

Farmers' risk perceptions of pesticides used for greenhouses vegetables production in Tunisian Center-East

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Abstract

The excessive use of pesticides has multiple adverse effects on the environment and human health. For a long time this problem was focused on the technical, agronomic, medicinal and pest management's aspects, while the problem is a behavioral problem and the socio-economic aspect plays an important role. In order to study the Farmers' risk perceptions of pesticides used in agriculture greenhouses in central-eastern Tunisia (Monastir Governorate), an ordered probit model was tested for 110 farms for greenhouse agriculture. The results showed the significance and positivity of the relationship between independent variables such as extension, use of protective equipment, experience, membership of the public irrigation perimeter, agricultural income, and the variable depending on Farmers' risk perceptions of pesticides used. On the other hand, absence of the relationship between the level of education and the perception that it seems contradictory, but it can be justified by the age of the farmers who is high. The overall significance of the ordered probit model with a perceived acceptable level of perception can be improved by taking into account the heterogeneity of the farmers in this region in terms of age, education level, membership in a public or private irrigation perimeter and the possibility of access to extension. Developing awareness-raising methods are based on demonstrative and simple techniques accompanied by optimal monitoring and control can reduce the rate of excessive use of pesticides and guarantee greenhouse agriculture sustainable in the central eastern region of Tunisia.

Keywords: *Perceptions, Pesticides use, Agriculture greenhouse, Farmers, Ordered probit, Center-East Tunisian.*

1. Introduction

Excessive use of pesticides has multiple adverse effects on the environment and human health, specifically; farmers are the first that are directly exposed to pesticides. This risk of intensive pesticide use has attracted scientific attention and researchers in different disciplines to develop

their research related to this issue: medical, environmental and agricultural. Nevertheless, few socio-economic researches studied this subject; they are mostly focused on the aspect of cost evaluation damage aspect (Wilson and Tisdell, 2001).

Most of the farmers justify this of over use by the fact that it's a way to ensure the harvest and

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realize a higher profit (Pingali and Gerpacio, 1997). Another point, some farmers do not respect pesticides retention times. That is to say, pesticides are also applied while the harvest continues. On the other hand, problems related to residues left by chemicals applied in agricultural products that affect the health of consumers. It is very common to find farmers who treat crops at harvest with dangerous pesticides that have long persistence and unapproved (over three weeks) (Yucel and Ulubilir, 1998). This is the case of approved systemic products that are dedicated to citrus; they are also applied to greenhouse crops.

2. Tunisian context and literature review

In Tunisia, the sector of leguminous crops protected occupies a place in the system of vegetable production and it also plays an important socio-economic role in the economy of the country. In addition, this sector allows better water and soil resources and presents the opportunity to offer great opportunities for intensification.

Protected crops are also characterized by their competitiveness and high value-added compared to vegetable crops grown in the open field. The Tunisian center-east constitutes the zone with a high concentration of crops under greenhouses (43.5% of the total area of the greenhouses in Tunisia) and remains promising to make good use of this sector. Greenhouse crops certainly have significant strengths but also weaknesses. Indeed, the protected crops are installed on small areas. The range of crops practiced is limited mainly to a few species of Solanaceous and Cucurbitaceous (green pepper, tomato, water melon...).

On the other hand, the greenhouses present an environment particularly favorable to the development of various pests of crops which further weaken this mainly family farming. To combat pests, farmers use irrationally chemicals without taking into account and without being aware of risks to the environment and human health (pesticide residues). Added to this, an inadequate management of water resources by greenhouses and soil degradation (loss of fertility, pollution

and salinization), aggravate the situation. Moreover, the persistence in protected crop systems of traditional practices that are poorly adapted, unproductive and destructive of biodiversity, reflect a weakness in the technical skills of small farmers and a lack of supervision.

