PhD THESIS

Research on the control of diseases and pests of plums in ecological system

(SUMMARY OF THE Ph.D. THESIS)

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INTRODUCTION

Ecological agriculture is expanding globally, and this trend is also evident in Romania due to the increasing demand from consumers for healthy ecological products. This represents a significant opportunity for Romanian farmers, but it also comes with challenges related to effective pest and disease control in ecological systems. Romania has substantial potential to become a major supplier of ecological fruits in Europe, thanks to favorable soil and climate conditions and a strong tradition in fruit growing. However, the area under ecological cultivation is still below the European average. The lack of specialized information on the effectiveness of some ecological products in controlling the main pests of the plum specie contributes to the low number of farmers who adopt ecological systems of cultivation of the plum specie.

The success of ecological plum orchards depends on the implementation of a pest management strategy using alternative plant protection methods correlated with the characteristics of the species. From the very beginning of the establishment of ecological crops, the chosen varieties must have good resistance to both climatic factors (such as drought and frost) and certain diseases and pests. This significantly reduces the risk of serious phytosanitary problems that could compromise the orchard's production. The knowledge of the principles of ecological agriculture and aspects related to the biology of the main pests are essential for the success of a crop in an alternative system. Farmers should be familiar with specific methods of pest and disease control in ecological systems before establishing such a crop. In ecological agriculture, prevention is the first priority, when it comes to managing the main pests. The specific agronomic disinfection methods are used, depending on the parasite, and plant protection treatments on warning are accepted in ecological agriculture. Another important element is the periodic monitoring of the crop to identify some phytosanitary problems at an early stage.

Taking into account various factors such as climate change, global efforts to reduce environmental pollution, and the increasing market demand for ecological products, the need to develop environmentally friendly alternative farming systems becomes evident.

Keywords: ecological plum, diseases and pests, ecological cropping system, control, ecological phytosanitary products, prevention, harmful agents, ecological fruit

Plums remain a fruit tree species of global interest, with over 2,000 varieties and cultivars (Sottile et al., 2022). This remarkable genetic diversity highlights the species ability to adapt to different climatic conditions and soil types, making it a suitable choice for farmers. The health benefits are attributed to the fruits rich content of vitamins and antioxidants, essential elements for a healthy diet. Daily consumption of 2-4 fruits (plums) significantly contributes to the daily intake of essential nutrients for the body (Gil et al., 2002). The culinary versatility of plums offers a wide range of uses, satisfying various preferences. The fruits can be consumed fresh, providing a delicious and healthy snack. They can also be processed in various forms: dried plums, jams, compotes, , offering a variety of options for healthy desserts and snacks. Moreover, plums can be used to produce alcoholic beverages, such as ‘ţuică’, a

traditional Romanian drink appreciated for its distinctive taste (Botu et al., 2008; Butac et al., 2013).

According to the latest statistics published by FiBL and IFOAM in The World of Organic Agriculture 2023, ecological agriculture has experienced significant growth globally. At the end of 2021, it is practiced in 190 countries, on an area of 76.4 million hectares, representing approximately 1.7% of the agricultural area of the Earth. This remarkable expansion, of 38 million hectares in the last ten years, highlights the changes at the global level regarding the approach of alternative solutions to do agriculture by protecting the environment and consumers health. In Romania, ecological agriculture has experienced a significant evolution in the last ten years. Official data from 2021 indicates that there are 11,029 certified ecological farmers, and the certified ecological area or in conversion is about 570 thousand hectares. This category represents approximately 4% of Romania's total agricultural land.

The final aim and objectives of the research

The topic addressed in this Ph.D. thesis has as its final goal the *development of a phytosanitary orientation program of ecological treatments* for the plum specie, capable of keeping the damage of the main pests and diseases below the economic threshold by achieving the following specific objectives:

- match cultural practices specific to ecological agriculture with the biological/ecological requirements of the plum (*Prunus domestica* L.);
- evaluation of the effectiveness of 15-20 products approved for ecological agriculture in the control of the main pests of the plum specie on micro variants in protected space and in the field;
- testing an ecological treatment scheme in the field at the Fruit Research & Development Station Bistrița (FRDS Bistrita), based on the most effective products studied previously on micro variants;
- correlation and statistical interpretation of the data obtained from the studies carried out regarding the control of the main harmful organisms in the plum specie;
- recommending an ecological phytosanitary program effective in controlling the main plum parasites, based on the results obtained in the previous research.

