesticide use. To investigate farmers’ environmental behavior, the findings of Zerinou et al. and Karasmanaki and Tsantopoulos were considered and to examine their pesticide use practices the findings of Karasmanaki et al., Houbraken et al., and Akter et al. were taken into account [2,11,12,18,19]. With the exception of two dichotomous questions, most items in the questionnaire were closed-ended questions with four- and five-point Likert scales. To ensure that the questionnaire would provide accurate and coherent results, a pilot study was conducted on a limited scale and few minor changes were made in the phrasing and formulation of certain items.

As for the sampling method of the study, the respondents were selected by simple random sampling. Simple random sampling was considered the most appropriate method because it is quite easy to perform and requires very little knowledge about the population under study. In addition, it is fundamental to estimate the size of the sample because greater sample sizes can waste valuable time and resources whereas smaller sample sizes can lead to inadequate information about the population. The sample size was thus estimated using the formula for finite population correction. Since variables refer to proportions, the sample size was calculated using the following formula:

$$n = \frac{t^2 p(1-p)}{e^2} \quad (1)$$

In this formula,  $p$  stands for the (estimated) proportion of the population and  $t$  for Student’s  $t$ -distribution with a probability of  $(1 - \alpha) = 95\%$  and with  $n - 1$  degrees of freedom. In addition,  $e$  represents the highest accepted difference which occurs between the unknown population mean and the sample mean. Since pre-sampling gave a large sample size (greater than 50), the value of  $t$  for the desired probability was taken from probability tables for normal distribution. This means that for a probability of 95% the value was 1.96. Moreover, the calculation gave  $e = 0.068$ ,  $t^2 = 1.96$ , and  $(1 - \alpha) = 95\%$  confidence interval with  $n - 1$  degrees of freedom [20]. A pre-sampling with 50 individuals had to be performed. Therefore, the proportion population ( $p$ ) was estimated for each variable. Since the questionnaire does not estimate only one but many variables, it is always necessary to calculate the sample size for each variable. In the case that the calculated sample sizes are similar and if it can be afforded, the highest sample size is chosen. In this manner, the most varying variable is calculated accurately whereas the other variables are estimated with higher accuracy than it was first determined [20]. In this study, the highest sample size scored for the variable “Are you a member of an agricultural cooperative?”. The proportion was  $p = 0.56$  and thus  $1 - p = 0.5$ . Hence, for  $t = 1.96$  and  $e = 0.068$ , the sample size was estimated at 207 farmers. In total, 210 farmers participated in the study and of these 199 farmers are members of agricultural cooperatives. In our analysis we included only the responses of those 199 farmers who are members of agricultural cooperatives.

Finally, the collected data were analyzed with the Statistical Package for the Social Sciences (SPSS) software version 23, and, more specifically, descriptive statistics, the non-parametric Friedman test, and ANOVA analysis were performed [21,22].

### 3. Results

#### 3.1. Respondents' Demographic Characteristics

The sample consisted of 199 farmers who were members of agricultural cooperatives in the study area. Most of them were male (by 62.3%). As for their age, substantial shares of participants were aged between 41 and 50 (49.2%), 31 and 40 (23.1%), and between 51 and 65 (17.6%). The overwhelming majority (by 85.4%) were married and a substantial share (58.8%) had two children. As for their educational level, considerable percentages of respondents were junior high school graduates (35.5%), high school graduates (34.2%), and 17.6% had only completed primary education. Finally, farming was the main occupation for the majority of respondents (82.9%) and 35.7% of respondents had been engaged in farming for 25–35 years and 33.2% for 16–25 years (Table 1).

**Table 1.** Social and demographic characteristics of respondents.

Variable	Category	Percentage %
Gender	Male	62.3
	Female	37.7
Age	18–30	7.5
	31–40	23.1
	41–50	49.2
	51–65	17.6
	>65	2.5
Family status	Unmarried	12.6
	Married	85.4
	Divorced	2.0
	Widow/Widower	-
Education level	Primary school graduate or having attended only some grades of primary school	17.6
	Middle school	35.2
	Technical school	5.0
	High school	34.2
	University	8.0
Number of children	0	15.1
	1	12.6
	2	58.8
	3	11.6
	4	2.0
Years working as farmer	Up to 5 years	6.0
	6–15	12.6
	16–25	33.2
	25–35	35.7
Type of involvement in agriculture	Over 36 years	12.6
	Main profession	82.9
	Supplementary work	17.1