In Tunisia, the intensive use of pesticides and chemical products in agriculture presents a real problem for the environment and human health in recent years. The greenhouse agriculture proves major consumer of pesticides and chemical fertilizers. The consumption of protected crops, alone accounts for 15% of the pesticides and fertilizers used in vegetable crops. These cultures consume 2-4 times more pesticides and fertilizers than field crops.

According to experts from the World Health Organization (WHO) and public health experts, this situation may partly explain the increase in cancer diseases observed in Tunisia (APIA, 2015). In the face these findings, the ministry of agriculture, water resources and fishing has responded through a framework of legislation, laws and institutions to limit these ecological risks. Indeed, we find for example Decree n. 2010-2973 dated 15 November 2010, amending and completing decree n. 92-2246 dated 28 December 1992, fixing the methods and conditions of obtaining the approval, the provisional authorizations of sale of the pesticides of agricultural use, as well as the conditions of their manufacture, importation, formulation, conditioning, storage, sale, distribution and the conditions of use of the pesticides of extremely dangerous agricultural use.

The development of this framework of legislation and instructions is necessary but insufficient because of the presence of several aspects in this context which requires a multidisciplinary approach taking into account the behavioral and the socio-economic aspects of the farmers.

In fact, this issue has been the subject of much debate in the economic literature: pesticide use, human health, environmental effects, safety concerns, exposure to pesticides and risk assessment indicators. Indeed, there is work that has focused on the economic evaluation of the economic cost of pesticide use considering it sometimes as inputs of agricultural production and in

other cases as the origin of negative externalities on environment, natural resources and human health, which need to be internalized. There are other works that focus on the behavioral aspect and the notion of risk aversion.

In agriculture, several economic quantification approaches have been developed to study or evaluate the intensive use of pesticides. Like the biological modeling approach for crop predators (Hall and Norgaard, 1973) or for optimal treatments against multiple pests simultaneously (Blackshaw, 1986). This line of research is pursued by Davis and Tisdell (2002) to, for example, study the management of problems related to the emergence of pesticide resistance (David and Tisdell, 2002).

There is also the adoption of classical economic specifications, such as Lichtenberg and Zilberman's (1986) approach for assessing the marginal productivity of plant protection products. This approach is in great demand by other researchers: Babcock, Lichtenberg and Zilberman (1992) and Chambers and Lichtenberg (1994).

Similarly, stochastic specifications approach developed by Just and Pope (1978) aimed at evaluating agricultural inputs such as pesticides on agricultural yield variation (Just and Pope, 1978). The work of Just and Pope has been extended by other approaches to farmers' attitudes towards the risk of pesticide use (Feder, 1979, Antle 1988 and Carpentier, 1995). The integration of farmers' attitudes towards the risk for the definition and the choice of policies of regulation of the use of pesticides is made the object of the several works that is through a taxation policy (Leathers and Quiggin, 1991) and Isik (2002) or an insurance policy, such as the program implemented by the USDA (Crop Insurance Program) in the United States (Glauber, 2004).

It can be seen that pesticide use evaluation approaches in agriculture are highly developed in economics but their applications are located almost in the countries of Europe and America. On the other hand, in developing countries, as in the case of Tunisia, these types of works are very limited. Some work that is based on modeling, such as technical-economic optimization

in agricultural model for improving the management of plant protection practices (Mghirbi *et al.*, 2016) or others that are based on environmental indicators of sustainability at the farm level using the IDEA method (Sustainability Indicators Farms) (M'hamdi, 2017).

The ratification of the Rotterdam Convention by Tunisia on February 9, 2016 represents an opportunity to create a pesticide management policy manual that respects the environment and human health for sustainable agriculture (FAO, 2016). This view of sustainability in the case of greenhouse agriculture requires a multidisciplinary approach to identify the determinants of a good perception of the risks of agricultural use of pesticides (Edwards-Jones, 2008).

The objective of this research paper is to assess the level of farmers' perceptions of pesticides used on health and agricultural environment for to identify socio-economic factors that influence their agricultural practices in greenhouse vegetable in Monastir governorate of east-central Tunisia.

