Non-chemical Methods in Controlling Pistachio Pests and their Role in Reducing Pesticide Use and Producing Healthy Crops in Anar and Rafsanjan

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Abstract

Introduction: In traditional agriculture, the decision to use pesticides is made based on various factors, including their effect on specific pests, their usage costs, a crop's economic value, and pesticide- arisen risks, such as environmental pollution. On the other hand, the main goal of organic farming is to prevent environmental degradation and health risks by reducing or eliminating the use of chemical pesticides. The present study investigates the current status and role of non-chemical methods to control pistachio pests.

Materials and methods: The information was collected using a questionnaire from 286 pistachio orchards selected by a random sampling method. Analysis of variance was used to measure the effect of non-chemical methods on the use of pesticides. The logit model was used to investigate the effect of socio-economic factors on the choice of pest management model.

Results: The results indicated that the non-chemical control methods used by farmers were not successful and were used only as a complement to those of chemicals. In contrast, due to the low quality and cheap pesticides on the market, spraying up to 18 times a year is economical for pistachio orchards.

Conclusion: Given the high benefits of controlling pistachio pests, there is a great economic incentive to use pesticides. Therefore, appropriate tools are required to be defined and implemented if other goals such as sustainability and protection of the environment, as well as producing a healthy product, are to be pursued besides economic benefits.

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1. Introduction

In traditional agriculture, the decision to use pesticides is made based on various factors, including its effect on specific pests, usage costs, the crop's economic value, and pesticide-arisen risks, such as environmental pollution. In this regard, the side effects of pesticides, including the effect on natural enemies, phytotoxicity, leaf and bud shedding, branch drying, the resistance in multigenerational insects, and residual pesticides in the crop, are taken into account in comparison to a condition of not using them, leading to pest outbreak, damage, and reduced yield. Producers of valuable products are likely to be more inclined to use pesticides to protect their crops, even when the pest population is below the economic loss threshold. In addition, farmers may be encouraged to use more pesticides, directly or indirectly, by the distribution agents of chemical inputs, strict standards (set by wholesalers), process industries, or distributors. The potential environmental and health risks associated with pesticide use are often less considered by decision-makers than the direct economic benefits or risk mitigation. On the other hand, the main goal of organic farming is to prevent environmental degradation and health risks by reducing or eliminating the use of chemical pesticides. Therefore, the need for accurate information on the effects of pesticides and their economic and environmental consequences is highly significant. Crop damage estimation using data from control methods is misleading because if there is one pest, the damage is different compared to conditions with several pests. Thus, it is necessary to identify different pest control management models [1,2,3].

Pest control management models are based on the logic that not all pests are required to be eliminated, and some can be tolerated. The economic loss level is the cornerstone of pest management because it provides a definition of the tolerable pest level. This definition includes biological criteria for a pest and its host, as well as economic criteria for host value and its management cost. Theoretically, for pest management, the determination of the economic loss level is of high significance since defining the status and importance of a pest requires certain criteria. In this definition, it does not matter whether the management option attempts to prevent or control. Moreover, the biological classification of the pest is not significant, but the level of economic loss of the pest determines its significance. Therefore, it is of great significance to investigate pest control management in terms of economy [4, 5].

Pistachio is an important product in Iran. Pests attack most parts of the plant during the growing season. Pistachio pest control is a very complex task and the main concern of pistachio producers in Iran for the past few decades [6, 7, 8]. Despite the significance of investigating the environmental effects and pest control management in pistachio orchards, no comprehensive study has yet been conducted in the socio-economic field to address this issue. Most socio-economic studies have been conducted on the function estimation of pistachio production. For example, Farbood et al. [9] investigated Rafsanjan orchard owners' views on pistachio yield. Their study showed that using different amounts of pesticides did not statistically affect pistachio yield.

