Available Online at EScience Press
**Plant Protection**
ISSN: 2617-1287 (Online), 2617-1279 (Print)
http://esciencepress.net/journals/PP

# STATUS OF PESTICIDE USE AMONG THYME (*THYMUS VULGARIS*) CROP FARMERS IN NORTH WEST BANK, PALESTINE

**Abdallah Alimari**
*Palestine Technical University-Kadoorie, Arroub Branch, Faculty of Agriculture, Department of Horticulture and Agricultural Extension, Palestine.*

**ARTICLE INFO**

***Article history***
*Received: 15th November, 2023*
*Revised: 14th December, 2023*
*Accepted: 14th December, 2023*

***Keywords***
*Thyme*
*Farmers' practices*
*Use of pesticides*
*Farmer's commitment*

**ABSTRACT**

The data were collected to diagnose the current status of pesticide use on thyme crops (*Thymus vulgaris*). In total, 111 questionnaires were used to calculate the means, standard deviation, and percentages of farmers' responses. Chi-square ($\chi 2$) and T-tests were employed to test the associations between pesticide application practices and demographic variables, recipients of extension, sources of farmer information, production, and marketing. The results showed that 69.7% of farmers used 23 insecticides, and 11.8% of the pesticides were not suitable for pest control. Additionally, 73.5% were not compatible with the safety period. There was a 29.2% increase in pesticide concentration from the recommended amount and a 32.4% increase in the number of spraying times during the season. Farmer commitment to pesticide use instructions was moderate, with a mean of 2.8 ± 0.68. In total, 51.4% of farmers received extension services, and 47.2% relied on their local experience for pesticide practices. Extension services influenced the overused dose. Most farmers did not participate in specialized courses or field days, and no regulatory extension was carried out by institutions for them. They did not adhere to a production guide or obtain a quality certificate. The application of different pesticides did not increase the productivity of thyme. The study findings revealed alarming trends in current farmer practices, with significant implications for crop, farmers, and consumer safety. They underscore the pressing need for targeted interventions, including improved extension services and increased farmer awareness to promote responsible pesticide use.

*Corresponding Author: Abdallah Alimari*
*Email: abdallah.alimari@ptuk.edu.ps*


## INTRODUCTION

Thyme (*Thymus vulgaris*) is considered the main source of many medicinal drugs (Silva et al., 2021). The thyme crop, in particular, and medicinal plants, in general, are essential strategic crops and commodities. The demand for these products is increasing due to population growth and an increased focus on improving quality (Ministry of Agriculture (MoA), 2022; Agricultural Sector Strategy, 2021-2023). Approximately 85% of the manufactured thyme is sold in local markets, with the remaining portion exported to Jordan, Gulf countries, the USA, the European Union, and Russia (GAERD, 2021).

Often, farmers adopt quick solutions to control agricultural pests affecting thyme by using agricultural pesticides to protect crops from pest damage. However, the frequent use of agricultural pesticides leads to several problems, including increased pest resistance to pesticides, environmental issues, and human health

concerns (Shabana et al., 2017). Improper use of agricultural pesticides results in many undesirable consequences, such as harm to various organisms, negative impacts on agricultural biodiversity, and environmental contamination of food and feed (Wei et al., 2018).

The toxic effects of agricultural pesticides also pose a high risk to human life (Lushchak et al., 2018; Lee and Choi 2020). The negative consequences related to the improper use of pesticides necessitate the exploration of alternative means for pest management, such as botanical pesticides. The adoption of best cultural and mechanical agricultural practices should be encouraged among farmers to reduce reliance on chemical pesticides (Miyittah et al., 2022).

Worldwide production of pesticides has been increasing at a rate of 11% annually. Large amounts of residual pesticides penetrate non-target plants and the environment, leading to pesticide contamination that has polluted the environment and caused negative effects on human health (Tudi et al., 2021). To mitigate these negative effects, it is necessary to reduce the use of pesticides and promote the use of non-chemical alternatives, adhering to the principles of integrated pest management in agriculture. Pesticides must be used compulsorily in a sustainable and sound manner to minimize risks and harmful effects on human health and the environment (Strassemeyer et al., 2017).

Despite improper pesticide use practices, when characterizing farmers' behavior, it was observed that in many cases, the majority of farmers were aware of the adverse effects of pesticides on human health and the environment (Rijal et al., 2018). A few farmers followed good practices for pesticide use. Education on pest management and increased contact with extension personnel were critical factors in improving farmers' understanding of the ecological hazards caused by the overuse of pesticides (Rahaman et al., 2018). In many regions, farmers applied unhealthy practices regarding the safe usage of pesticides, with only 34.4% of farmers obtaining information on the safe usage of pesticides from the Department of Agriculture Extension (Rahaman et al., 2019).

The literature consistently highlights the inappropriate application of pesticides on numerous crops, resulting in health risks for farmers and consumers, as well as adverse environmental consequences. This study seeks to assess the current state of pesticide usage in thyme cultivation in the northern West Bank. The investigation included an examination of farmers' practices in pesticide use, their adherence to instructions, extension services and awareness, as well as aspects related to production and marketing. Additionally, the study aims to illuminate the relationships among the variables under consideration.

## MATERIALS AND METHODS

### Study Area

The study was conducted with thyme farmers in the North West Bank of Palestine, encompassing the governorates of Jenin, Tubas, Nablus, Tulkarem, and Qalqelia. This region has a total land area of 2024 $km^2$.

### Data Collection

Previous experiences in thyme farming and relevant literature were utilized to develop a structured questionnaire. The questionnaire covers details about the study sample's characteristics, farmer practices related to pesticide use, adherence to pesticide use instructions, extension and awareness efforts, as well as aspects related to production and marketing. By incorporating questions in these categories, the questionnaire aimed to gather a comprehensive dataset enabling researchers to analyze the multifaceted factors influencing pesticide use in thyme cultivation, identify potential challenges, and propose informed recommendations for sustainable and responsible agricultural practices.

