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Shahini, Shpend
Department of Plant Protection, Agricultural University of Tirana

Mustafaj, Silvana
Department of Mathematics and Informatics, Agricultural University of Tirana

Sula, Ueda
Department of Plant Protection, Agricultural University of Tirana

Shahini, Ermir
Department of Economic Sciences, Aleksander Moisiu University

他

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Biological Control of Greenhouse whitefly *Trialeurodes vaporariorum* with *Encarsia formosa*: Special Case Developed in Albania

Shpend Shahini[1*], Silvana Mustafaj[2], Ueda Sula[1], Ermir Shahini[3], Eugen Skura[4], Fatbardh Sallaku[1]

[1]Department of Plant Protection, Agricultural University of Tirana, Tirana, Albania

[2]Department of Mathematics and Informatics, Agricultural University of Tirana, Tirana, Albania

[3]Department of Economic Sciences, Aleksander Moisiu University, Durrës, Albania

[4]Departament of Environment and Natural Resources, Agricultural University of Tirana, Tirana, Albania

*Author to whom correspondence should be addressed:
E-mail: shahinishpend3@gmail.com

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Abstract: The purpose of this study was to assess the effects of biological and non-biological methods of controlling pests of agricultural plants in the Mediterranean region based on open data. During the study, analysis methods and comparison of selected studies on pest management were used. Additionally, a synthesis was performed to identify the optimal methods that are both highly effective and environmentally conscious for controlling these pests. The chosen studies provided a dataset on control application methods, precise quantities, usage conditions, timing details, and corresponding efficiency percentages. As a result, it was determined that the potential of *Encarsia formosa* as a promising biological agent for the control of the greenhouse whitefly. Additionally, it was found that many pests of fruit and vegetable crops are characterized by seasonal activity peaks. Thus, the optimal timing of biological control is key to success. It was suggested that the seasonal inoculative release of *Encarsia formosa*, combined with the active use of traps and the limited use of insecticides, is the most effective sustainable method of controlling the greenhouse whitefly. From a practical point of view, this study offers an optimal approach to the use of *Encarsia formosa* as a biological pest control method for agriculture in the Mediterranean region.

Keywords: sustainable agriculture; insect pests; insecticides; inoculative release; vegetable cultures

1. Introduction

The greenhouse whitefly (*Trialeurodes vaporariorum*) is a polyphagous hemipteran insect, which poses a significant challenge to greenhouse horticulture and agricultural systems globally due to its rapid reproductive rate, high fecundity, and ability to transmit plant infections. With increasing global awareness of the need for sustainable agricultural practices, finding effective and ecologically friendly methods to manage pest populations is crucial. B.P. Baker et al. showed that conventional chemical control methods have several limitations, including the emergence of pesticide-resistant populations and adverse effects on beneficial non-target organisms and the environment[1)]. Consequently, there is an escalating interest in investigating sustainable, biologically-based alternatives for effective greenhouse whitefly management.

One of the most significant advantages of biological control is its minimal impact on the environment. According to S.G. Seabra et al.[2)], unlike chemical pesticides, which can persist in the ecosystem and harm non-target organisms, biological control agents are often highly specific to their target pests, reducing the risk of collateral damage to beneficial insects, wildlife, and the broader ecosystem. Biocontrol offers a sustainable, long-term solution for pest management. S. Panno et al. showed that when implemented correctly, it can establish a natural balance between pests and their predators or parasites, leading to a self-regulating system that requires less intervention over time[3)]. P. Bielza et al. demonstrated that once established, some biological control agents can reproduce and persist in the environment, reducing the need for repeated applications which can lead to cost savings for farmers[4)]. According to F. Acheuk et al.[5)], pests can develop resistance to chemical pesticides over time, rendering them less effective. In contrast, the dynamic nature of biological control agents, with their diverse modes of action, makes it less likely for pests to develop resistance against them, ensuring more reliable long-term control. L. de Pedro et al. showed that biological control can be effectively integrated with other pest management strategies, such as cultural practices, physical barriers, and genetic resistance[6]. This integrated approach, known as Integrated Pest Management (IPM), optimizes pest control while minimizing environmental impact and economic costs.