Several studies have been conducted in the field of non-chemical control of pistachio pests, most of which are technical research. Karbakhsh Ravari et al. [10] investigated the effect of some plant extracts compared to Dinotefuran

insecticide on the nymph of common pistachio psyllid under field conditions. Their study showed the highest reduction effect on the population of nymphs in Starkel pesticide and the highest nymph mortality in lavender, stinking assa, and tobacco, respectively. Basirat et al. [11] showed *Anthochoris minki pistaciae*, *Anystis baccarum*, *Chrysoperla lucasina*, and *Psyllaephagus pistaciae* ladybugs to be active as psyllophage in pistachio orchards of Kerman province. Soheili et al. [12] investigated the effects of thyme extract on controlling pistachio psyllid. Their study indicated that the reaction of nymphs and the number of psyllid eggs in pistachio trees to the consumption of thyme extract and its different doses was significant. Moreover, thyme extract reduced the number of nymphs and eggs compared to control and water treatments.

Mazar et al. [13] investigated the knowledge, attitude, and behavior of Iranian pistachio farmers about the environmental aspects of pesticide use. Their results indicated that those participating in health and safety training classes during the spraying period enjoyed an improved level of knowledge and attitude. Porkhosravani et al. [14] investigated the insecticide effects of some mineral compounds including lime sulfur, boric acid, kaolin + nonionic surfactant and potassium silicate + nonionic surfactant on pistachio psylla nymphs. Their results indicated that these mineral copounds can be used to control pistachio psylla.

None of the earlier studies have investigated the consequences of different models of pistachio pest management and the use of non-chemical methods in the garden. The present study attempts to investigate non-chemical pest control methods in pistachio orchards of Anar and Rafsanjan (in Kerman province) within the integrated management framework of pistachio pests.

2. Materials and methods

The information in this study was obtained from a questionnaire completed by farmers. For this purpose, the study sample was selected from Anar and Rafsanjan. The sampling method was multi-stage random. From the total villages of the two cities, 286 pistachio orchards were selected based on a random sampling method. A questionnaire was prepared for each orchard, and farmers were inquired about different pest control models used. The models included the use of different pesticide types, their use at different times, their quantity, the identification and control of pests, and the use of other pest control methods (agricultural, biological, and physical (such as pruning dry branches to control *Osphranteria coerulescens Redtenbacher*)). In each model, factors of cost and product yield were also inquired. Further, the socio-economic characteristics of farmers and the properties of the orchards were also inquired.

To measure the effect of non-chemical methods on pesticide use, analysis of variance and mean comparison were used. The logit model was used to investigate the effect of socio-economic factors on the choice of management model [15, 16,17]. In this model, the dependent variable is zero and one. If one uses non-chemical methods to control pistachio pests, the dependent variable is one; otherwise, it is zero. The logit model is based on the logistic cumulative probability function, expressed as follows:

$$(1) \qquad P_i = F(Z_i) = 1/ (1 + e^{-zi})$$

Here, P_i is the probability of choosing the first option by the i^{th} decision-maker, $XB= Z_i$, X_i is the vector related to the socio-economic characteristics of the i^{th} decision-maker, B is the

vector of parameters to be estimated, and e is the base of the natural logarithm. In this equation, Z_i varies from infinite positive to infinite negative, yet the probability of acceptance (P_i) is between zero and one. Since Equation 1 is a nonlinear function, the maximum likelihood estimation method should be used to estimate the parameters. In the present study, if one does not use the integrated models, the dependent variable is zero, while if one uses them, it is one. In this regard, SPSS22 was used.

3. Results

Table 1 presents the non-chemical models used to control pests in the investigated pistachio orchards.