By achieving the specific objectives listed above, the research was carried out in the framework of the Ph.D thesis and will provide essential data regarding the alternative methods of effective control of parasites for the plum specie. These methods use phytosanitary products accepted in ecological farming and are correlated with agrotechnical sanitary disinfection measures.

The methodology used in research

I. In order to obtain relevant and applicable results in the context of Romanian fruit growing, the study focused on two plum varieties that are widespread and adapted to the pedoclimatic conditions in the country: Stanley and Reine Claude d'Althan. The varieties used are recommended and presented in the economic technical guide on fruit trees and shrubs, provided by MADR.

II. In the experiments, certified ecological products were used, whose effectiveness in controlling the main diseases and pests of plum species is reasonably well-documented in the specialized literature. Ovipron Top product, based on paraffin mineral oil and Prev-AM product, based on orange extract are recognized as having insecticidal properties (Al-Antary et al., 2018; Abdel et al., 2018; Soares et al., 2019; Butac et al., 2021). In the case of pests from the orders *Lepidoptera*, *Diptera*, *Coleoptera*,and *Isoptera*, the product BactoSpeine DF is recognized to have an effective effect on their control. The bacterium *Bacillus thuringiensis,* in the composition of the product, creates a toxin capable of killing insects (Liu et al., 2014; Mnif and Ghribi, 2015; AbdAllah et al., 2021; Ahmad et al., 2021). Products based on cinnamon extracts (Canelys) or *Quassia amara* (Konflic) extracts are known to have fungicidal and bactericidal properties (Renkema et al., 2016). For the control of fungal diseases , the Mimox product is known, which contains mimosa extract, that it can reduce the infections caused by this disease. Other products with the same effect are Zytron, based on citrus seeds, and Funres, which is based on extracts of mimosa and citrus seeds. (Braham et al., 2008; Brankica et al., 2013; Adenir et al., 2017; Arici and Özkaya, 2022). Specialized literature, that presents the effects of natural active substances in controlling various pests is primarily focused on fodder or vegetable crops. The number of specialized studies conducted in fruit tree crops, specifically for plum specie, is limited or completely absent for certain diseases or pests. The high number of pathogens, that can compromise plum crops, necessitates, long-term studies, especially in the context of climate changes, to obtain effective control solutions.

III. Within the experiments conducted to develop a provisional phytosanitary control program against the main pests of the plum specie, a series of experimental models were designed, both in the field and in the laboratory. The main target pests were: brown rot (*Monilinia* spp.), plum curculio (*Eurytoma schreineri*), aphids (*Aphis* spp.), and defoliating larvae from the order *Lepidoptera*. For each experiment, standard experimental techniques specific to phytopathology and entomology were employed, following the guidelines for determining resistance to diseases and pests published by ISTIS. Depending on the pests organism, the data were expressed in terms of frequency (F%), intensity (I%), and degree of damage (DD%).

STRUCTURE OF THE WORK AND RESEARCH RESULTS

The Ph.D. thesis with the title *Research on the control of diseases and pests in plums in an ecological culture system* is structured in two distinct parts. In the first part, an overview of the current knowledge on the specific topic studied is presented, in three chapters of the Ph.D. thesis. Thesecond part of the doctoral thesis, presents aspects related to the personal contribution regarding the approached topic . These aspects are structured in seven chapters, which include experiences from 2019-2023, as well as conclusions and final recommendations. A total of 173 bibliographic sources were consulted for the Ph.D. thesis, with 130 of them originating from scientific literature available online up to the beginning of 2024.

Chapter 6 entitled **Material and working method** approaches the specific botanical aspects of the biological material used in the experiments. It also provides essential data for the uniqueness of ecological products, through their chemical composition, highlighting the action of molecules in the control of different pests and diseases to the plum specie. At the same time, a diagnosis was made of the evolution regarding the climatic changes that occurred during the study period at FRDS Bistrita. The data were correlated with the working methodology applied in plant protection, taking into account plant phenophases and the behavior of pests in the field. This chapter also presents all the details about the six experimental phytoprotection models tested which were developed. Some of the experiments were carried out in the field and some in the laboratory, depending on the pest studied. For the interpretation of the results obtained from the experimental model implemented in the field and in the laboratory, the phytosanitary standards for evaluating the degree of damage of diseases and pests were used. The standards are regulated by the General Directorate for Agriculture and Food, together with the Inspectorate for Plant Protection and Phytosanitary Quarantine.