3. Research Methodology

3.1. Study Area and Justification

Monastir governorate in the central-east of Tunisia was selected in this study for the following reasons. The greenhouse farming is the main agricultural activity in this region; it ranks first in the country in terms of agricultural land allocated by extending 1.6 % between 1992 and 2016. Today, the area of greenhouse crops in the Monastir area exceeds 245 hectares. The extension of agricultural land is also accompanied by a massive use of pesticides and chemicals to obtain an early harvest and realize higher benefits. The main greenhouse vegetable crops produced in this region are: tomato, pepper and cucumber. This region is a typical agricultural area that is threatened by high pesticide use in the central-east of Tunisia. 110 farmers practicing greenhouse crops were randomly selected from three delegations of Monastir region: "Baklta", "Tboulba" and "Moknine". The average number exceeds 5 greenhouses for 2 hectares of agricultural area by farmer (Figure 1).



Figure 1 - Location of Monastir Governorate.

3.2. Data and Analytical Model

Taking into account the objective of the study, data related to variables such as socio-economic variables, farm structure and pesticides used are collected as independent variables. The perception of farmers' risk of pesticides used and their awareness about its harmful effects on human health and environment are considered a dependent variable (PERC).

Dependent variable:

PERC: Farmers' risk perception of pesticides used and their awareness about their effects on their on human health and environment (PERC) is the Dependent variable.

As independent variables:

Socioeconomic variables: age (AGE), number of years' experience (EXP), farmer' civil state (CVF), education level (EDU) and extension service quality (SERV), household farm income (HFINC)

Farm structure variables: public irrigated perimeter (PIP), number of greenhouses (NG), agricultural area size (AAS).

Pesticide use variables: protective measures during pesticide application (PMPA), Number of

pesticide application (NPA), pesticides retention time (PRTIM),

3.3. Ordered Probit Model

Response chosen in an opinion survey often appears as a discrete choice set rather than a continuous one. When the dependent variable takes more than two values, but these values have a natural ordering, as is common in survey responses, the ordered probit model is often appropriate. The Ordered Probit model is a fairly straight forward extension of the binary probit model that can be used in cases where there is multiple and ranked discrete dependent variables. Discrete choice variables fall into two categories: The first is ordered variable and the second is unordered variables.

The previous studies have mostly used multiple regression models and binary probit or logit models to study statistical relations between dependent and explanatory variables. Because of the discrete nature of the dependent variable in this study, ordinary least squares regression would be an inappropriate model.

Probit or logit model specification is used for dichotomous dependent variables and it gives discrete outcomes too. With this in mind, mul-

tinomial model for discrete choice of ordered data is more applicable for this data analysis. Nevertheless the ordered probit model, which can make full use of every response choice, is statistically more efficient than the binary logit and probit model. Therefore the ordered probit model that uses Maximum Likelihood (ML) analysis was employed in this study (Borooah, 2002). Models for ordinal dependent variables can be formulated as a threshold model with a latent dependent variable (1).

$$Y_i^* = \beta_i'X_i + \varepsilon_i \quad (1)$$

Where, Y_i^* is unobserved variable. It is assumed that Y is normally distributed with zero mean. β is a vector of respondent characteristics.

Ordered probit model was used to examine the factors that influence the farmers' perceptions on the environments and health risks of pesticides use. The dependent variables were categorized as 1, 2 and 3, corresponding to “un-

aware”, “aware” and “very aware”, respectively on farmers' perceptions on the environment and health risks of pesticides use. The model, based on the latent regression function, was specified as:

$$Y = \begin{cases} 1, & \text{if } Y_i^* < \mu_1 \\ 2, & \text{if } \mu_1 < Y_i^* < \mu_2 \\ 3, & \text{if } Y_i^* > \mu_2 \end{cases} \quad (2)$$

Where μ_1 and μ_2 are the classifying threshold values.

