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Technical Report

Comprehensive survey of the present status of environmental management of pesticides consumption in rice paddies

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Environmental management of pesticide consumption is one of the most important aspects of pest management programs. The present study was carried out considering the farmers' knowledge, attitudes and practices of pest management in rice paddies in four Iranian cities: Sari, Babol, Amol and Nour in Mazandaran province, which are the highest rice-cultivating regions. The effective factors in pesticide consumption management are education, pesticide application technology, regulations, Integrated Pest Management implementation and the price of pesticides; therefore, a questionnaire with 27 items regarding these factors was designed and 220 farmers were interviewed. The obtained data were converted to quantitative measures by the Likert procedure and then analyzed by descriptive statistical methods. In order to evaluate the current status of pesticide environmental management, the quantitative information was categorized into five levels: very poor, poor, medium, good and excellent, based on the Food and Agricultural Organization and Iran Plant Protection Organization index. The weakness of the education parameter in studied samples was one of the most significant results of this research. The total education score was 1.9, which is very poor. The study demonstrated that the existing regulations have many deficiencies in comparison with the standards. The 48% overall management rank was considered poor. In 35%, the pest management rank was medium and in 17%, the rank was very poor. No good or excellent rank was obtained in this research. Hence, a comprehensive practical program needs to be initiated to improve the present status of pesticide consumption management in the province. The results achieved in this study may be used as a database to establish a management and monitoring program for pesticide consumption environmental management in Mazandaran province.

Keywords: environment, pesticide, management, rice paddies.

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Introduction

1. Rice importance and role of pesticides in rice production

Rice is one of the most significant food products and grows conveniently in humid and warm areas. After wheat, rice has the second place in case of food significance. Consistent with agricultural development, pesticides have become an important tool as plant protection agents for increasing food production. Pesticides play a significant role in controlling pests, while exposure to pesticides both occupationally and environmentally could cause a wide range of human health problems. It has been observed that pesticides have a direct connection to immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities and cancer.[1,2] The main reason for farmers to use a high amount of chemical pesticides, such as insecticides and herbicides, is to achieve higher rice yield. Undoubtedly, these pesticides contribute to increase rice production and to control pest problems.

2. Pesticide management

Thus, due to the importance of rice for human food and regarding the necessity of pesticide use in rice cultivation, an integral management program should be designed. One of the most useful concepts for better management is to identify existing deficiencies and submit each effective factor to a managerial approach. The definition of Integrated Pest Management (IPM) is: "a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks."[3,4] The steps of IPM are described as:

• *Scouting or Monitoring*: The purpose of scouting is to detect the presence, concentration, and type of pests.

• *Identification*: Identifying pests properly is an important aspect of scouting.

• *Pest Situation Assessment*: In this step, scouts analyze the information obtained from scouting and pest identification, and then the need for pest control is determined. The key question is whether the potential damage is more costly than the control cost. The last stage of pest management is considered to be chemical pesticide consumption.

• *Implementation:* Once the management strategies have been selected, they should be employed in a timely manner.

• *Evaluation:* Compare pest activity before and after implementation of pest management strategies.[5]

Notwithstanding that pesticides are valuable tools in pest management, their misuse has led to some disadvantages, such as pest resistance to the pesticide, outbreaks of secondary pests, and adverse effects on non-target organisms, unwanted pesticide residues and direct hazards to the users. Used correctly, pesticides are indispensable tools in pest management programs.[6] Several efforts have been made globally to devise location specific systems which integrate different available pest management practices in a

compatible manner to keep the pest population below the economic injury level, in such a way that it is not only economically viable, but also ecologically sound.[7] Many projects/programs have been launched in the USA,[8,9] Canada[10] and Asia.[11,12]

Most Asian rice-cultivating farmers have adopted pesticides as the main pest control tactic, using insecticides more frequently than herbicides and fungicides.[13,14] In many cases, insecticide application is unnecessary and also unlikely to result in economic turnover. For example, in the Philippines, about 80% of insecticide sprays were misused as they were applied at the wrong time and for the wrong target due to the lack of education of the farmers.[15]

The rapid growth in intensive rice production systems in Asia was studied in 1997. The consequent increase in using indiscriminate insecticide led to a disruption of the pest predator environment, pest outbreaks and yield losses. Adverse consequences for the environment, paddy ecology and human health are well documented. Policy and institutional requirements for implementing a reduced insecticide usage strategy for rice were also presented.[16] A strategic research approach to pest management has been applied to the problem of rice pest management in Malaysia. Initially, the major components of the problem surrounding rice pests and their control are identified. Generally, identifying effective key factors in increasing chances of pest management improvement is the major purpose of such an approach.[17]