Chapter 7 with the title **Results regarding the effectiveness of some ecological products in the control of apterous aphids (*Aphis* spp.),** all the results obtained during the study period from 2019 to 2021 are presented. The experience was carried out, both in the field and in laboratory. Within these experiments, the effects of eight ecological products were compared to five well-established chemical synthesis products, commonly used in conventional orchard pest control for aphids..

In field tests, remarkable overall results were obtained for two of the tested ecological products, with outcomes similar to those achieved by the conventional variant. Specifically, the ecological product Ovipron Top (concentration 2.5%) caused an average aphid mortality rate up to 96% over the three years of study, while the product Prev-AM (conc 0.5%) caused a mortality rate of up to 85%.

In the laboratory, Ovipron Top and Prev-Am, the two ecological products, achieved remarkable results, similar to those in the field of controlling aphids. Ovipron Top (conc. 2.5%) resulted in an aphid mortality rate up to 96.3%, while Prev-AM caused a mortality rate of 85%. The other tested products yielded modest results in both field and laboratory experiments.

The statistical interpretation carried out after applying the analysis of variance ANOVA and later the Duncan test, revealed that there are significant differences between the ecological products tested. The ecological products Ovipron Top and Prev-Am achieved remarkable results, being classified in the same significance group as those of chemical synthesis products. Thus, there are no significant differences between the two ecological products tested that proved effective and the conventional ones.

Chapter 8 is entitled **Determination of the repellent effects of some ecological products in the control of winged aphids (*Aphis* spp.).** The study was carried out for two years (2020-2021) and consisted in the determination the repellent effects of some ecological versus conventional products. In the experiment, six ecological/conventional products were tested over two months, from June to July, both in nursery and orchard conditions. The ecological products tested were: Konflic 0.3%, Deffort 0.3%, Oleorgan 0.3%, Laser 240 SC 0.06%, Algasil 0.5% and Prev-Am 0.8%.

In the nursery experiments, after two years of study, a significant reduction in the total number of captured winged aphids was demonstrated in both the conventional and ecological variants. The conventional variant recorded a decrease in the total number of captured winged aphids by up to 35% compared to the control variant, while the ecological variant recorded a decrease of 30%. Both conventional and ecological products showed a visible repellent effect against winged aphids in the nursery. The effect recorded during the study period (2020-2021) between the two treatment variants was similar.

The results obtained in the plum orchard demonstrated the existence of a repellent effect for both ecological and conventional products. The difference between the conventional variant and the untreated control variant was 21%, and between the ecological variant and the control variant, it was 13%.

Following statistical analysis, the results obtained during the nursery study period for the ecological and conventional variants showed no significant differences between the two treatment variants. In the orchard experiment, according to the data obtained and statistical interpretations, significant statistical differences were recorded between all variants. Thus, the conventional variant is classified as the most effective, followed by the ecological variant and the untreated control variant.

Chapter 9, titled **Field evaluation of the effects of some ecological treatments in the control of the plum pest *Eurytoma schreineri***, presents data regarding the control of the plum seed wasp after applying 11 ecological treatments throughout the plant's growing season. The tests were conducted on two plum varieties (Stanley and Reine Claude d'Althan). Besides the ecological variant, a conventional variant and an untreated control were also considered.

The overall results indicate a significant difference in the damage caused for the two plum varieties for all treatment variants. The Stanley variety was preferred by the pest, causing an frequency of the damage of up to 32% (in the untreated variant), whereas the Reine Claude d'Althan variety had only a 4% (in the untreated variant). The differences between the two varieties highlight the importance of choosing resistant varieties that are less attractive to pests when establishing a plum orchard.

Following statistical processing using the Duncan test, significant differences were identified among the treatment variants concerning the mean frequency of pest damage on the Stanley variety. Thus, the conventional variant is significantly more efficient than the ecological variant and the untreated control, while the ecological variant is significantly better than the untreated control. For the variety Reine Claude d'Althan, there are statistically significant differences between all treatment variants.

For the plum seed wasp, careful monitoring and timely intervention are essential to increase the effectiveness of applied ecological products. Additionally, agronomic disinfection methods for plum orchards are crucial for reducing pest populations.

Chapter 10 presents **Determination of the efficacy of some ecological products in control of the defoliating larvae from the order *Lepidoptera***. In the experiment were tested four ecological products in the laboratory to determine their efficacy in controlling *Lepidoptera* larvae on plum species.