Table 1. Non-chemical models used to control pests in the investigated pistachio orchards

Pest	Percentage of orchards using the non-chemical method	Non-chemical methods used to control the pest
Psyllid (*Agonoscena pistaciae*)	20	Yellow sticky traps, winter plowing, winter ice water, watering, liquid fertilizer
Bug (*Acrosternum* spp)	6	leaving weeds
The pistachio twig borer moth (*Kermania pistaciella Amsel)*	46	Pheromone traps, pruning twigs and burning them
pistachio twig borer *beetle* (*Hylesinus vestitus)*	100	Pruning and burning the dry branches
The pistachio *root* beetle (*Capnodis cariosa hauseri)*	16	Preventing water from reaching the tree trunk, emptying the area around the stump, removing the worm with a thin and soft wire, watering and strengthening the tree
Indian meal moth (*Plodia interpunctella*)	71	Keeping the warehouse dry and cool, selling the product before the beginning of the warm season, preventing the pistachio from contacting the floor of the warehouse, using water traps, and properly ventilating the warehouse

Reference: Research results

As seen in Table 1, 20% of the investigated pistachio orchards use methods other than spraying to control pistachio psyllid. The non-chemical methods used are also presented in Table 1. Of them, yellow sticky traps are one of the most common. These traps are used to absorb the pests and eliminate them. Winter plowing and ice water are other agricultural practices used against psyllids. Moreover, some farmers control psyllids by spraying water or liquid fertilizers instead of pesticides.

Moreover, only 6% of the investigated pistachio orchards use non-chemical methods to control bugs. The only method used in this field is to leave weeds in orchards at times of the year

when the bug population is likely to increase. Another pest presented in the table is the pistachio twig borer moth. As can be observed, 46% of the studied pistachio orchards use some non-chemical methods to control this pest. The methods used also include pheromone traps and pruning and burning twigs.

The pistachio twig borer *beetle* is also one of the pests listed, which is controlled by non-chemical methods in all pistachio orchards. The only method used in this regard is pruning and burning the dry branches of the pistachio tree. In 16% of the investigated pistachio orchards, non-chemical methods are used to control pistachio *root* beetle or *Capnodis*. However, other farmers either do not know about this pest or do not know how to control it. In other words, no pesticides or chemicals are used to treat *Capnodis* among the gardeners. Preventing water from reaching the tree trunk, emptying the area around the stump, removing the worm with a thin and soft wire, and irrigating and strengthening the tree are some of the non-chemical methods used in this regard.

Indian meal moth (*Plodia interpunctella*) is the only warehouse pest investigated in this study. As presented in the table, 71% of the owners of the investigated pistachio orchards know the non-chemical methods of controlling this pest. These methods include keeping the warehouse dry and cool (at a temperature of fewer than 13 degrees Celsius), selling the product before the beginning of the warm season, preventing the pistachio from contacting the warehouse floor with wooden plates, using water traps, proper ventilating the warehouse. As for other pests, no non-chemical control methods are used in pistachio orchards.

In the following, the interaction effects of using chemical and non-chemical methods on one other are investigated. In other words, the issue of whether using non-chemical methods in the studied gardens have any effect on reducing the use of pesticides and chemical methods. In this regard, psyllid and pistachio twig borer moth are studied since they are the only two pests for controlling of which both chemical and non-chemical methods are used in a significant number of studied pistachio orchards. As for the other investigated pests, these conditions do not exist, and conducting the desired test is impossible. The results are reported in Tables 2 to 5.

In Table 2, the two groups of pistachio orchards are compared, orchards that used both chemical and non-chemical methods to control psyllids and those that used only chemical methods. For this purpose, the f-test is used. The right column shows the significance level of the f-test.

As seen in the table, the number of spraying against psyllids in the two groups (with and without non-chemical methods) does not differ significantly at the level of 10% or less. In other words, non-chemical methods are not successful in controlling pistachio psyllids, not resulting in a reduced rate of chemical control. Also, farmers using non-chemical methods use more pesticides to control psyllids. In other words, they have a greater variety in using pesticides. These farmers also start spraying earlier. Although both groups had their first round of spraying against psyllids in May, farmers using non-chemical methods started 9 days earlier on average. This group seems to use non-chemical methods as a precaution and not as a substitute for chemical methods. As a precaution, the first round of spraying against psyllids was started earlier. However, according to Table 2, no difference was observed between the two groups in terms

of the end of the spraying period. Also, no significant difference was observed between the two groups regarding the amount of pesticide used per spraying per hectare. In other words, using non-chemical methods by the studied farmers did not change the number of spraying per year or the amount of pesticides used per hectare. However, in the group using non-chemical methods, the variety of pesticides used to control psyllids was greater, and the first spraying round was done earlier.