#### 3.2. Farmers' Environmental Behavior

To discover respondents' environmental behavior, they were required to assess various daily practices and habits based on the frequency of performing them on a five-point scale ranging from "never" to "very often". Results given in Table 2 indicate that 82.9% of respondents avoided littering in public places and 76.4% recycled. Moreover, as many as 72.8% used energy efficient light bulbs and 72.4% saved water. However, significantly fewer

respondents reported buying organic products, using environmentally friendly packages, participating in voluntary groups, and using solar water heaters.

**Table 2.** Percentages regarding the frequency with which the respondents perform various environmental practices and habits.

	Never	Seldom	Sometimes	Usually	Always
Avoiding littering in public places	6.0	6.0	5.0	25.6	57.3
Avoiding using the car or motorbike unless necessary	7.5	10.1	28.1	37.7	16.6
Participation in voluntary groups	39.7	31.2	22.6	3.0	3.5
Recycling	6.5	3.0	14.1	30.2	46.2
Water saving	1.0	5.0	21.6	37.7	34.7
Using energy efficient light bulbs	4.5	4.0	18.6	25.6	47.2
Using solar water heater	47.7	7.0	9.0	16.6	19.6
Using environmentally friendly packages	16.1	16.6	35.2	18.6	13.6
Buying organic products	27.1	26.1	24.6	12.6	9.5

Responses were then ranked using the non-parametric Friedman test. As it can be seen in Table 3, “Avoiding littering in public places” ranked first (mean rank 6.81), “Using energy efficient light bulbs second” (6.52) and “Recycling” third (mean rank 6.45). “Water saving”, and “Avoiding using the car or motorbike unless necessary” also received high rankings (6.31 and 5.14, respectively). On the contrary, respondents gave the lowest ranking to “Participation in voluntary groups” (mean rank 2.46).

**Table 3.** Hierarchy of farmers’ daily practices and habits.

Daily Practices and Habits	Mean Rank
Avoiding littering in public places	6.81
Avoiding using the car or motorbike unless necessary	5.14
Participation in voluntary groups	2.46
Recycling	6.45
Water saving	6.31
Using energy efficient light bulbs	6.52
Using solar water heater	3.69
Using environmentally friendly packages	4.29
Buying organic products	3.32

$N = 199$  Chi-Square = 652.134 Df = 8  $p < 0.001$ .

### 3.3. Farmers’ Practices before and during Pesticide Application

Farmers were then asked to report the practices they perform before and during pesticide application as well as to report the use of personal protective measures. As it can be seen in Table 4, 99.5% of respondents stated that they usually and always keep a record of pesticide applications. Moreover, 95% of them stated that they usually and always read the directions on the label of the pesticide before every application. Moreover, 65.3% of respondents reported not using the same spraying equipment to perform sprayings with

other types of pesticides (herbicides, fungicides, insecticides). However, an appreciable share of participants (by 19.1%) sprayed pesticides in unfavorable wind conditions. As for protective behavior, 93% of farmers usually and always wore masks during sprayings. Nevertheless, significantly fewer farmers wore gloves during applications. In specific, 17.6% of respondents stated that they sometimes wear gloves, and 11.5% reported that they seldom and never wear gloves. In addition, a considerable share of farmers (by 16%) reported sometimes or seldom or never wearing appropriate clothes during pesticide application. Additionally, 23.6% reported not having acquired a first-aid kit.

**Table 4.** Percentages regarding farmers' practices before and during pesticide application.

	Never	Seldom	Sometimes	Usually	Always
Reading the directions on the label of the pesticide before every application	1.0	1.0	3.0	20.6	74.4
Having acquired a first aid kit	17.6	6.0	21.1	16.6	38.7
Wearing appropriate clothes during pesticide application	2.0	4.5	9.5	24.1	59.8
Wearing gloves during pesticide application	2.0	9.5	17.6	14.1	56.8
Wearing a mask during pesticide application	2.0	0.5	4.5	17.1	75.9
Recording in a logbook every pesticide application for each crop	0.0	0.0	0.5	20.1	79.4
Avoid pesticide application if wind conditions are unfavorable	2.0	1.0	16.1	30.7	50.3
Avoiding using the same spraying equipment for applications of herbicides, fungicides and insecticides	12.6	7.5	14.6	8.0	57.3