Data were collected through face-to-face interviews with farmers from different communities. The questionnaire underwent a scientific background check during construction and tests for validity and reliability. It was presented, reviewed, and evaluated by several academics and specialists. The stability of the tool was verified, and the Cronbach alpha coefficient was calculated to examine the internal consistency of the paragraphs, yielding a value of 81.0. The study population comprised all thyme farmers in the north of the West Bank in Palestine, during the period from 2020-2021. The study sample for the questionnaire was calculated from the community (approximately 415) of thyme farmers (Aleiwi and Al-Omari, 2018). Using the sample size calculation program www.calculator.net, the sample size was determined to be 111 with a confidence level of 95% and a marginal error of 8%. Six farms were excluded due to their small cultivation area, bringing the total to 105.

The questionnaire consisted of a demographic section, covering area, production, pesticides used to control thyme pests, farmer commitment to pesticide use instructions, extension, awareness, and marketing. Farmers' commitment to pesticide use instructions was measured using a Likert-type scale from 1 to 5, as follows: 1 = very low agree, 2 = low agree, 3 = intermediate, 4 = high agree, and 5 = very high agree. A total of 8 safety measures regarding pesticide use were adopted from Hashemi et al. (2012) for evaluation. Regarding pesticides used to control thyme pests, farmers were asked to specify all used pesticides, including commercial name, dose, safety period, and the specific pest targeted. For the extension and awareness section, farmers were asked to mention the source of information, and other questions were answered with yes or no. In the marketing section, farmers were asked to specify the type of marketing channels and whether it was for local or export markets. Meetings with farmers were also conducted to elucidate the reasons for some answers.

**Data Analysis**

The data were analyzed using the Statistical Package for Social Sciences (SPSS) version 23. Means, standard deviations, and percentages of farmers' responses were calculated to identify and diagnose the operations carried out by farmers in terms of the use of agricultural pesticides from the farmer's perspective. The data on pesticide application were categorized as applicable or not applicable for the dose of the pesticide, applicability of the type of pesticide on thyme, applicability on the pest, and safety period. The association between the application of agricultural practices related to the use of pesticides and the main demographic variables (age, gender, educational level, farm area, location, and income level) was assessed using the $\chi 2$ test and T test.

## RESULTS AND DISCUSSION

### Characteristics of the study sample and the association with pesticide application

The average age of the farmers was 44.2 years, and the average land area was 0.55 hectares. Regarding gender distribution, the majority of respondents were males, constituting 74%, while females accounted for 26%. The educational qualifications of the study sample revealed that the highest percentage (39%) held a secondary degree, while the lowest percentage (5.7%) belonged to those with an illiterate degree.

The data further indicated that the category with the highest percentage (30.5%) for land area was 0.1-0.2 hectares. In terms of age distribution, the 41-50 years category was the highest, representing 48.3%. Tubas governorate constituted the largest portion of the sample with 31.4%. The results also indicated that 61.8% of the respondents fell within the middle-income bracket, while 3.9% had very little income (Table 1).

Table 1: The main characteristics of the study sample.

| Item | Level | Percent | Item | Level | Percent |
|---|---|---|---|---|---|
| Gender | Male | 74 | Location | Jenin | 28.6 |
| | Female | 26 | | Tubas | 31.4 |
| Education level | Illiterate | 57 | | Tulkarem | 22.9 |
| | Primary | 26.7 | | Qalqelia | 5.7 |
| | Secondary | 39 | | Nablus | 11.4 |
| | University | 28.6 | Area | 1-2 du | 30.5 |
| Age | 18-25 | 4.3 | | 3-5 du | 28.6 |
| | 26-30 | 7.4 | | 6-9 du | 13.3 |
| | 31-35 | 11.7 | | More than 10 | 27.6 |
| | 36-40 | 14.9 | Income | Very low | 4.9 |
| | 41-50 | 38.3 | | low | 2 |
| | 51-60 | 18.1 | | Medium | 61.8 |
| | More than 60 | 5.3 | | High | 27.5 |
| | | | | Very high | 3.9 |

There was no significant association ($\alpha \leq 0.05$) found in the responses of the respondents regarding the correlation between pesticide application and all demographic variables, except for the dose used, applicability on thyme crops, and the safety period related to the location (Table 2). Nonetheless, it is essential to note that demographic variables do play a significant role in influencing farmers' choices, providing valuable understandings into farmers' behavior (Burton, 2014).

In Tubas governorate, 78% of farmers used excessive doses (Figure 1) and 80% used inappropriate pesticides for the thyme crop (Figure 2). Moreover, Tubas (48.6%) and Jenin (34.3%) had the highest rates of non-compliance with the safety period (Figure 3). Tubas and Jenin are the largest producers of vegetables and medicinal plants in the West Bank, where the intensive use of pesticides is common, according to Zakarnah (2023).