Equation (1) and (2) can be used to specify the empirical model given in equation (3).

$$y(PERC)^* = \beta_0 + \beta_1 AGE + \beta_2 EXP + \beta_3 FCV + \beta_4 EDU + \beta_5 SERV + \beta_6 HFINC + \beta_7 PIN + \beta_8 NG + \beta_9 AAS + \beta_{10} PMPA + \beta_{11} PRTIM + \varepsilon \quad (3)$$

Where the variables used in equation (3) are defined in Table 1.

Table 1 - Variables used in ordered probit model.

Variable Name	Description of Variable	Type of Variable
PERC	Farmers' risk perceptions of pesticides used in greenhouse agriculture	Y_i^* 1 to 3 levels ordinal
AGE	Farmers' Age	Continuous
EXP	Number of years' experience in farming	Continuous
FCV	Farmers' Civil State; Single = 1, Married = 2	Scale
EDU	Education level; Illiterate = 1, Primary = 2, Secondary = 3, University = 4	Scale
SERV	Vulgarization Service quality; not satisfying = 1, satisfying = 2 and very satisfying = 3	Scale
HFINC	household farm income; no profitable = 1, average profitable = 2, profitable = 3	Scale
PIN	Farmer belongs to a public irrigation network; yes = 1, no = 0	Dummy
NG	Number of greenhouses	Discrete
AAS	Agricultural area size: small (AAS < 1) = 1, average (1 ≤ AAS < 2) and large (AAS > 2)	Scale
PMPA	Protective measures during pesticide application; yes = 1, no = 0	Dummy
PRTIM	Pesticides retention time; no = 1, approximately = 2 and scrupulously = 3	Scale

4. Results and Discussion

4.1. Data analysis and characteristics of farmers in greenhouse agriculture system

Analysis of data collected from a survey involving 110 farms with greenhouse cultivation in the Monastir region in the central-east of Tunisia showed that the average age of farmers is 49 years with an experience exceeding 26 years. More than 90 % of farmers surveyed are married and they are heads of households. Formal education was average with almost 53% of farmers having up to primary, about 21% had secondary education and almost of 2% had higher education. But, nearly 11% of the sample are literate (Table 2).

These socioeconomic variables show that farmers in this region have an important know-how to practice greenhouse cultivation. But the question is that, if this knowledge is accompanied by an understanding about pesticide use and its negative harmful effect on human health and environment.

Almost half of farmers surveyed have between 3 and 5 greenhouses, with an average of 5 greenhouses per farmer on an agricultural area not exceeding one hectare to 58% of them. This high concentration of greenhouses on small size will limit the change of the greenhouse from one place to another (Table 2).

44% of farmers belong to a public irrigation network, while 56% of them have private irrigation resources. For the level of vulgarization, 31% of farmers believe that the level is satisfying 11% think that it is very satisfying and 58% find it not satisfying (Table 2). If one crosses the vulgarization level variable with the belonging to a public or private irrigation network, it can be inferred that the vulgarization is focused on the public irrigation network while in the private network where farmers have several greenhouses and their productions are market-oriented, we find that vulgarization is almost absent. This low level of vulgarization can negatively affect farmers' risk perception of the pesticides use on the environment and human health.

In terms of economic profitability of greenhouses agriculture in the region of Monastir, over 48% of farmers think that this system is

not profitable, 35% of them say that profitability is average, while other farmers who own about 21% find that profitability is good. The majority of farmers predicated that greenhouse agriculture can be very beneficial, provided that certain constraints must be resolved (Table 2).

Table 2 - Sample profile and characteristics of farmers.