Table 2. The effect of non-chemical methods for controlling pistachio psyllid pest on its chemical management model

Variable	Variable value in pistachio orchards that do not use non-chemical methods to control psyllids	Variable value in pistachio orchards that use non-chemical methods to control psyllids	f-statistic	The significance level of f-statistic
Number of spraying per year	6.51	6.68	0.18	0.67
Number of pesticides used	2.19	2.57	4.55	0.03
Beginning of spraying	1.88	1.59	5.12	0.02
End of spraying	6.60	6.70	1.40	0.24
Amount of pesticide used per round (liters per hectare)	3.82	4.03	0.59	0.44

Reference: Research results

Table 3 presents the effect of non-chemical methods of controlling pistachio psyllids on the chemical management of other pistachio pests. As this table indicates, there was no significant difference in the number of spraying against Cicada, fruit borer, twig borer, and scale insects. However, the number of spraying against bugs fruit hull borer moth was higher, and the number of spraying against lace bugs was lower. In other words, no specific pattern could be identified in this regard.

Table 3. The effect of non-chemical methods for controlling pistachio psyllid pests on the chemical management model of other pistachio pests

Variable	Variable value in pistachio orchards that do not use non-chemical methods to control psyllids	Variable value in pistachio orchards that use non-chemical methods to control psyllids	f-statistic	The significance level of f-statistic
Number of spraying per year against Cicada	0.18	0.14	0.24	0.62
Number of spraying per year against lace bugs	0.14	0.05	3.12	0.00
Number of spraying per year against bugs	0.09	0.33	21.76	0.02
Number of spraying per year against pistachio fruit borer	0.04	0.05	0.18	0.67
Number of spraying per year against pistachio twig borer moth	0.15	0.10	0.66	0.41
Number of spraying per year against Scale insect	0.27	0.33	0.62	0.43
Number of spraying per year against pistachio fruit hull borer moth	0.11	0.21	4.44	0.04
Number of spraying per year against spring pests	0.88	1.00	2.64	0.11

Reference: Research results

Table 4. The effect of non-chemical methods for controlling pistachio twig borer pests on the chemical management model of psyllid control

Variable	Variable value in pistachio orchards that do not use non-chemical methods to control twig borer	Variable value in pistachio orchards that use non-chemical methods to control twig borer	f-statistic	The significance level of f-statistic
Number of spraying per year	7.29	5.72	2.98	0.00
Number of pesticides used	2.53	1.98	2.26	0.00
Beginning of spraying	1.73	1.90	2.75	0.10
End of spraying	6.55	6.70	4.01	0.05
Amount of pesticide used per round (liters per hectare)	3.85	3.88	0.01	0.90

Reference: Research results

Table 4 indicates the effect of non-chemical methods to control pistachio twig borer on the chemical management model of psyllid pest. As can be observed, farmers who used non-chemical methods to control the pistachio twig borer did fewer spraying against psyllids per year. This group also used a lower variety of pesticides against psyllids. The first round of spraying against the psyllid was later, and the last round of spraying was completed later as well. However, the amount of pesticide used in each spraying round was not significantly different in the two groups.

Table 5 shows the effect of using non-chemical methods against twig borer on the chemical management model of other pistachio pests.