Table 2: Association of demographic variables with pesticide application.

| Variable | Sex | | | Education | | | Income | | |
|---|---|---|---|---|---|---|---|---|---|
| | χ2 | DF | P | χ2 | DF | P | χ2 | DF | P |
| Dose | 1.498[a] | 1 | 0.22 | 0.404[a] | 3 | 0.939 | 4.908[a] | 5 | 0.427 |
| Applicable on thyme | 0.161[a] | 1 | 0.689 | 0.338[a] | 3 | 0.953 | 4.309[a] | 5 | 0.506 |
| Applicable on pest | 1.825[a] | 1 | 0.177 | 4.670[a] | 3 | 0.198 | 3.146[a] | 5 | 0.678 |
| Safety period | 0.224[a] | 1 | 0.636 | 1.950[a] | 3 | 0.583 | 4.911[a] | 5 | 0.427 |
| Variable | Location | | | Age | | | Farm size | | |
| | χ2 | DF | P | χ2 | DF | P | χ2 | DF | P |
| Dose | 27.177[a] | 4 | 0.000 | 10.998[a] | 7 | 0.139 | 22.842[a] | 14 | 0.063 |
| Applicable on thyme | 14.561[a] | 4 | 0.006 | 3.841[a] | 7 | 0.798 | 9.715[a] | 14 | 0.783 |
| Applicable on pest | 5.712[a] | 4 | 0.222 | 3.725[a] | 7 | 0.811 | 15.921[a] | 14 | 0.318 |
| Safety period | 23.782[a] | 4 | 0.000 | 3.987[a] | 7 | 0.781 | 21.752[a] | 14 | 0.084 |

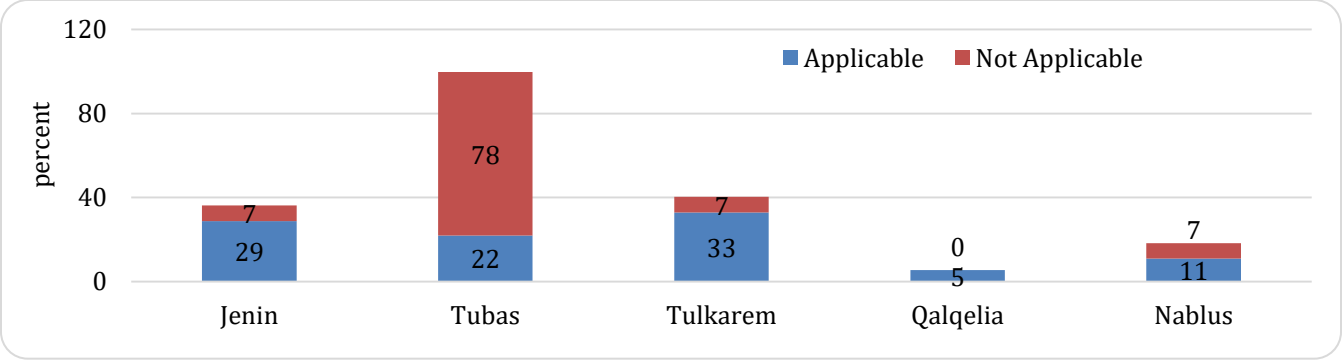


Figure 1: The applicability of pesticide dose in Tunas governorate.

**Pesticides use**

The analysis of the collected data revealed that farmers used two herbicides, constituting 6.1% of the total pesticides, primarily for weed control in thyme. Additionally, 69.7% of farmers utilized 23 insecticides, while 24% used 8 fungicides. About 11.8% of the pesticides employed were inappropriate for specific pests, and 73.5% were incompatible with safety periods. There ass a worrisome trend, with a 29.2% increase in pesticide dosage beyond recommended levels and a 32.4% rise in the frequency of spraying during the season.

Consequently, the magnitude of the issue related to pesticide use was alarming, indicating a lack of knowledge among farmers in pesticide application

(Ghasemi and Karami, 2009; Weng and Black, 2015). These findings align with the study in the Sinai Governorate, Arab Republic of Egypt, which found that 48% of farmers did not implement preventive measures when controlling agricultural pests (Al-Sayed et al., 2020). It is evident that farmers mishandle pesticides, particularly in developing countries, as supported by studies in Bangladesh where over 47% of farmers misuse pesticides (Dasgupta et al., 2005). Similarly, in a study by Tsakiris et al. (2023), nearly 24.8% of farmers neglected protective measures during pesticide handling.

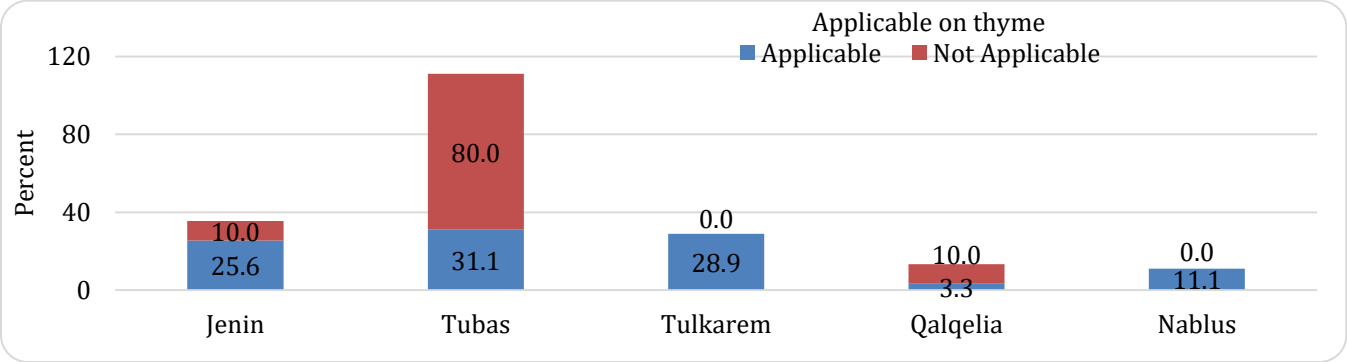


Figure 2: The applicability of pesticide for thyme crop in Tubas governorate.