The overall results obtained after two years of study (2020-2021) revealed that among the four products tested under laboratory conditions, Laser 240 SC (0.06%) achieved the best results. The product caused a mortality rate of up to 80% four days after treatment application. Bactospein DF (0.1%) was the second most effective product, causing a mortality rate of up to 31%. In future studies, the efficacy of Bactospein DF can be improved by adjusting the applied concentration, as it has a high potential for pest control.

Statistical interpretation of multi-annual data using the Duncan test regarding the efficacy of ecological products in controlling defoliating larvae demonstrated significant differences between the tested products. Thus, the ecological product Laser 240 SC proved to be the most effective solution, being significantly better compared to the other tested products. Bactospein DF ranked second among the tested products but showed modest results compared to the former product. The products Deffor and Konflict obtained significantly the weakest results, placing them in the lowest performance category.

The overall results demonstrate the efficacy of Laser 240 SC, placing it as a strong contender for controlling *Lepidoptera* pests. This product can be successfully integrated into ecological treatment programs, both as a standalone treatment and in combination with other phytosanitary products.

Chapter 11, titled **Effects of some ecological products in controlling monilinia (*Monilinia* spp.) on plum fruits**, presents the potential to control one of the most dangerous plum diseases using ecological products. The experiment was conducted in the field on two plum varieties, Stanley and Anna Spath, using two treatment variants: ecological and conventional, along with an untreated control. A total of 11 treatments were applied throughout the growing season.

After two years of study (2020-2021), the results revealed notable effects of the tested ecological products compared to the conventional ones for both plum varieties. For the Stanley variety, the overall results showed an infection frequency caused by brown rot on fruits of up to 12.43% for the conventional variant, 13.51% for the ecological variant, and 24.05% for the untreated control. Therefore, the efficacy of the ecological products is evident when compared to the conventional variant and the

untreated control. For the Anna Spath variety, the overall results showed an effectiveness of 7.85% for the conventional variant, 14.64% for the ecological variant, and 22.45% for the untreated control.

The statistical analysis of the overall data obtained in the control of brow rot revealed significant differences between the treatment variants. Following the application of the Duncan test, the data obtained for both plum varieties were grouped into two significance classes. Specifically, the ecological and conventional treatment variants were grouped in the same significance class, demonstrating that there were no statistically significant differences between these two. The untreated control variant was classified in a different significance category, showing statistically significant differences compared to the other two treatment variants.

The study conducted in the field during 2020-2021 highlighted the high efficacy of the applied ecological fungicides, Funres (0,3%), Mimox (0,3%), and Zytron (0,15%). These products have the potential to reduce brow rot infections on fruits during the growing season.

In **Chapter 12**, titled **Disease and pest control schemes for plums, in an ecological culture system, developed and applied in the period 2020-2023**, represents the final experimental model tested. It encompasses all the previously obtained results into a comprehensive, indicative ecological phytosanitary program. In the first phase, studies were conducted from 2020 to 2021, focusing on the effects of ecological treatment programs in controlling of major pest agents on two plum varieties (Stanley and Reine Claude d'Althan). In 2023, the experiment was expanded to incorporate all the knowledge accumulated from studies conducted both in the field and in the laboratory. The experiments included a parallel comparison with a conventionally treated variant and an untreated control variant to compare the results obtained with the ecological treated variant.

The results obtained in the two years (2020-2021) of study showed improvments year by year. The only issues encountered were related to the damage of *Eurytoma schreineri* and *Monilinia* spp., while differences were noted between the conventional and ecological treatments. By optimizing the treatment program based on the results obtained and increasing the total number of treatments applied during the growing season from 9 treatments in 2020 to 12 in 2023, most of the previously encountered issues were largely resolved.

Thus, in 2023, the results regarding the control of major plum pest agents were comparable to those obtained through conventional treatments. In 2023, for the first time, observations were made regarding the productivity of the Centenar and Anna Spath varieties for two treatment variants: ecological, conventional, and an untreated control. Remarkable results, close to the conventional variant, were obtained for both studied varieties under the ecological variant. The average production per tree for the Centenar variety was 22.53 kg for the conventional variant, 21.68 kg for the ecological variant, and 13.99 kg for the untreated control variant. For the Anna Spath variety, the average production per tree was 18.44 kg for the conventional variant, 16.53 kg for the ecological variant, and 12.17 kg for the untreated control. The statistical analysis of data obtained regarding the productivity of the Centenar and Anna Spath plum varieties revealed that there are no significant differences between conventional and ecological treatment variants.