Table 5. The effect of non-chemical methods for controlling pistachio twig borer on the chemical management model of other pistachio pests

Variable	Variable value in pistachio orchards that do not use non-chemical methods to control twig borer	Variable value in pistachio orchards that use non-chemical methods to control twig borer	f-statistic	The significance level of f-statistic
Number of spraying per year against Cicada	0.12	0.22	2.94	0.09
Number of spraying per year against lace bugs	0.09	0.16	3.67	0.06
Number of spraying per year against bugs	0.15	0.13	0.08	0.77
Number of spraying per year against pistachio fruit borer	0.03	0.06	1.91	0.17
Number of spraying per year against pistachio twig borer moth	0.14	0.14	0.00	0.97
Number of spraying per year against scale insect	0.20	0.37	6.18	0.01
Number of spraying per year against pistachio fruit hull borer moth	0.13	0.13	0.00	0.99
Number of spraying in the flowering stage	0.91	0.91	0.00	0.97

Reference: Research results

As Table 5 shows, people using non-chemical methods against pistachio twig borer had more spraying against Cicada, lace bugs, and scale insects. However, as for the other pests and twig

borer itself, there was no significant difference. In other words, using non-chemical methods against pistachio twig borer did not prevent chemical control against this pest. More precisely, farmers used non-chemical methods as a complement to those of chemicals. Moreover, farmers using non-chemical methods against twig borers used more chemical methods against Cicada and lace bugs, indicating that this group had a higher level of knowledge about pest control. In other words, pioneering and more knowledgeable farmers have taken the lead in using non-chemical methods. However, non-chemical methods did not reduce the use of chemical methods. In other words, although users of non-chemical methods against twig borers conducted a lower spraying number against twig borers (Table 4), this does not mean that the methods resulted in less spraying against twig borers; indeed, this was due to their higher knowledge of pesticide use. Thus, by preserving natural enemies, spraying against psyllids is either postponed or the need for spraying is reduced. Generally, in the investigated pistachio orchards, there is no comprehensive and codified program for non-chemical pest control to reduce the need for chemical methods. The first step in effective control is that the orchard owner should estimate the population of twig borer moth at harvest time and start controlling the pest in the following year; however, none of the orchard owners referred to this issue.

The logit model was used to investigate the effect of socio-economic factors on the choice of pistachio pest management model. In this regard, two logit models were estimated. Spraying or not spraying against four pests, i.e., Cicada, lace bugs, twig borers, and fruit borers, and using and not using non-chemical methods against pistachio twig borers were considered as indicators of the model of chemical and non-chemical control against pistachio pests. If the intended model was used, the dependent variable was one, and if the intended model was not used, it was zero. The results are presented in Table 6. In this table, only independent variables are presented that are statistically significant. Thus, other variables are avoided. The statistics specified in the table also indicate a good fit for the model. The reason for not using the management model of the main pest of pistachios (psyllids) is that this pest has been controlled by all investigated orchard owners; therefore, it cannot be compared and estimated by the logit model. Also, the non-chemical model could not be estimated for other pests.

Table 6. Regression of socio-economic factors affecting the acceptance of different models of pest management in the investigated pistachio orchards

Variable	Estimated coefficient

	Regression of socio-economic factors affecting spraying against four pests, i.e., Cicada, lace bugs, twig borers, and fruit borers	Regression of socio-economic factors affecting non-chemical control of twig borer
Constant	0.06	- 1.01
Farmer's age (year)	- 0.02	-
Farmer's literacy and knowledge (years of formal education)	-	0.05
Relationship with agricultural extension agents (yes=1, no=0)	0.48	-
Reading technical and extension journals (yes=1, no=0)	-	0.55
The total area of the orchard owned by the respondents (hectare)	0.01	0.01
-2log likelihood	344.69	357.88
Cox & Snell R^2	0.05	0.10
Nagelkerke R^2	0.07	0.13
Chi-square	15.34	28.28
Chi-square Sig	0.00	0.00

Reference: Research results

As indicated in Table 6, the farmer's age has a negative effect on the chemical control model of four pests, including Cicada, lace bugs, twig borers, and fruit borers. In other words, as farmers get older, the likelihood of controlling these four pests decreases. The second effective variable on the probability of using the chemical control model against the four pests is the relationship with agricultural extension agents. Farmers in touch with agricultural extension agents are better aware of the four pests, thus attempting to control them. However, farmers with no relationship with agricultural extension agents do not attempt to control the pest as they lack the required knowledge. They just spray at the flowering stage without knowing the reason. The third significant variable regarding the chemical control of the four pests is the total area of the orchards owned by the respondents; this variable has a positive sign. In other words, farmers with more orchards pay more attention to controlling the pests.