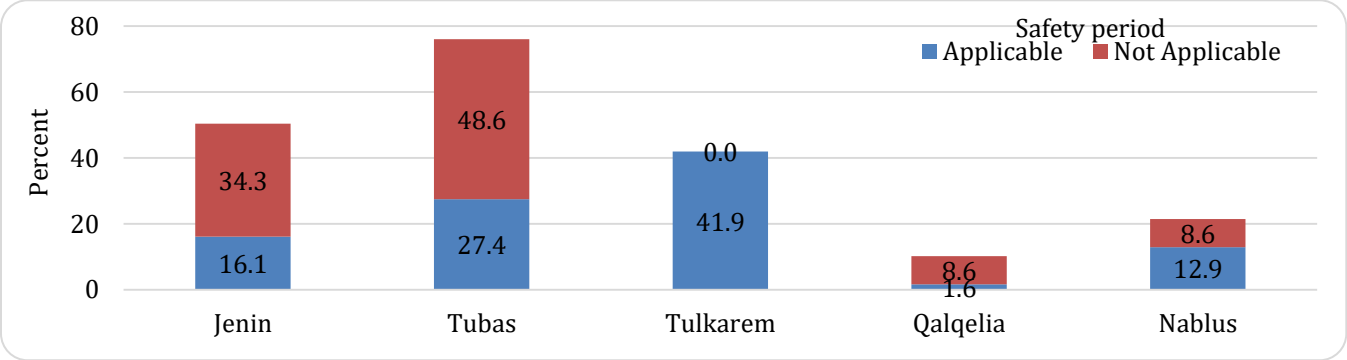


Figure 3: The compliance of the farmers with the safety period.

The farmers aim to generate more income through the extensive application of pesticides on thyme crops, capitalizing on heightened demand both locally and internationally. They believe that such practices increase crop yield and obtain better prices. Unfortunately, this perspective overlooks the critical role that pesticides can play in impacting human health and the environment, highlighting the need for a more balanced and sustainable approach to agricultural practices. This aligns with the findings of Sarma (2022) indicating that farmers' intentions to comply with pesticide specifications are closely linked to government regulations and technical support. Farmers adhere to these specifications to achieve specific objectives, including cost reduction, increased yields, and enhanced market value for their products. They are also more likely to follow food safety regulations when they value the healthiness of their agricultural goods.

**Farmer commitment to pesticide use instructions**

The mean of the farmer's commitment to the instructions for the use of pesticides was about 2.8 ± 0.68, indicating a medium level of commitment from the farmer's perspective. It is clear that "washing hands after spraying" obtained the highest arithmetic mean of 4.44 ± 0.62, indicating a very high level of impact, followed by the commitment to not using empty pesticide bottles with an average of 4.17 ± 1.08. Commitment to the safety period is moderately agreed upon by the farmers (3.02 ± 0.65). Commitment to appropriate spraying times received the lowest score (2.1 ± 0.55). Commitment to wearing special clothing for spraying pesticides, adhering to the recommended

amount of pesticide according to the instructions on the package, commitment to general safety procedures on the farm, and finally, commitment to using types of pesticides approved by the Ministry were all low (2.14 ± 0.66, 2.15 ± 0.63, 2.3 ± 0.60, 2.35 ± 0.68) respectively (Table 3).

Table 3: Mean for farmer compliance with pesticide use instructions.

| Sr. No. | Parameter | Mean | SD |
|---|---|---|---|
| 1 | Commitment to the safety period | 3.02 | 0.65 |
| 2 | Commitment to use the types of pesticides approved by the Ministry | 2.35 | 0.68 |
| 3 | Commitment to the use amount of pesticide according to the instructions attached to the package | 2.15 | 0.63 |
| 4 | Commitment to general safety procedures on the farm | 2.3 | 0.60 |
| 5 | Commitment to wear special clothing for spraying pesticides | 2.14 | 0.66 |
| 6 | Commitment to the appropriate spraying times | 2.1 | 0.55 |
| 7 | Commitment to wash hands after spraying | 4.44 | 0.62 |
| 8 | Commitment to not to use of empty pesticide bottles | 4.17 | 1.08 |
| | Total average | 2.83 | 0.68 |

Despite the fact that farmers employed harmful practices to use pesticides in order to obtain more financial profit and reduce crop losses, they were also aware of some pesticide instructions. The reason was that farmers perceive the harm of polluted hands and bottles on the digestive system, but they were careless about the harmful effects of pesticides on other organs, such as the skin and respiratory system. This was documented during farmers' meetings. This aligns with the results of Rijal et al. (2018), who found that some farmers were aware of the adverse effects of pesticides on human health and the environment.

**Extension and awareness**

The analysis showed that 51.4% of farmers received extension services. The analysis also revealed that most farmers did not participate in specialized courses, failed to attend field days and observations, were not supervised by institutions, and did not adhere to a production guide or obtained a quality certificate. Only 35.2%, 30.5%, 29.5%, 27.6%, and 19% of them respectively received such trainings (Table 4). These results are in contrast to findings that indicated that only a few farmers (34.4%) obtained information on the safe usage of pesticides from the Department of Agriculture Extension (Mubushar et al., 2019).

In terms of information sources, a total of 47.2% of farmers rely on their local experience for pesticide use, followed by information provided by the Ministry of Agriculture (23.6%), with only 1.9% obtaining information from cooperatives (Figure 4).

Table 4: Percentage of extension and awareness items for farmers.

| Sr. No. | Item | Yes | No |
|---|---|---|---|
| 1 | Receive extension services | 51.4 | 48.6 |
| 2 | Participation in specialized courses | 35.2 | 64.8 |
| 3 | Attending field days and sightings | 30.5 | 69.5 |
| 4 | Are there regulatory institutions that supervise the farm | 29.5 | 70.5 |
| 5 | Do you adhere to a productive guide | 27.6 | 72.4 |
| 6 | Do you get a quality certificate | 19.0 | 81.0 |

The relationship between pesticide application practices and awareness was examined, and Table 5 revealed that there was no statistically significant association at the significance level $\alpha \leq 0.05$ in the responses of the participants regarding the connection between pesticide application and the source of farmer's information on one side and the recipient of extension on the other side. However, there was a significant association observed in the relationship with the dosage used.