Among the various natural enemies under scrutiny, the parasitic wasp *Encarsia formosa* has garnered considerable attention as a useful biocontrol agent, offering a sustainable solution to the greenhouse whitefly infestation predicament. There are mounting concerns about the environmental repercussions of chemical insecticides and the escalating demand for sustainable agricultural practices. According to C.-S. Chen et al.[7], the deployment of biological control through the parasitic wasp *Encarsia formosa* emerges as an ecologically prudent, economically viable, and highly efficacious approach to curtail the greenhouse whitefly population. A comprehension of the intricacies of this biocontrol system is essential for researchers, horticulturists, and farmers, as it is prospective in mitigating the devastation caused by this pest while fostering a more sustainable and resilient future for crop cultivation.

This study has the potential to alleviate economic losses by providing growers with an efficient and cost-effective means of controlling whitefly populations, ultimately leading to enhanced crop productivity and profitability. The adoption of *Encarsia formosa* as a biological control agent supports the conservation of natural predators and parasitoids in agroecosystems. By reducing the need for chemical pesticides, the study contributes to maintaining a balanced ecosystem where beneficial insects play a vital role in pest regulation. In this regard, the purpose of this study was to analyze the biological control methods common in Albania in order to determine the optimal methods for applying *Encarsia formosa* as a biological control. The objectives of the study included finding sources that focused on pest control, selecting the most effective approaches to applying biological control methods, comparing them with non-biological methods, and predicting the optimal way to use *Encarsia formosa* to control *Trialeurodes vaporariorum*.

2. Materials and Methods

Data for the study were collected from open sources, such as scientific articles, books, and publications related to biological pest control in Albania. The search was conducted using electronic databases: Google Scholar, Scopus, and Web of Science, utilizing relevant keywords such as “agricultural pests”, “greenhouse plants”, and “biological control”. Inclusion criteria for the analysis were as follows:

– studies focused on pest control methods for berry and vegetable crops;
– statistical analysis of results was carried out;
– control methods were studied for at least two years;
– the research was conducted in Albania

Studies not in English, meta-analyses, or not meeting statistical significance criteria were excluded. An initial review of study titles and abstracts was performed to determine eligibility, obtaining and further assessing full-text articles of potentially relevant studies. Data extraction from each included study encompassed details such as authors, publication year, study design, crops tested, pests, control methods used, and the effectiveness of their implementation. Methodological quality and risk of bias in the studies were independently assessed by two reviewers using predefined criteria, which considered study design, reporting clarity, and potential sources of bias. The analysis included three selected sources[8-10]. The study utilized data from vegetable and fruit crops grown in Albania to describe various approaches to biological pest control. Data were extracted on the methods of reproduction of *Encarsia formosa* individuals, optimal conditions for their reproduction and parasitism, the number of individuals for inoculation, methods and timings of inoculation, as well as the effectiveness of various methods. Information on the effectiveness of the applied methods was gathered from sources that provided data for at least two years.