Hashemi *et al.* studied farmers' knowledge in Iran. The study was conducted using 90 farmers in Karaj, a city with widespread agricultural fields, during 2007–2008. Hashemi's study showed that farmers who perform pest management had significantly higher knowledge scores than their non-educated counterparts.[18] Another study in Iran explored the impacts of pest management studies on farmers' competence in pest management practices and identified their need for pest management training.[19] Koushiar *et al.* (2005) performed the same analysis procedure for hospital waste management in Iran and evaluated the overall management by a descriptive analysis method and, subsequently, the results of their study were used as complete research in order to be used for other case studies in Iran.[20]

3. Scope of this study

Due to the suitable weather conditions near the Caspian Sea, in the north of Iran, rice is the best cultivated product in this area. Mazandaran province with a 2,440,000 hectare area is significant in this region and was therefore chosen as the case study of this research. Rice is cultivated in 235,000 hectares in Mazandaran province. According to Mazandaran's Plant Protection Unit, there are around 250,000 farmers in Mazandaran. In 2010, the rate of herbicide consumption was 526,027 kg out of total of 4,572,509 kg pesticides consumed in rice paddies in Mazandaran. For example, Diazinon insecticide has the highest consumption in Iranian rice paddies. It is used in two formulations, EC 60% and Granule 10%. The total amount of Diazinon granules consumed in rice paddies was 1,815,422 kg, and 1,047,619 kg was for other insecticide formulations.[21]

Agricultural management is a concept that uses the components of agriculture in accordance with certain policies and to achieve defined objectives. It is necessary for each component of the environmental management of pesticide consumption to be measured individually as variables of the study. There are specific variables, such as educational systems, lack of suitable regulations by governmental organizations, nonperformance of integrated pest management and etc., so the necessity of considering IPM performance as an important factor to achieve better management is distinct.

The main goal of the present study was to assess the present status of pesticide consumption in rice paddies in Mazandaran province to establish a baseline to improve the environmental management of pesticide usage in this province. The approach, however, is inferred to clarify a method for more sustainable rice production, a better environment and healthier lives for the farmers and their families as well as others.

Materials and Methods

1. Designing the research tools

According to the information achieved from similar researches and expert comments, some of the effective factors for providing a comprehensive approach to the environmental management of pesticide consumption are:

- *Education*
- *Current law and regulations*
- *Approach in pest management standards*
- *Pesticide application technologies*
- *Effects of pesticide price*

The farmers were assessed using a questionnaire with 27 questions to cover all of the above categories. These were considered as the variables of the study. The questionnaire was designed to convert the answers to quantitative measures by the Likert scale, which assigns a range from "very poor" to "excellent". The Likert-type scale is a psychometric scale commonly used in questionnaires and is the most widely used scale in survey research. This scale generates a widespread range of scores that improve the transparency of the data and also increases the reliability and accuracy of research outputs.[22] According to the above descriptions, five levels of the Likert scale are shown in Table 1 and applied for the development of experimental tools.[23] An example of Likert scale performance can be found in most social survey researches. McKeiver and Gadenne (2005)[24] studied Environmental Management Systems in Small and Medium Businesses using a Likert-type

Table 1. Five levels of Likert scale

Variable number	Rank
1	Very poor
2	Poor
3	Medium
4	Good
5	Excellent

Table 2. Amount of cultivated area of rice paddies in Mazandaran cities (Mazandaran PPO, 2011)

City	Cultivated area of rice paddies (hectares)	City	Cultivated area of rice paddies (hectares)
Behshahr	12,500	Neka	10,200
Sari	31,100	Jouibar	10,000
Savadkooh	3,000	Ghaemshahr	16,098
Babol	49,120	Chaloos	2,000
Fereidounkenar	6,524	Amol	37,708
Mahmoudabad	20,650	Nour	13,498
Noshahr	3,500	Tonekabon	13,000
Ramsar	1,200		

scale. Their study examined the various external, moderating and internal factors that may influence the implementation of an environmental management system by five-point Likert scale items. The Likert scale was used for each of the measures of External Influences, Internal Influences and Moderating Variables.