A total of 63.3% of farmers receiving extension

services used an applicable dose, while 65% of farmers without access to extension services used an inapplicable dose (Figure 5). These results highlighted the impact of awareness in encouraging farmers to adopt better practices. Awareness of the harmful effects of pesticides contributed to a reduction in the application rate of active pesticide ingredients (Lin et al., 2022).

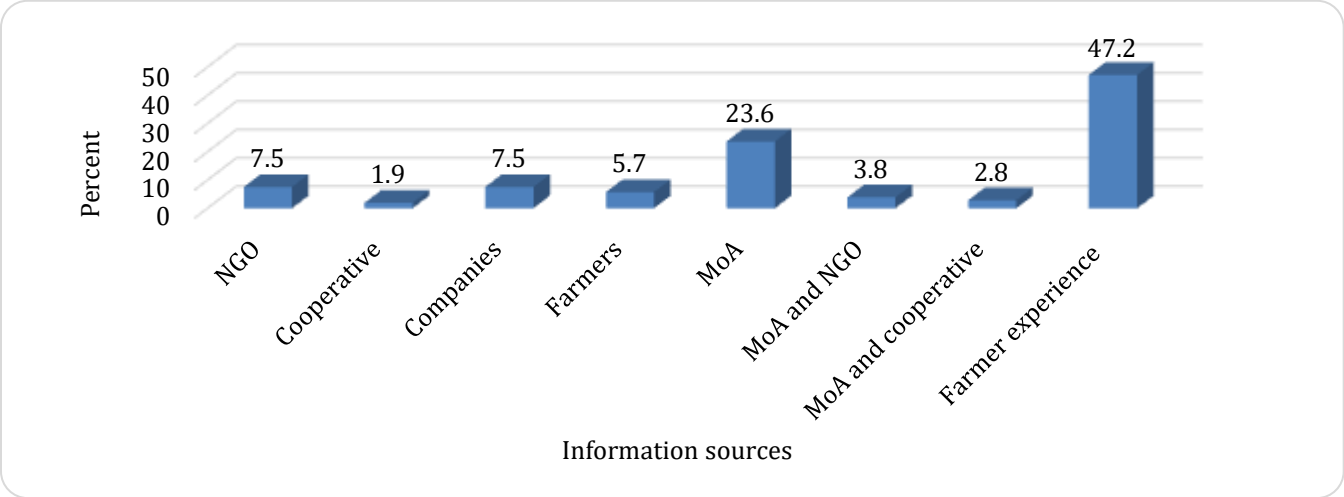


Figure 4: Different information sources about pesticides.

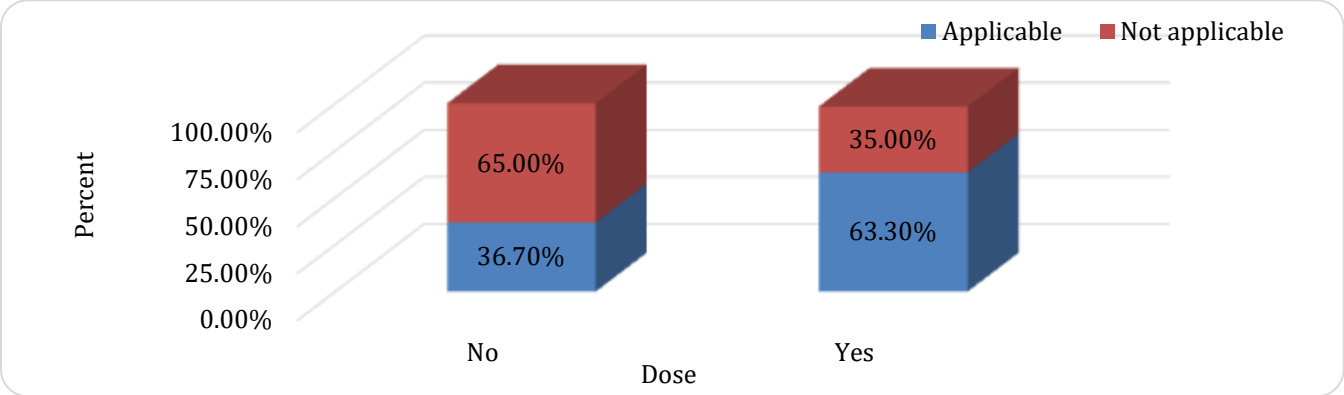


Figure 5: Recipient of extension and dose used association.

Table 5: Association of demographic variables with pesticide application.

| Variable | Recipient of extension | | | Source of farmers information | | |
|---|---|---|---|---|---|---|
| | χ2 | DF | P | χ2 | DF | P |
| Dose | 4.586[a] | 1 | 0.032 | 10.080[a] | 5 | 0.073 |
| Applicable on thyme | 0.090[a] | 1 | 0.764 | 2.127[a] | 5 | 0.831 |
| Applicable on pest | 3.037[a] | 1 | 0.081 | 5.826[a] | 5 | 0.323 |
| Safety period | 1.229[a] | 1 | 0.268 | 8.749[a] | 5 | 0.119 |

**Production and marketing**

The dunum (0.1 hectare) produced an average of 2590 ± 2000 kg of fresh thyme and 1720 ± 130 kg of dry weight per year. The harvest occurred approximately 3.7 ± 1.5 times per year, with an interval between harvests of about 46.4 ± 20 days. Table 6 revealed that there was no statistically significant association at the significance level $\alpha \leq 0.05$ in the respondents' responses concerning

the relationship between pesticide application and production variables, except for the relationship between the safe period and the duration of thyme harvest. The application of different pesticides did not enhance thyme productivity, as aromatic plants and their bioactive metabolites can impact plant diseases by inducing systemic resistance, defense responses, and inhibiting the growth of pathogens (Greff et al., 2023).