Further, the farmer's literacy and knowledge have a positive effect on the non-chemical control of twig borer pests. In other words, more literate and knowledgeable farmers are more likely to use non-chemical methods to control the pest than illiterate and less-knowledgeable farmers. Thus, it can be predicted that as the farmer's general literacy level increases, the possibility of developing non-chemical methods of controlling pistachio pests increases. The second effective variable for using non-chemical methods to control pistachio twig borer pests is

reading technical and extension journals. Farmers who have read these journals are more likely to use non-chemical methods to control twig borer pests. Here, the area owned by the farmer positively affects the probability of using non-chemical methods to control twig borer pests. In other words, farmers with the majority of orchards are more likely to use non-chemical methods to control pistachio pests.

4. Discussion

The potential environmental and health risks associated with pesticide use are often less considered by decision-makers than the direct economic benefits or risk mitigation. On the other hand, the main goal of organic farming is to prevent environmental degradation and health risks by reducing or eliminating the use of chemical pesticides. The present study investigates the state and current role of non-chemical methods in controlling pistachio pests in two cities, i.e., Anar and Rafsanjan, in Kerman province. In this respect, the effect of non-chemical methods on the amount of pesticide used is investigated to move towards less use of chemical methods and improve the quality and health of the product and the environment.

Regarding non-chemical control of pistachio pests, the results indicated that the twig borer beetle, Indian meal moth, twig borer moth, common psyllid, *Capnodis*, and bugs were prioritized first-sixth. As for other pests, no non-chemical control was common among farmers. In this regard, the study's results indicated that only for pests such as twig borer beetle and Indian meal moth (feeding principally on stored food products) non-chemical control was successful. However, as for other important pests of pistachios, especially psyllids, non-chemical methods used by farmers were not successful. Farmers did not use non-chemical methods as a substitute for chemical methods but as a complement. Thus, non-chemical methods failed to reduce the use of pesticides in pistachio orchards for these pests; as for beetles and Indian meal moths, the use of pesticides was reduced. According to Abdolahi-Ezzatabadi et al. [18], given the benefits and costs, on average, spraying up to 18 times per year is economical for pistachio orchards.

Investigating the role of socio-economic factors on the choice of pistachio pest control model shows that as farmers get older, the likelihood of using scientific chemical and non-chemical methods of pistachio pest control reduces. On the other hand, farmers' increased literacy and knowledge level, relationship with agricultural extension agencies, and increased area under pistachio cultivation increase the likelihood of using scientific chemical and non-chemical methods of pistachio pest control. This result is consistent with the result of Headrick [19] and Grafton-Cardwell et al.[20] studies. Thus, using effective tools, farmers should be reminded of two points. In the first step, effective non-chemical methods should be introduced, and the way of their use is required to be promoted. Then, the logic of using non-chemical methods (being substitutes for chemical methods) should be explained to farmers. In other words, farmers should be informed that the main aim of using non-chemical methods is to reduce environmental risks and produce healthy, pesticide-free, and organic products.

5. Conclusion

Given the high benefits of pistachio pest control, there is a strong economic incentive to use different pesticides. Thus, appropriate tools are required to be defined and implemented if

other goals such as sustainability and protection of the environment, as well as producing a healthy product, are to be pursued besides economic benefits. In other words, decisions made based on economic criteria alone will not lead to the production of a healthy product.

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Conflict of interests

The authors state that there is no conflict of interest in publishing this study.

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