The non-parametric Friedman test was next performed with the intention to rank farmers' practices before and during pesticide application. According to the Friedman test results displayed in Table 5, "Recording in a logbook every pesticide application for each crop" ranked first (mean rank 5.43), "Wearing a mask during pesticide application" ranked second (mean rank 5.29), and "Reading the directions on the label of the pesticide before every application" (mean rank 5.26). Conversely, the lowest ranked practices were "Avoiding using the same spraying equipment for other applications with different types of pesticides" and "Having acquired a first aid kit" with a mean rank of 4.05 and 3.13, respectively.

**Table 5.** The application of the Friedman test for ranking respondents' practices before and during pesticide application.

Practices before and during Pesticide Application	Mean Rank
Reading the directions on the label of the pesticide before every application	5.26
Having acquired a first aid kit	3.13
Wearing appropriate clothes during pesticide application	4.57
Wearing gloves during pesticide application	4.14
Wearing a mask during pesticide application	5.29
Recording in a logbook every pesticide application for each crop	5.43
Avoid pesticide application if wind conditions are unfavorable	4.13
Avoiding using the same spraying equipment for applications of herbicides, fungicides, and insecticides	4.05

N = 199 Chi-Square = 242.779 Df = 7  $p < 0.001$ .

### 3.4. Farmers' Practices for Handling the Remaining Pesticide in Containers

The questionnaire also included an item which examined how farmers handle the pesticide that remains in the pesticide container and their practices after pesticide application. As Table 6 shows, the overwhelming majority of respondents (by 95%) reported always avoiding releasing the remaining pesticide into irrigation canals and rivers while 83.4% reported washing the spraying equipment thoroughly after every application. However, 49.3% disposed of the remaining pesticide to non-arable land and 74.9% reported keep on using it until the container is empty. Finally, 98.5% of respondents stated that they

usually or always allow the required time (pre-harvest interval) to pass between pesticide application and harvest.

**Table 6.** Percentages concerning farmers' practices in handling the remaining pesticide in the container and their practices after pesticide application.

	Never	Seldom	Sometimes	Usually	Always
Avoiding storing the remaining pesticide in order to use it next time	44.2	23.6	9.5	3.0	19.6
Avoiding disposing of the remaining pesticide to non-arable land	34.2	15.1	9.5	11.6	29.6
Avoiding releasing the remaining pesticide of the container into rivers or irrigation canals	0.5	0.5	0.5	3.5	95.0
Using the remaining pesticide until the container is empty	13.6	1.5	10.1	22.6	52.3
Allowing the proper amount of time to pass between pesticide application and crop harvest according to the directions for use on the pesticide label	0.0	0.5	1.0	17.6	80.9
Washing the spraying equipment with abundant water and detergent	6.5	3.0	7.0	17.1	66.3

To detect whether statistical differences occur among farmers' practices in handling the remaining pesticide in the container and their practices after pesticide application, statistical analysis was conducted by the non-parametric Friedman test. As Table 7 shows, the practice "Avoiding releasing the remaining pesticide of the container into rivers or irrigation canals" ranked first (mean rank 4.67) followed by the practice "Allowing the proper amount of time to pass between pesticide application and crop harvest according to the directions for use on the pesticide label" (mean rank 4.35). However, the practices "Avoiding disposing of the remaining pesticide to non-arable land" and "Avoiding storing the remaining pesticide in order to use it next time" ranked in the last positions with mean ranks of 2.62 and 2.04, respectively.

**Table 7.** The application of the Friedman test for ranking farmers' practices in handling the remaining pesticide in the container and their practices after pesticide application.

Practices in Handling the Remaining Pesticide in the Container and Practices after Pesticide Application	Mean Rank
Avoiding storing the remaining pesticide in order to use it next time	2.04
Avoiding disposing of the remaining pesticide to non-arable land	2.62
Avoiding releasing the remaining pesticide of the container into rivers or irrigation canals	4.67
Using the remaining pesticide until the container is empty	3.44
Allowing the proper amount of time to pass between pesticide application and crop harvest according to the directions for use on the pesticide label	4.35
Washing the spraying equipment with abundant water and detergent	3.88

N = 199 Chi-Square = 403.284 Df = 5  $p < 0.001$ .