The mean duration was approximately 50.22 ± 17.74 days for the applicable safety period, whereas it was 32.38 ± 13.58 days for the non-applicable period (Table 7). This was due to the extended time required for harvesting. Subsequently, farmers can adjust pesticide use directly after harvest, rendering the safety period applicable.

Table 6: T test of production variables with pesticide application practices.

| Variable | Green weight | | | Dry weight | | |
|---|---|---|---|---|---|---|
| | T | DF | P | T | DF | P |
| Dose | -1.296 | 31 | 0.205 | 0.150 | 28 | 0.882 |
| Applicable on thyme | -0.674 | 32 | 0.505 | 1.304 | 28 | 0.203 |
| Applicable on pest | 0.802 | 21 | 0.432 | 0.069 | 19 | 0.946 |
| Safety period | 1.937 | 26 | 0.064 | 2.020 | 23 | 0.058 |
| Variable | Number of harvest times | | | Duration between harvest times | | |
| | T | DF | P | T | DF | P |
| Dose | 0.593 | 59 | 0.555 | -1.253 | 47 | 0.216 |
| Applicable on thyme | 1.704 | 58 | 0.094 | -0.259 | 46 | 0.797 |
| Applicable on pest | -1.689 | 48 | 0.098 | 0.456 | 36 | 0.651 |
| Safety period | 0.175 | 53 | 0.862 | 3.717 | 42 | 0.001 |

Table 7: Means of applicability of safely period for safely period.

| Item | Applicable | | Not applicable | |
|---|---|---|---|---|
| | Mean | Std. Deviation | Mean | Std. Deviation |
| Duration between harvest times | 50.22 | 17.74 | 32.38 | 13.58 |

More than 82.9% of the product was sold in local markets, while 17.1% was exported to international markets. In total, 40% of the product was sold to traders, followed by the local market at 22.9% and companies at 18.1%, whereas only 1% was sold to organizations (Figure 6).

Table 8 indicated that there was no statistically significant association at the level of significance $\alpha \leq 0.05$ in the responses of the respondents regarding the relationship between pesticide application and marketing channels, as well as export/local markets, except for the association with the dose of pesticide used. In total, 44.9% of the product sold to traders had an applicable dose (Figure 7). Traders represented sustainable marketing channels, and farmers made efforts to maintain high product quality for them.

**CONCLUSIONS AND RECOMMENDATIONS**

The study concluded that there was improper pesticide use in thyme cultivation, resulting in pesticide contamination of the product. This contamination not only diminished the marketability of the product but also posed environmental risks and had adverse effects on both humans and plants. The evidence for these findings stemmed from data collected from farmers during the pesticide application on thyme.

In the same questionnaire, farmers were asked about their adherence to safety rules during pesticide spraying, and the responses indicated a moderate level of commitment. Essentially, farmers expressed a moderate commitment to adhering to instructions. Non-compliance issues were identified through the questionnaire when farmers were questioned about the pesticide's name, spraying quantity, safety period, and frequency of application.

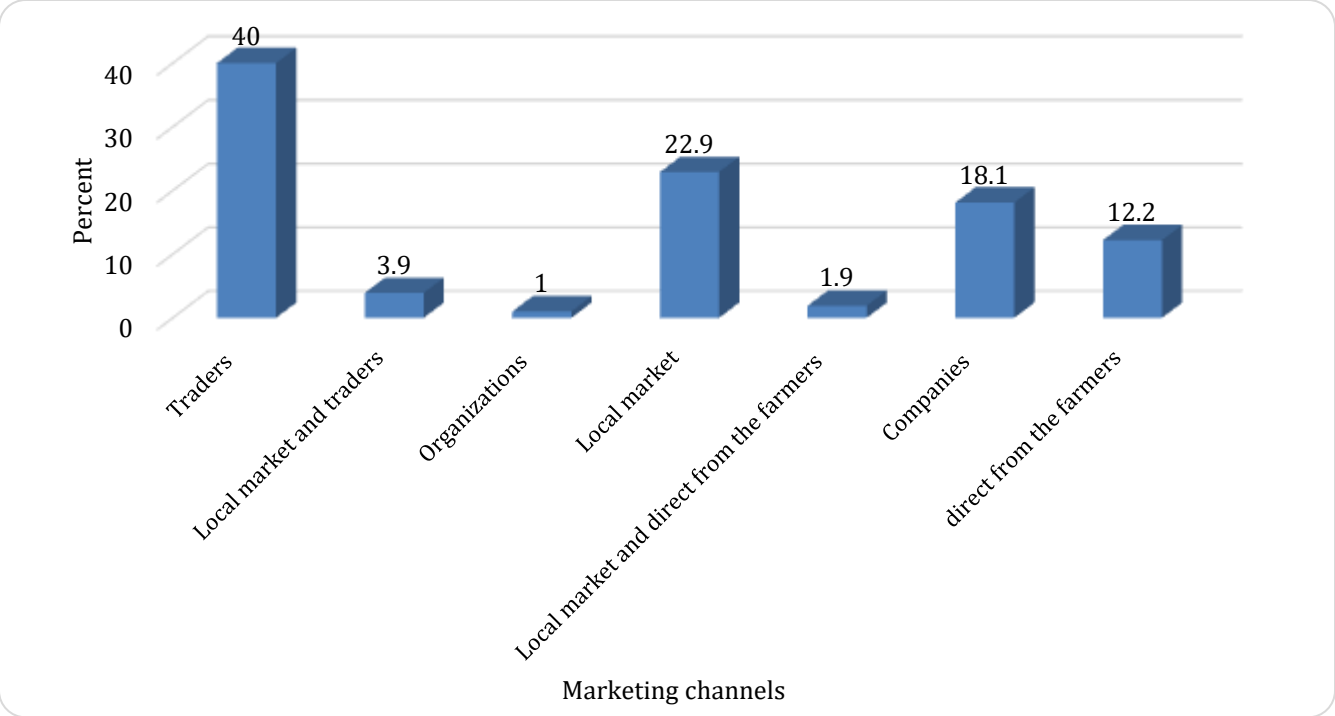


Figure 6: Marketing channels of thyme crop.