2. Research samples

There are fifteen cities in Mazandaran province, which all cultivate rice, as shown in Table 2. Regarding their characteristics and the cultivated area in these cities, four cities, Sari, Babol, Amol and Nour, were selected as the study sample for assessment of the present status in this research.

The Cochran model was adopted to estimate the sample size. Mazandaran's farmers comprise 250,000 individuals; therefore, 220 farmers from Mazandaran were selected to fill in the questionnaires. Implementation of the sample size formula is used when the number of centers is large and the success rates of each individual center are not clearly known.[25] The Cochran formula is given below:

$$n = \frac{NZ^2_{\frac{\alpha}{2}} p(1-p)}{\varepsilon^2(N-1) + Z^2_{\frac{\alpha}{2}}(1-p)}$$

Where ε represents the margin of error; $Z_{\alpha/2}$ describes the normal distribution of data and p shows the success probability.[26] Two hundred and twenty farmers were interviewed using the questionnaires, which were completed from May 2010 to January 2011.

3. Data analysis

The answers to the questionnaires were collected, summarized and analyzed by descriptive statistical tools using SPSS (originally, Statistical Package for the Social Sciences) software to evaluate all of the factors described above, such as education, IPM implementation, *etc*. that comprise the environmental management of pesticide consumption. Descriptive analysis is recommended when the objective is to describe and discuss a data set more generally and conveniently than would be possible using raw data alone. In this research, descriptive analysis was performed for the data after categorizing them using SPSS software. Factors such as variance, average, standard deviation, *etc*. were considered for analysis.

The explored results of the analytical procedure were compared with the existing standards of Iran Plant Protection Organization, all of which were based on the guidelines of FAO in order to find differences between the actual situation and the standard's figures. The standard includes some general contents as below:

- Proper specification of sprayers such as nozzles, calibration, *etc*.
- Educational instruction such as holding Farm Field School (FFS) courses
- Biological controls
- Formulators' commitments such as compatibility of their formulations with environmental standards
- Pesticide distribution

Some questions were discussed using the questionnaire in order to evaluate the above points in real situations. According to the prepared questionnaire, score 5 was assigned to answers which were compatible with the standards (Optimal condition) and score 1 was assigned to answers that did not comply with the standards.

Results

In this research, we decided to specify the main factors which comprise the environmental management of pesticide consumption and to consider the current situation in detail. The results of computed scores for all farmers were processed to reveal the current status of environmental management of pesticides in Mazandaran (Table 3) explained as below:

1. Education

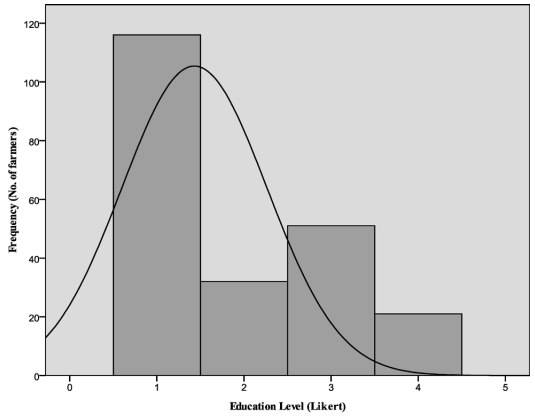
This is one of the most significant factors in the formation of environmental management of pesticide consumption. Education includes training in correct usage methods, proper application of the instruments, awareness of suitable times for spraying, the best selection of recommended pesticides, *etc*. The study showed that the average and standard deviation of education scores were 1.90 and 1.065, respectively. Education scores varied from 1 to 4. In 90% of cases, education scores were 3, indicating intermediate levels of education. Moreover, in 50% of cases, the scores were $\leq$1. In comparison with the standard figures, the weakness of the education parameter in studied samples was one of the most significant outputs of this research. The total education score was 1.9, which was very poor, demonstrating that farmers do not have any information about pesticide use. The distribution of education level in selected Mazandaran cities is shown in Fig. 1.