### 3.5. Farmers' Practices for Rinsing Pesticide Containers before Disposing of Them

Empty pesticide containers can be dangerous for human health and the natural environment if they are not rinsed and disposed of properly. For this reason, the respondents were asked how they rinse the empty pesticide containers before disposing of them. As shown in Table 8, over half (by 55.8%) of the respondents stated that they usually or always triple rinse pesticide containers, pour the rinse water in the spray tank and then let it dry under the sun. In addition, a high share of participants (92.4%) stated that they do not rinse the container with water and do not throw it somewhere in the field. In addition, 84.9%

reported not emptying the contents of the containers and throwing it somewhere in the field.

**Table 8.** Percentages concerning farmers' practices for rinsing pesticide containers before disposing of them.

	Never	Seldom	Sometimes	Usually	Always
Not releasing the remaining pesticide on the ground and then not throwing the container in the field	6.5	4.5	4.0	4.5	80.4
Not rinsing the container with water and then not throwing it somewhere in the field	0.0	3.0	4.5	6.5	85.9
Not rinsing the container once with water inside the spray tank and then not throwing it somewhere in the field	22.1	14.6	10.1	4.0	49.2
Rinsing the container with water three times, then pouring the rinse water in the spray tank and finally turning the rinsed container upside down so that it dries in the sun	29.6	5.0	9.5	11.6	44.2

Then, to detect statistical differences among farmers' practices for rinsing pesticide containers before disposing of them, statistical analysis was conducted using the non-parametric Friedman test. According to the test's findings (Table 9), the practice "Not rinsing the container with water and then not throwing it somewhere in the field" was ranked first (mean rank 2.96) and the practice "Not releasing the remaining pesticide on the ground and then not throwing the container in the field" was ranked second (mean rank 2.80).

**Table 9.** The application of the Friedman test for ranking farmers' practices for rinsing pesticide containers before disposing of them.

Practices for Rinsing Pesticide Containers before Disposing of Them	Mean Rank
Not releasing the remaining pesticide on the ground and then not throwing the container in the field	2.80
Not rinsing the container with water and then not throwing it somewhere in the field	2.96
Not rinsing the container once with water inside the spray tank and then not throwing it somewhere in the field	2.11
Rinsing the container with water three times, then pouring the rinse water in the spray tank and finally turning the rinsed container upside down so that it dries in the sun	2.13

N = 199 Chi-Square = 143.318 Df = 3  $p < 0.001$ .

### 3.6. Farmers' Practices for Disposing of Pesticide Containers

Pesticides must be disposed of properly in order to prevent accidents and to protect the natural environment. Farmers were thus asked to report how they dispose of the containers. According to the results displayed in Table 10, all respondents do not throw the containers in irrigation canals and rivers. In addition, most respondents do not bury (98.5%) the containers in the fields and do not keep them for other uses (90.5%). Finally, a considerable share reported collecting the containers for recycling.

**Table 10.** Percentages regarding the frequency with which the respondents perform various practices to dispose of the pesticide containers.

Practices for Disposing of Pesticide Containers	Never	Seldom	Sometimes	Usually	Always
Avoiding burying the containers in the fields	0.0	1.0	0.0	0.5	98.5
Avoiding keeping the containers for other uses	0.5	1.0	5.0	3.0	90.5
Collecting the containers for recycling	17.1	2.0	3.5	12.6	64.8
Avoiding collecting the containers and burning them	8.0	9.0	11.6	6.0	65.3
Disposing of the containers in landfills and other waste disposal sites	82.9	6.0	3.0	5.5	2.5
Avoiding throwing the containers in irrigation canals and rivers	0.0	0.0	0.0	0.0	100

Farmers' practices for disposing of pesticide containers were then ranked using the non-parametric Friedman test. As it can be seen in Table 11, the practice "Avoiding throwing the containers in irrigation canals and rivers" ranked first (mean rank 4.39) while the practice "Disposing of the containers in landfills and other waste disposal sites" received the lowest ranking (mean rank 1.31).