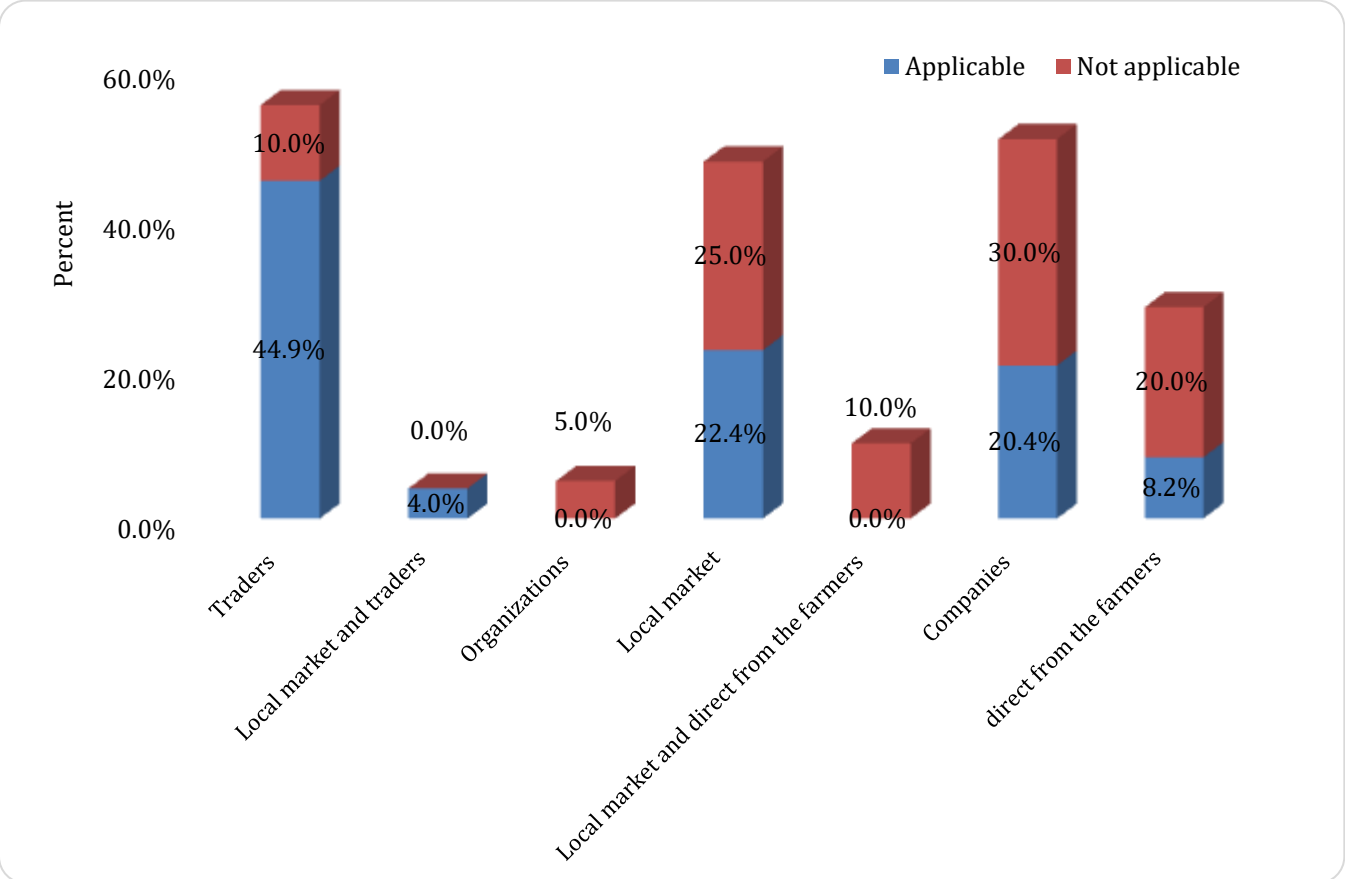


Figure 7: The association of marketing channels of thyme crop with doze application.

Therefore, this study recommends enhancing farmers' awareness of the hazards associated with pesticide use, advocating and facilitating the adoption of Integrated Pest Management (IPM) practices, with a focus on biological control and alternative pest management strategies. Additionally, there is a need to develop incentives, subsidies, or recognition programs for farmers who implement IPM practices. It is also suggested to collaborate with the Ministry of Agriculture and agricultural cooperatives to establish and maintain a platform for disseminating information on the proper use of pesticides.

**ACKNOWLDGMECT**

I wish to express my gratitude to Palestine Technical University - Kadoorie, Arroub branch, particularly the Faculty of Agriculture and the Department of Horticulture and Agricultural Extension, for providing me with the opportunity to conduct this research.

**AUTHOR'S CONTRIBUTIONS**

AA perceived the idea, designed methodology, retrieved data from database, performed analysis, wrote up of manuscript and proofread it.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**REFERANCES**

Agricultural Sector Strategy for 2021-2023. Ministry of Agriculture. 2021. Palestine. Available on the website of the Sectoral Strategy for Agriculture. (palestinecabinet.gov.ps).

Aleiwi, A., Al-Omari, A., 2018. The role of agricultural practices in achieving food safety in medicinal plants in the West Bank. Quds University. Palestine

Al-Sayed, A., Salem, A., Eid, E., 2020. Farmers' knowledge of the dangers of unsafe use of pesticides used in controlling agricultural pests in South Sinai Governorate. Journal of the Scientific Association for Agricultural Extension 24(3), The Egyptian Arabic Republic.