2. Regulations

This factor generally resulted in the average performance of farmers and other related parties such as governmental supervisors, pesticide sellers, *etc*. The more comprehensive the regulations and laws, the better the results will be for pesticide consumption and,

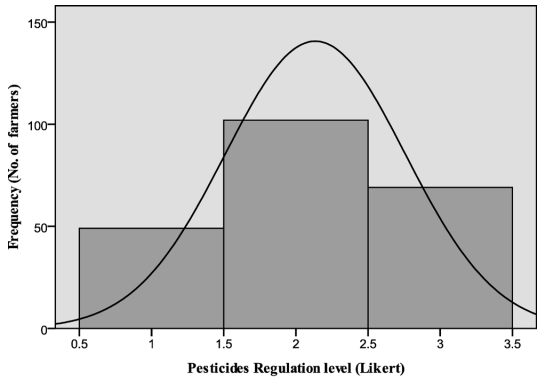
Table 3. Descriptive statistical analysis of computed scores of different farmers

Statistical parameters	Education level	Pesticide law and regulation	IPM approach in pest control	Pesticide application technology	Effects of price of pesticides	Overall pest management
Number of farmers	220	220	220	220	220	220
Missing	0	0	0	0	0	0
Mean	1.90	2.09	2.57	3.71	2.36	2.52
Std. Deviation	1.065	0.728	0.794	0.637	0.698	0.529
Variance	1.135	0.531	0.630	0.406	0.487	0.281
Range	3	2	4	2	2	2
Minimum	1	1	1	3	1	1
Maximum	4	3	5	5	3	3
Percentiles 25	1.00	2.00	2.00	3.00	2.00	2.20
50	1.00	2.00	3.00	4.00	2.00	2.50
75	3.00	3.00	3.00	4.00	3.00	3.00
90	3.00	3.00	3.00	4.00	3.00	3.20



N = 220; Mean = 1.9; SD = 1.065

Fig. 1. Distribution of education scores in Mazandaran province.



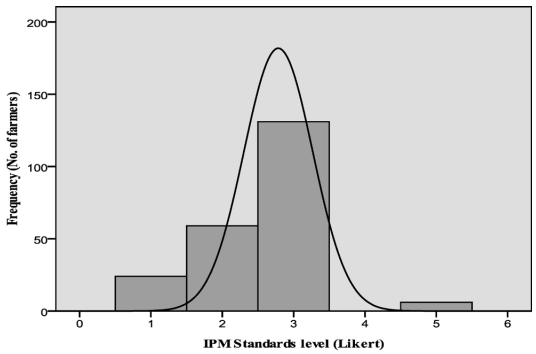
N = 220; Mean = 2.09; SD = 0.728

Fig. 2. Distribution of pesticide regulation scores in selected cities.

subsequently, environmental friendly rice will be produced. The average and standard deviation of pesticide regulation condition scores were 2.09 and 0.728, respectively (Table 3). The current regulation scores varied from 1 to 3. In 90% of cases, the efficiency of pesticides regulations and instructions scores was ≤3. Also, in 50% of cases, the scores were ≤2. The findings showed that the total score of pesticide regulation was poor. Individual regulation situations in selected Mazandaran cities are shown in Fig. 2.

3. IPM implementation

The average and standard deviation of pest management standard application in Mazandaran samples were 2.57 and 0.794, respectively (Table 3). This parameter scores varied from 1 to 5. In 90% of cases, pest management scores were ≤3. Also, in 50% of cases, the scores were ≤3. The awareness of farmers about integrated pest management was below the medium level. The distribution of the scores of this parameter in Mazandaran samples is presented in Fig. 3.



N = 220; Mean = 2.57; SD = 0.794

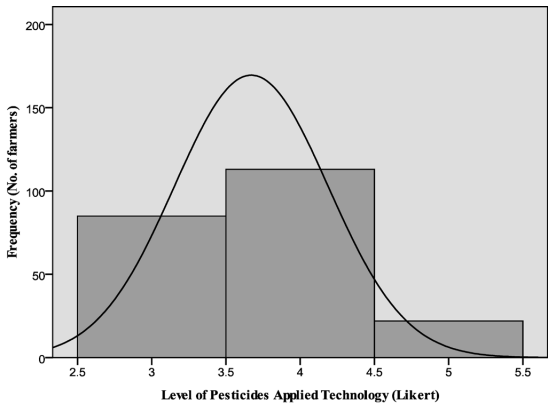
Fig. 3. Distribution of pest management standard application scores in selected cities.

4. Applied technology

The average and standard deviation of pesticide application technology scores were 3.71 and 0.637, respectively (Table 3). The quality of sprayers and other tools of pesticide application varied from 3 to 5. The farmers' equipment for pesticide application in rice paddies was of an intermediate level in comparison with the Plant Protection Organization (PPO) standards. The distribution of the scores of this parameter in Mazandaran samples is presented in Fig. 4.