**Table 11.** The application of the Friedman test for ranking farmers' practices for disposing of pesticide containers.

Practices for Disposing of Pesticide Containers	Mean Rank
Avoiding burying the containers in the fields	4.35
Avoiding keeping the containers for other uses	4.15
Collecting the containers for recycling	3.38
Avoiding collecting the containers and burning them	3.41
Disposing of the containers in landfills and other waste disposal sites	1.31
Avoiding throwing the containers in irrigation canals and rivers	4.39

$N = 199$  Chi-Square = 644.738 Df = 5  $p < 0.001$ .

### 3.7. Correlation between Farmers' Environmental Behavior and Their Pesticide Use Practices

Comparison between farmers' environmental behavior and their pesticide use practices was conducted with ANOVA. According to the results of the analysis, there is a positive correlation only between farmers' environmental behavior and the practices they utilize in order to dispose of pesticide containers ( $r = 0.296$ ,  $p < 0.01$ ). However, environmental behavior is not correlated with the remaining pesticide practices. Moreover, practices for rinsing pesticide containers before disposal are correlated with the practices the farmers follow before and during pesticide application ( $r = 0.271$ ,  $p < 0.01$ ). Finally, the practices that the respondents perform in order to dispose of pesticide containers are correlated with the practices they perform to rinse the empty containers before disposing of them ( $r = 0.296$ ,  $p < 0.01$ ) (Table 12).

**Table 12.** ANOVA correlation table of farmers' environmental behavior and their pesticide use practices.

<b>Correlations</b>					
	<b>Environmental Behavior</b>	<b>Practices before and during Pesticide Application</b>	<b>Practices for Handling the Remaining Pesticide in Containers</b>	<b>Practices for Rinsing Pesticide Containers before Disposing of Them</b>	<b>Practices for Disposing of Pesticide Containers</b>
<b>Environmental behavior</b>	1 199				
<b>Practices before and during pesticide application</b>	0.107 199	1 199			
<b>Practices for handling the remaining pesticide in containers</b>	0.033 199	0.093 199	1 199		
<b>Practices for rinsing pesticide containers before disposing of them</b>	0.106 199	0.271 ** 199	0.092 199	1 199	
<b>Practices for disposing of pesticide containers</b>	0.296 ** 199	0.268 ** 199	0.043 199	0.190 ** 199	1 199

\*\* Correlation is significant at the 0.01 level (2-tailed).

#### 4. Discussion

This study sought to examine the pesticide use practices of Greek farmers, who have joined agricultural cooperatives, and to analyze the relationship between these practices and their environmental behavior. In this regard, the insights gained in this study can help us assess whether campaigns aiming at raising environmental awareness among the general public could be effective in prompting farmers to adopt proper pesticide practices.

An important finding was that most farmers complied with the guidelines of proper pesticide use which are stated in the Greek National Action Plan. For instance, most respondents reported reading the directions on pesticides' label before applying pesticides and recording every pesticide application. However, our findings concerning the adoption of personal protective measures raise implications. While most respondents wore masks during sprayings, a considerable share did not wear gloves, nor did they keep a first-aid kit at hand. This could be associated either with the reduced physical flexibility associated with gloves and the inconvenience that they create to users or to their relatively high cost which have been indicated as causes of not using them in other studies [11,23]. Regardless of the reason that drives farmers not to use them, gloves are a very important protective measure and policymakers should ensure that this is adequately explained to the farmers who attend training programs in order to obtain the certificate of knowledge on the sustainable use of pesticides.

Moreover, it was alarming that an appreciable share of farmers disposed of the remaining pesticide to non-arable land. This practice can cause point source pollution because the remaining pesticide left in the container is not diluted and can contaminate ground water bodies through leaching. However, most farmers rinsed the empty containers three times before disposing them and refrained from other inadequate rinsing methods such as rinsing the container only once. This suggests that the training programs have been effective in teaching farmers how to rinse properly the containers so that it is safe to recycle or dispose of them.

Farmers' practices for disposing empty containers are another point requiring discussion. Interestingly, 100% of respondents reported never throwing the containers in irrigation canals and rivers. In an attempt to explain this impressively high percentage, it should be noted that in the study area farmers fill their tanks from rivers, which flow into the sea. Hence, it is possible that the respondents and their families swim in this part of the sea in the summer and this may have made farmers greatly mindful of water quality. Moreover, it cannot be stated with certainty that the water is uncontaminated because no studies have so far examined the levels of pesticide-related pollution in the rivers and streams which are located in the study area. Meanwhile, in the wider region of Thessaly two studies have indicated that certain water ecosystems have been contaminated with pesticides, heavy metals and other residues [24,25]. Moreover, our findings showed that most respondents do not bury the containers in fields, do not burn them and do not dispose of them in landfills. Hence, our farmers' practices for disposing containers are significantly different from those of the Vietnamese farmers who stored the empty containers for incineration, and many threw them in the garbage or took them to landfills [12].