Burton, R.J.F., 2014. The influence of farmer demographic characteristics on environmental behaviour: A review. Journal of Environmental Management 135, 19-26. doi:10.1016/j.jenvman.

Dasgupta, S., Meisner, C., Haq, M., 2005. Health effects and pesticide perception as determinants of pesticide use: evidence from Bangladesh. World Bank Policy Research Working Paper 3776. https://papers.ssrn.com/sol3/papers.cfm.

GAERD (General Administration of Extension and Rural Development)., 2021. Bulletins and reports of the Palestinian Ministry of Agriculture. Palestine.

Ghasemi, S., Karami, E.A., 2009. Attitudes and behaviors about pesticides use among greenhouse workers in Fars province. Agriculture Development 23, 28-40.

Greff, B., Sáhó, A., Lakatos, E., Varga, L., 2023. Biocontrol activity of aromatic and medicinal plants and their bioactive components against soil-borne pathogens. Plants 12(4), 706. https://doi.org/10.3390/plants12040706

Hashemi, S.M., Rostami, R., Hashemi, M.K., Damalas, C.A., 2012. Pesticide use and risk perceptions among farmers in Southwest Iran. Human and Ecological Risk Assessment: An International Journal 18(2), 456-470.

Lee, G.H., Choi, K.C., 2020. Adverse effects of pesticides on the functions of immune system. Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology 235. https://doi.org/10.1016/j.cbpc.2020.108789

Lin, Y., Hu, R., Zhang, C., Chen, K., 2022. Effect of agricultural extension services in the post-reform era since the mid-2000s on pesticide use in China: evidence from rice production. International Journal of Agricultural Sustainability, 20(5), 955-966. DOI: 10.1080/14735903.2022.2028399

Lushchak, V., Matviishyn, M., Husak, V., 2018. Pesticide toxicity: A mechanistic approach. EXCLI Journal 17, 1101.

Ministry of Agriculture, 2022. Data of the Palestinian agricultural departments on the thyme crop. Palestine.

Miyittah, M.K., Kosivi, R.K., Tulashie, S.K., Addi, M.N., Tawiah, J.Y., 2022. The need for alternative pest management methods to mitigate risks among cocoa farmers in the Volta region, Ghana. Heliyon, 8(12). https://doi.org/10.1016/j.heliyon.2022.e12591

Mubushar, M., Aldosari, F.O., Baig, M.B., Alotaibi, B.M., Khan, A.Q., 2019. Assessment of farmers on their

knowledge regarding pesticide usage and biosafety. Saudi Journal of Biological Sciences 26(7), 1903-1910.

Rahaman, M.M., Islam, K.S., Jahan, M., 2018. Rice Farmers' knowledge of the risks of pesticide use in Bangladesh. Journal of Health and Pollution 8(20), 181203. doi: 10.5696/2156-9614-8.20.181203. PMID: 30560002; PMCID: PMC6285676.

Rahman, M.R., Islam, M.S., Rahman, M.M., Prodhan, M.D.H., Uddin, M.K. 2019. Organochlorine pesticide residue status in dry fish of Bangladesh and their risk assessment: a review. International Journal of Scientific and Research Publications 9, 619-639. https://doi.org/10.29322/IJSRP.9.10.2019.p9480

Rijal, J.P., Regmi, R., Ghimire, R., Puri, K.D., Gyawaly, S., Poudel, S., 2018. Farmers' knowledge on pesticide safety and pest management practices: A case study of vegetable growers in Chitwan, Nepal. Agriculture 8(1). https://doi.org/10.3390/agriculture8010016

Sarma, P.K., 2022. Farmer behavior towards pesticide use for reduction production risk: a theory of planned behavior. Cleaner and Circular Bioeconomy 1. https://doi.org/10.1016/j.clcb.2021.100002

Shabana, Y.M., Abdalla, M.E., Shahin, A.A., El-Sawy, M.M., Draz, I.S., Youssif, A.W., 2016. Efficacy of plant extracts in controlling wheat leaf rust disease caused by *Puccinia triticina*. Egyptian Journal of Basic and Applied Sciences 4(1), 67-73. https://doi.org/10.1016/j.ejbas

Silva, A.S., Tewari, D., Sureda, A., Suntar, I., Belwal, T., Battino, M., Nabavi, S.M., Nabavi, S.F., 2021. The evidence of health benefits and food applications of *Thymus vulgaris* L. Trends in Food Science & Technology 117, 218-227.

Strassemeyer, J., Daehmlow, D., Dominic, A.R., Lorenz, S., Golla, B., 2017. SYNOPS-WEB, an online tool for environmental risk assessment to evaluate pesticide strategies on field level. Crop Protection 97, 28-44. https://doi.org/10.1016/j.cropro.2016.11.036

Tsakiris, P., Damalas, C.A., Koutroubas, S.D., 2023. Safety behavior in pesticide use among farmers of northern Greece: the role of information sources. Pest Management Science 79(11), 4335-4342. doi: 10.1002/ps.7632. Epub 2023 Jul 13. PMID: 37380619.

Tudi, M., Ruan, H.D., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C., Phung, D.T., 2021. Agriculture development, pesticide application and its impact on the environment. International Journal of Environmental Research and Public Health. 18(3), 1-24. https://doi.org/10.3390/ijerph18031112

Wei, J., Chen, Y., Tiemur, A., Wang, J., Wu, B., 2018. Degradation of pesticide residues by gaseous chlorine dioxide on table grapes. Postharvest Biology and Technology 137, 142-148. https://doi.org/10.1016/j.postharvbio.2017.12.001

Weng, C.Y., Black, C., 2015. Taiwanese farm workers' pesticide knowledge,attitudes, behaviors and clothing practices. International Journal of Environmental Health Research 25(6), 685-696.

Zakarnah, J., 2023. Ministry of agriculture. Jenin directorate. Palestine.