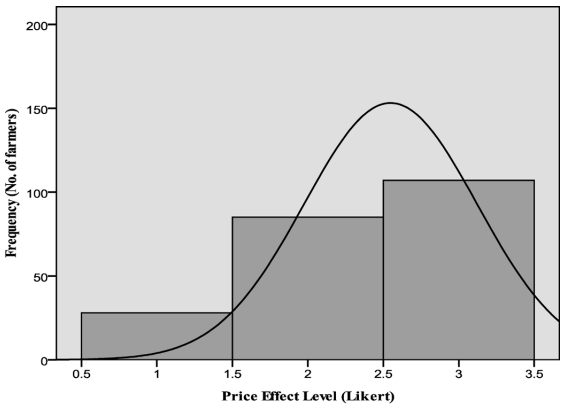
5. Pesticide price

The price of the pesticides specifies the farmers' tendency of purchasing them from sellers. The average and standard deviation of the effects of the price of pesticides were 2.36 and 0.698, respectively (Table 3). This parameter score varied from 1 to 3. In 90% of cases, this score was 3. Also, in 50% of cases, it was ≤2. The price variable was considered because of its high effect on farmers' selection of pesticides. The distribution of price scores in four selected cities in Mazandaran is presented in Fig. 5.



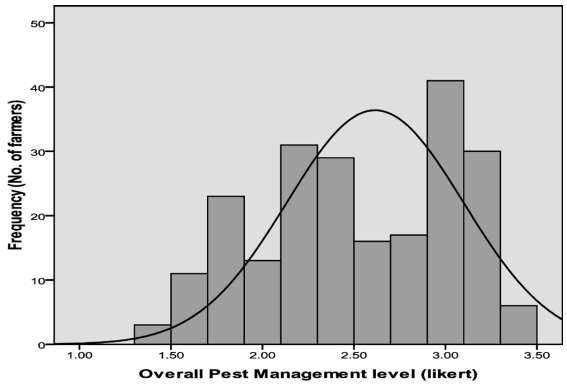
N = 220; Mean = 3.71; SD = 0.637

Fig. 4. Distribution of applied technology scores in selected cities.



N = 220; Mean = 2.36; SD = 0.698

Fig. 5. Distribution of price parameter scores in selected cities.



N = 220; Mean = 2.52; SD = 0.529

Fig. 6. Distribution of overall pest management scores in selected cities.

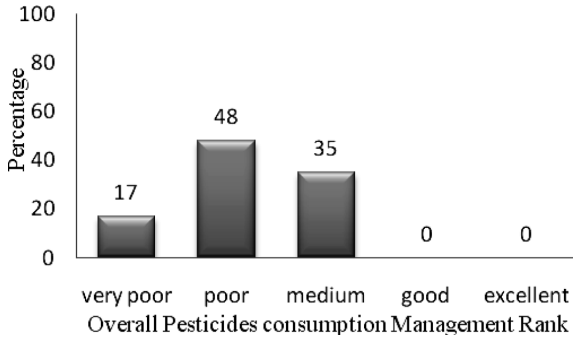


Fig. 7. Share of each pest management rank in this study.

6. Overall management

According to the above mentioned items, education, regulation, IPM implementation and the price of pesticides constitute the overall management of pesticide consumption in this study. The average and standard deviation of the overall environmental management of pesticide scores were 2.52 and 0.529, respectively (Table 3). Overall management scores varied from 1 to 3 Comparing with PPO standards, total pest management was below the medium level. The distribution of overall management scores in Mazandaran cities is presented in Fig. 6.

As shown in Fig. 7, the pest management factors have been considered overall; 48% of the results were poor and 17% were very poor in the environmental management of pesticides, and only 35% received a medium score for the environmental management of pesticide consumption through rice paddies.

Discussion

Many deficiencies were recognized during the comprehensive study of the current status of pesticide environmental management.

1. Analysis of education variable

Although the Ministry of Agriculture has offered educational courses, the farmers are not interested in attending these classes (the farmers are not motivated to attend educational courses), and

believe that these courses may waste their time, since there is a wide gap between objective farming and objective prescriptions. They prefer to rely on their own experiences of pesticide application, disregarding the experts' guidelines. Moreover, in some regions, the farmers attend FFS classes but, when it comes to applying pest management standards in rice paddies, they encounter many problems, such as a lack of spraying tools as well as specific equipment needed to go through the pest management steps. It is necessary to mention that such problems can be solved by offering the farmers a way to obtain appropriate spraying tools and equipment to be able to implement their knowledge gained from educational courses. If the farmers do not have enough equipment, they cannot use their educational knowledge, so they will be forced to start pest management programs from the last step, which is chemical pesticide application. One of the most significant recommendations of this study is the expansion of training courses for better management of rice paddy pesticides.