	Number	Percentage %	Means
PERC	110		
<i>Unaware = 1</i>	11	10	
<i>Aware = 2</i>	35	31.8	
<i>Very aware = 3</i>	64	58.2	
AGE	110		49
EXP	110		26
NG	110		5
FCV	110		
<i>Single = 1</i>	17	15.5	
<i>Married = 2</i>	93	85.5	
EDU	110		
<i>Illiterate = 1</i>	13	11.8	
<i>Primary = 2</i>	59	53.6	
<i>Secondary = 3</i>	36	32.7	
<i>University = 4</i>	2	1.8	
SERV	110		
<i>Not satisfied = 1</i>	64	58.2	
<i>Satisfied = 2</i>	34	30.9	
<i>Very satisfying = 3</i>	12	10.9	
HFINC	110		
<i>No profitable = 1</i>	48	43.6	
<i>Average profitability = 2</i>	39	35.5	
<i>Profitability = 3</i>	23	20.9	
PIN	110		
<i>Yes = 1</i>	48	43.6	
<i>No = 0</i>	62	56.4	
PMPA	110		
<i>Yes = 1</i>	69	62.7	
<i>No = 0</i>	41	37.3	
PRTIM	110		
<i>No = 1</i>	25	22.7	
<i>Approximately = 2</i>	46	41.8	
<i>Scrupulously = 3</i>	39	35.5	

4.2. Knowledge about harmful effects of pesticides used on the environment and human health

Nearly 63% of farmers do not wear appropriate protective equipment during pesticide application and are completely contaminated. Some farmers have said that they sometimes wear masks and the smokers farmers are almost totally avoided these habits of smoking during spraying (Table 2).

Another more serious problem is the respect of pesticide retention times. In fact, 22% of surveyed farmers do not wait after pesticide application to harvest, while 42% wait approximately and only 35% of them scrupulously respect pesticide retention times before harvesting. The majority of questioned farmers are aware that certain health problems such as cancer are result of pesticide residue on crops (Table 2). In a general way, the problem of not complying with the rules on intervals between the last pesticide application and harvest is the main reason for harmful residues which may affect the health of consumers (Gün and Kan, 2008, Amaro Da Costa *et al.*, 2015).

For the purpose of assessing the perceived risk of pesticide use in greenhouse agriculture, 58% of farmers are very aware of the adverse effects of pesticide use on crops and human health versus 32% farmers who are somewhat aware and 10% that are not aware. Despite that perception is a subjective variable difficult to quantify, the methodology based on the ordered probit model will allow not only detecting important variables but to explain the relevance and the relationship between these variables with the issue of research and behavior of farmers in greenhouse agriculture (Table 2).

4.3. Ordered probit model analysis

The results of the probit analysis of the 110 observations are presented in Table 3. The quality of fit of the model show acceptable pseudo R² of 0.20 and significant at 1% level, suggesting that 20% of the variability of perception can be explained by sets variables selected from the ordered probit regression model.

The ordered probit model focused on variables that influence the farmers' perception of pesticides used on the environment and human health in greenhouses agricultural. Age (AGE) and Agricultural Area Size (AAS) were negative and respectively significant at 10% and 1% level to explain the farmers' perception about pesticides used in greenhouses agricultural.

The negative sign of the variable (AGE) explains that the majority of farmers, who are surveyed, are senior, the average age is 49 and they are also household practicing agriculture as a main activity. These farmers, although are aware of the risk of pesticide use, perceptions about this type of risk still very limited because of their low education levels not exceeding the primary. The absence of a significant relationship with the level of education justifies that the challenge of having a high level of perception is not only in the behavior of farmers, but in their practices. This contradiction is explained also by other variables in the ordered probit model.

Married farmers also show a positive and significant attitude showing that householders have an acceptable perception of pesticide use risk than young farmers. This perception is significantly explained by the experiences of farmers (EXP) in agriculture greenhouse practice. Indeed, these experienced farmers more than 26 years in farming are not looking to change their farming practices even if these farming practices sometimes do not meet safety standards. They believe as long as they are physically able to do their farming activities and there has not symptoms of diseases that prevent him from doing, they are healthy.