It was concerning, however, that many respondents reported not collecting the containers for recycling although it is recommended to collect the empty containers in collection basins, and, then take them to licensed companies which are responsible for managing the containers in terms of energy recovery or recycling. This suggests that there may be difficulties hindering the collection and recycling of containers.

Finally, a very important finding was that there is no significant correlation between farmers' environmental behavior and their pesticide use practices. In essence, this means that farmers' environmental behavior is not affecting their pesticide use practices. Taking this a step further, it may be argued that, in the case of farmers, environmental awareness is not translated into following proper pesticide use practices. As far as policy is concerned, this suggests that strategies aiming at raising environmental awareness among the general public would not be effective in prompting farmers to follow proper pesticide use practices.

In order to improve the practices the farmers follow to handle pesticides, it is recommended to develop strategies explicitly addressed for farmers and ensure that farmers are further trained on proper pesticide use practices.

## 5. Conclusions

The improper use of pesticides can have severe impacts on human health and the natural environment and, in this regard, farmers are able to prevent these risks. This study has contributed to the relevant literature strand by analyzing farmers' pesticide use practices and by investigating whether farmers' overall environmental behavior affects the practices they follow in the use of pesticides. Such insights can enable policymakers to understand whether common campaigns aimed at raising environmental awareness would be effective in prompting farmers to adopt proper pesticide use practices.

Overall, this study indicated that farmers follow proper practices when they apply pesticides and conform to most guidelines stated in the EU Directive on the Sustainable Use of Pesticides and the relevant Greek National Plan. More specifically, the overwhelming majority of respondents reported reading directions for use on pesticide labels, rinsing properly pesticide containers, never throwing containers or releasing the remaining pesticide concentrate in rivers and irrigation canals, as well as keeping a logbook of sprayings. From a policy perspective, it may be inferred that the Directive has been effective in promoting proper practices among farmers. Nevertheless, future policy designing should address certain improper practices which were detected in this study. In particular, the farmers reported not wearing gloves during application and not keeping a first-aid at hand while an appreciable share disposed of the remaining pesticide concentrate to non-arable land. Hence, the implications for policymakers and organizers of farmer training programs are to ensure that the farmers take these personal safety measures, and it is also necessary to mitigate the disposal of pesticides to non-arable land by perhaps establishing laws that ban it. In addition, this study discovered that a considerable share of farmers do not collect containers for recycling and thus policymakers should consider developing strategies and measures aiming at increasing the recycling rate for pesticide containers.

It is also fundamental to recognize the need for future research. In particular, future research could employ qualitative approaches in order to examine in depth the perceptions of farmers who do not wear gloves and do not keep first-aid kits near the place of pesticide application to understand why they neglect these personal safety practices. Furthermore, the views of farmers who do not collect the empty containers for recycling or dispose pesticides to non-arable land should be investigated.

This study discovered that farmers' environmental behavior does not affect their pesticide use practices. In essence, this means that farmers who have pro-environmental behavior do not necessarily adopt proper pesticide use practices. Therefore, the existing strategies which have been developed in order to raise environmental awareness among the general public would not be effective in motivating farmers to adopt proper practices when they handle pesticides. To that end, strategies and programs specifically designed for farmers should be developed and the application of the same strategies addressed to other social groups should be avoided.

Moreover, certain limitations must be recognized. The findings are not generalizable to all farmers in Greece but represent only the farmers in the study area. Future studies in other Greek rural areas could indicate whether the situation recorded in this study applies to more farmer samples. Another limitation is that our study was based on responses and perhaps qualitative field research methods would offer further insights.

To conclude, it is not feasible for agriculture to stop relying on pesticides in order to produce food at affordable prices, but it is possible to improve the safety of pesticide use. As the key stakeholders in agriculture, farmers can easily turn into important allies when delivering schemes to reduce pollution levels due to pesticides.

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