2. Analysis of regulation variable

The current regulations do not comprehensively cover environmental management components of pesticide use. Unfortunately, the current PPO regulation goes back to 1967 and requires an updated revision and amendment to cover all environmental aspects. As a result of the lack of environmental considerations and insufficient supervision by PPO on usage methods of pesticides, experts always face serious problems when following the regulations. The main problems are due to the weakness of presentation of many items, such as clarification of equipment specifications, description of pest management components in detail, *etc*.

3. Analysis of IPM implementation variable

The findings demonstrated that, in many cases, the farmers had no experience and no information about this managerial parameter. Obviously, a detailed educational system is required to inform farmers about pest management advantages in long-term usage.

4. Analysis of applied technology variable

The quality of sprayers has an important effect on the correct usage of pesticides. According to the standard, the calibration of sprayers plays an important role in pesticide application; the more calibrated the sprayer, the better the distribution of pesticides. This will reduce the amount of pesticide needed for rice paddies. In fact, this is the most significant reason why applied technology was included as a management variable in this research. The only variable which has a medium level is the applied technology of sprayers. It is possible to increase spraying quality only by updating the spraying tools and establishing instructions to be followed. For instance, encouraging the farmers to undergo periodic repair and maintenance courses is a good idea to tackle this variable in the current situation.

5. Analysis of price variable

In the current situation, the price of biological pesticides, which are less hazardous to the environment, is much higher than chemical pesticides; therefor, the farmers do not tend to apply such pesticides. Some farmers are educated and aware of the hazardous effects of chemical pesticides; however, the economic condition plays a key role in choosing between pesticides. Sometimes farmers only wanted to control their fields, without paying attention to the side effects of agrochemicals.

6. Analysis of overall management variable

According to the results of overall management, there is a serious problem in the current situation of the environmental management of pesticide consumption. These problems derive from a marked gap in PPO instructions because of their shortcomings to handle the current situation. Due to the fact that agricultural issues are inherently dynamic, the related instructions should be revised yearly.

Pesticide application in agriculture imposes several risks to both human health and non-target agro-ecosystems. Due to the lack of information about the monetary value of pesticide risk reduction, it is difficult to perform economic analysis to address the social efficiency of policy and draw a conclusion about the appropriate degree of regulation.[27] Similar research was performed by Zink in 2008[28] using concepts for the integrated assessment and design of organizations, and an approach for analyzing the current situation was established to identify the "lack of integration" in the change initiatives of a company. Along with the development of pests and consumer resistance to pesticides, pest-management and economic incentives increase the emphasis on these alternative non-residual/non-chemical measures.[29,30]

Developing computing technology has provided an opportunity for environmental pest management to change from simple variables into new managerial methodologies, emphasizing greater complexity and detail. Future improvements in computing technology will continue to facilitate the application of complex descriptive statistical methods for pests, incorporating extensive ecological and managerial knowledge. The long-term security of the global food supply depends in part on scientists providing decision-supporting tools, including pest management approaches. These approaches ensure the continuation of efficient and sustainable agricultural production. The role of such methods in ecological and insecticide-based pest control strategies was first discussed in Ascough *et al.*'s article, followed by a description of the major types of available pest management methods. Current approaches are then presented followed by future research requirements.[31]

As shown in Fig. 7, in 48%, the overall management ranks were considered as poor. In 35%, the pest management rank was medium and in 17%, it was very poor. No good or excellent score was obtained in this research. The results confirm that environmental management of pesticide consumption is lower than the standards of the Plant Protection Organization and Ministry of Agriculture, and approximately below the average level. Thus, a comprehensive practical program should be initiated to improve the present status of pesticide consumption management in the province. This program should include all components of envi-

ronmental management and cover the standard points relevant to the current situation. The necessity of establishing a program and also the lack of integrated approaches were observable through the research participants' answers. In conclusion, the findings of this study can be used as baseline data to establish a management and monitoring program for the environmental management of pesticides in Mazandaran province.

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