This belief in the short term can be explained by an insignificant relationship between the use of protective equipment (PMPA) when during pesticide application and the perceived risk of pesticide use. Farmers do not necessary adopt precautionary measures using fully body covers such as mask, gloves and caps when using chemical products.

The positive and significant contribution of the variable experience in the perception of risk of pesticide use shows that in the central-east region, the farmers have become specialists in the greenhouse agriculture. Its knowledge is jus-

tified by the positive and significant relationship between the number of greenhouse (NG) and the dependent variable of perception (PERC). The practice and experience enriched the knowledge of farmers in mastering techniques of greenhouses crop production. So having a large area does not reflect a high number of greenhouses in fact, include in the sample studied an average of 5 greenhouses per farmer while the average area is about 2 hectares.

This low density can be explained by lack of the financial resources but also another very limiting factor is water availability and quality especially during this crop year 2015-2016 almost where rainfall is very low. The negative and significant relationship between variable agricultural area (AAS) and the perception (PERC) justifies the low density and also shows that these farmers are unable to handle large area while respecting the technical and sanitary standards by giving the time needed for each agricultural task.

The other reason for the negative contribution of the variable of Agricultural Area Size (AAS) to risk perception can be explained by the sample structure, found almost 56.4% of the surveyed farmers belong to the scope of private irrigation with water surface well these are farmers who have large areas where access to irrigation water is free and available for cultivation practiced in open fields. While 43.6% of farmers belong to the scope of public irrigation, access to irrigation water is very limited and even the regional decision maker of Agriculture intervenes to establish the prohibition to grow water intensive crops like the potato crop.

The positive and significant contribution of the variable belonging to public irrigation networks (PINs) to the perception of risk can be explained by the variable extension service (SERV). The ease of access has played an important and significant role in raising the awareness of farmers belonging to public irrigation networks. While, the difficulty of access to extension service and supervision for farmers belonging to private irrigation networks is behind this level of perception that does not exceed 20% according to the ordained probit model. Developing a more comprehensive extension and strategy for access

to information and guidance for different types of farmers in the region has become a priority to combat the over-use of pesticides in greenhouse agriculture in the east-central Tunisia.

The positive and significant sign of the variable farm income (HFINC) justifies a good perception of risk of pesticide use may lead to the achievement of a profitable farm income since the cost allocated for the purchase of these pesticides will be minimum. Have adequate cultural and health technology reduces additional costs and encourages farmers to obtain a profitable farm income but that is also sustainable and beneficial to the greenhouse agriculture and human health.

Another important point is the respect for the pesticides retention times (PRTIM). The ordered probit model shows the significant and positive impact of this variable on the perceived risk. Despite that found only 35.5% of the surveyed farmers scrupulously respect the latency period, the possibility of further educate these farmers remain possible, despite the age and the level of education will present major challenges especially for farmers in private irrigation. Convince farmers about the danger of non-compliance with the time limit that must be left between the last application of pesticides and harvesting on human health and crops. Each pesticide has a time period when residues fall under the toleration limits. In the cases when these intervals are not followed, crops contain harmful pesticide residues and form a danger for consumer health.

The significance of certain variables taken by the models confirms the hypothesis that good perception of the risk of pesticide use requires good vulgarization, experience and good cultural practice respecting the pesticide retention times. These variables have also been confirmed by other work done on greenhouse agriculture. On the other hand, the level of education does not detrimentally affect the safe use of pesticides. This result of the absence of a significant relationship between the level of education and the safe use of pesticides is verified by farmers practicing the greenhouse farmer in Spain (Lamosa Quinteiro *et al.*, 2013). Other authors have verified these results for the case of Indonesian

Table 3 - Factors revealing Farmers' risk perceptions of pesticides used applying Ordered Probit Model.