The extended studies in 2023 revealed the high effectiveness of the ecological treatment scheme developed in the Ph.D. thesis, based on the results obtained from 2019 to 2023. Thus, the proposed treatment program can serve as an essential reference point for all farmers which opt for ecological plum cultivation. It can provide a foundation for strategies to manage phytosanitary issues in cultivation.

GENERAL CONCLUSIONS

- According to the multi-annual results obtained both in the field and in the laboratory, from testing eight ecological products for the control of wingless aphids, two products yielded outstanding results. The product Ovipron Top (paraffin mineral oil 800 g/l) caused a mortality rate of over 90%, while Prev-AM (orange mineral oil 60 g/l) caused a mortality rate of over 80%. These two ecological products can be successfully used in the control of wingless aphids on plums.
- The multi-annual results obtained in the nursery for plum specie regarding the repellent effect of some ecological products in the control of winged aphids confirm the existence of a visible repellent effect (Konflic 0,3%, Oleorgan 0,3%, Laser 240 SC 0,06%, Algasil 0,5%, Prev-AM 0,8%). The differences observed between the conventional and ecological treatment variants proved to be insignificant after statistical processing. Consequently, the experimental results indicate that the analyzed ecological products possess significant potential in repelling winged aphids through their olfactory properties. This suggests a possible application of these products in ecological control strategies for plum crops.
- According to the results obtained in the two years of study (2020-2021) regarding the control of the pest *Eurytoma schreineri*, the tested ecological contact products showed lower efficacy compared to conventional ones. The pest is difficult to control due to its mode of damage. The larvae localize inside the fruit, specifically within the seed, which prevents direct interaction with ecological products. To optimize pest control, it's crucial to apply treatment at the opportune moment when adult females begin laying eggs. Another important aspect is reducing the pest reservoir through agrotechnical disinfection measures, involving the collection and destruction of damaged and fallen fruits on the ground
- Based on the overall results obtained for the control of defoliating larvae from the order *Lepidoptera*, two ecological products showed visible efficacy. The product Laser 240 SC (spinosad 240 g/l) recorded the best efficacy, up to 85%, four days after treatment, while BactoSpeine DF (*Bacillus thuringiensis* extract) showed an efficacy of up to 31%. Laser 240 SC can be successfully used in ecological phytosanitary programs for controlling defoliating larvae from the order Lepidoptera in plum crops.
- The results regarding the effects of some ecological phytosanitary products have reduced infections caused by the fungus *Monilinia* spp. in the Reine Claude d'Althan and Stanley plum variety. Their efficacy was similar to those obtained with conventional treatments, with no significant statistical differences. Therefore, in addition to the copper-based products accepted in ecological farming, which are applied at the beginning of the vegetation period, the products Funres (extract of *Mimosa tenuifolia* 60% and citrus extract 20%), Mimox (80% extract of *Mimosa tenuifolia*), and Zytron (20% citrus seed extract) proved effective in controlling fungal infections on fruits.

- The final results from 2023 for the Centenar plum variety, which focused on the quality and productivity of the trees after applying the final form of the ecological phytosanitary program, were a real success. The average plum production per tree for the ecological variant was 21.68 kg (27.10 t/ha), while the conventional variant yielded 22.53 kg (28.16 t/ha). The differences between the two treatment variants are not statistically significant but are significant when compared to the untreated control, where the average production per tree was only 13.88 kg (17.35 t/ha).
- The final form of the ecological phytosanitary treatment program applied in 2023 also achieved outstanding results for the Anna Spath plum variety. The productivity results for this variety were similar to those obtained for the Centenar variety, although the yield was slightly lower due to varietal characteristics. The applied ecological indicative program recorded a production of 16.53 kg/tree (20.66 t/ha), while the conventional variant achieved a production of 18.44 kg/tree (23.05 t/ha). Significantly lower results were obtained in the untreated control, with an average production of 12.17 kg/tree (15.21 t/ha).
- The success of the ecological phytosanitary treatment program tested in 2023 for both the Centenar and Anna Spath varieties was also influenced by the careful and rigorous application of agrotechnical disinfection methods accepted in ecological farming. The effect of these sanitary agrotechnical methodologies reduced the reserve of diseases and pests. The final results obtained represent a valuable resource that "fill a gap" in the specialized literature, providing farmers with crucial information for the successful and effective control of major parasites in ecological plum crops.

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