Ordered probit regression					Number of obs = 110 LR chi2(12) = 40.14 Prob > chi2 = 0.0000 Pseudo R2 = 0.2005
Log likelihood = -80.001992					
PERC	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
AGE	-.0260**	.0153	1.70	0.089	.0561 .0039
FCV	.8557**	.4591	1.86	0.062	.0441 1.7557
EDU	.0793	.1962	0.40	0.686	-.3052 .4639
EXP	.0363***	.0138	2.62	0.009	.0092 .0635
SERV	.3603**	.2069	1.74	0.082	-.0453 .7660
HFINC	.3235**	.1775	1.82	0.068	-.0244 .6716
PIN	.4837**	.2812	1.72	0.085	-.0675 1.0350
AAS	-.5771***	.1848	-3.12	0.002	-.9393 -.2148
NG	.1866***	.0540	3.46	0.001	.0807 .2924
PMPA	.3968	.2752	1.44	0.149	-.1427 .9363
PRTIM	.6818***	.1880	3.63	0.000	.3132 1.0505
/cut1	2.6231**	1.1351			.3983 4.8479
/cut2	4.0459***	1.1732			1.7463 6.3455

* $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$.

farmers (Feder *et al.*, 2004) and Farmer of Ohio (Prochaska, 1998).

The heterogeneity of the sample is not the only reason for the correlation between the level of training and the implementation of good pesticide application practices, but the characteristics of rural areas in particular regions of developing countries, whose population is characterized by high poverty rates, a low level of education and an inadequate vulgarization (Mandel *et al.*, 2000).

To overcome this education constraint in order to have a good perception of the level of risk in the study area, it is necessary to implement simple extension methods suitable for a population of heterogeneous farmers whose level of education is diversified. For example, how to use insect-proof in greenhouses? How to identify symptoms and indications for preventive treatments?

The use of experimental training accompanied by monitoring and control as a demonstrative prototype of pesticide safety techniques can change the behavior of farmers for sustainable and healthy agriculture (Atreya, 2007).

Good safety practices of pesticides according to agronomic and health standards can improve

the social welfare of farmers in the central-eastern region by increasing farm income and reducing the purchase cost of pesticides but also the implicit costs of monitoring of health.

5. Conclusion

The intensive use of pesticides in greenhouse agriculture poses a threat not only to the sustainability of agriculture but it is a serious threat to human health in particular as a result of the increase of cancer disease.

This problem seems to be an environmental problem, whereas it is a wider problem and affects different disciplines such as medicine, agriculture, environmental and socio-economic. The resolution of this problem requires an understanding of the behavior of farmers in a specific context in order to detect the determinants of the perception of the risk of pesticide use in greenhouse agriculture in the central-east region of Tunisia.

The adoption of an ordered probit model in this paper is a means of revealing farmers' perception of the risk of pesticide use. The results of the application of this model have shown that the

heterogeneity of educational level and the age of the farmers are fundamental points to develop methods of vulgarization that are simple and comprehensible by the different categories of the farmers. The objective of vulgarization is to convince farmers that their incomes depend on agricultural practices that respect environment, agriculture and human health.

Vulgarization and sensitization of farmers require more than specific training, monitoring and continuous control of agricultural practices. The extension workers' intervention must be synchronized with the cycle of agricultural production of greenhouse crops in order to help farmers overcome the problems at the right time (Perry and Layde, 2003).

The development of an adequate and optimal extension program in time and place taking into account these different socio-economic, agronomic and phytosanitary aspects can modify the behavior of the farmers of the center-east of Tunisia to develop a sustainable greenhouse agriculture and healthy.

This work, like any other research work, has certain limitations related to the absence of variables: the price, the market and the marketing of agricultural chemicals. The integration of these variables and other variables reflecting the Rotterdam Convention's guidelines as well as the registration of chemicals allowed in agriculture can shed light on the causes behind the heavy use of pesticides (FAO, 2016).

Develop a methodological approach that takes into account the different actors: farmers, suppliers of agricultural chemicals, market and prices; will be the subject of further research in agricultural economics on the rational management of pesticide use for sustainable agriculture in Tunisia.

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