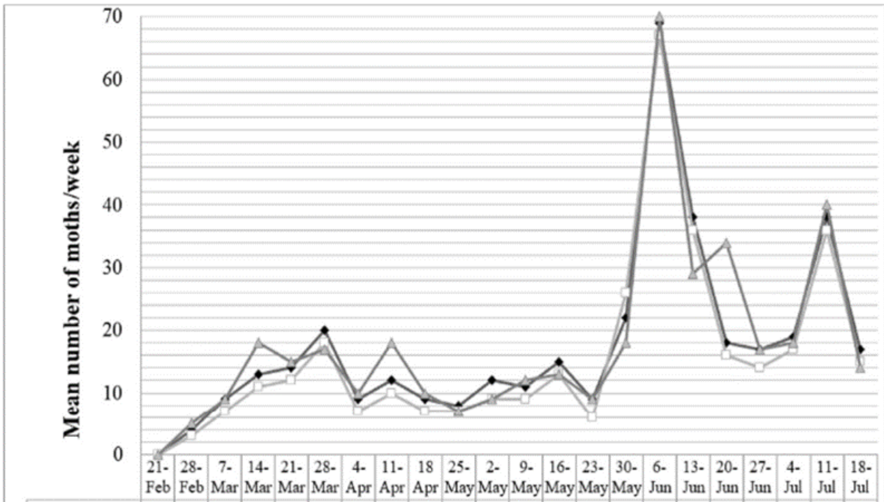
This study was focused on exploring different strategies for biological pest control in Albanian greenhouse plants, comparing them with non-biological methods. Methods included analyzing different pest control methods, comparing them and synthesizing the most successful techniques. Throughout the research, various aspects of pest control methods for vegetable and fruit crops were considered, including implementation techniques, factors influencing their success, identifying optimal ways for biological control, and assessing their limitations. Comparative analysis was conducted to assess pest control approaches based on effectiveness, environmental friendliness, ease of use, and long-term impact.

The results obtained by various researchers were compared, on the basis of which the synthesis of the most effective and environmentally friendly methods of biological control, as well as the features of their implementation, was carried out. The paper specifically discussed the potential use of the parasitic wasp *Encarsia formosa* to combat the greenhouse whitefly *Trialeurodes vaporariorum*. This analysis involved examining results from previous studies and practical experiences related to biological and non-biological pest control methods for vegetable and fruit crops. Additionally, the main advantages and risks associated with using biological control methods in comparison to alternative options were identified. By following these methodologies, the analysis aimed to provide a robust and evidence-based assessment of the efficacy of *Encarsia formosa* as a biological control agent for greenhouse whitefly management, elucidating its potential as a sustainable approach to pest control.

3. Results

3.1 Analysis of pest control methods in Albania

The study conducted by S. Shahini et al. endeavors to outline the oscillations in T. absoluta populations over the course of three consecutive years during the winter-to-summer cultivation period within a greenhouse setting[8)]. The surveillance of population fluctuations was facilitated by Delta traps imbued with pheromones, which also aided in pinpointing the optimal treatment window. The dynamics of the pest population found by the researchers are shown in Fig. 1.



	21-Feb	28-Feb	7-Mar	14-Mar	21-Mar	28-Mar	4-Apr	11-Apr	18 Apr	25-May	2-May	9-May	16-May	23-May	30-May	6-Jun	13-Jun	20-Jun	27-Jun	4-Jul	11-Jul	18-Jul
YEAR I	0	4	9	13	14	20	9	12	9	8	12	11	15	9	22	69	38	18	17	19	38	17
YEAR II	0	3	7	11	12	18	7	10	7	7	9	9	13	6	26	67	36	16	14	17	36	15
YEAR III	0	5	9	18	15	17	10	18	10	7	9	12	13	9	18	70	29	34	17	18	40	14

Fig. 1: Seasonal fluctuations in the population of T. absoluta.

Source: [8].

The efficacy of mass trapping, along with treatments involving Indoxacarb and *Bacillus thuringiensis* (Bt), was assessed in terms of their capacity to maintain pest populations below the threshold for economic harm. Many control methods, such as biological control agents or certain cultural practices, may have a broader spectrum of activity, targeting multiple pest species. By comparing their effectiveness across different pests, resource allocation and decision-making can be optimized. In addition, the study looked at the effects of chemical pesticides such as indoxacarb as well as other control practices such as traps. Understanding the effectiveness of these techniques is essential to predict the success of biological control of *Trialeurodes vaporariorum* using *Encarsia formosa*. Shahini et al. showed that over the course of the three consecutive years, the infestation levels detected in the leaves of control plants surpassed those observed in the treatment groups[8]. Across all trials, the extent of leaf damage exhibited a notable decrease, amounting to approximately 48%, 31%, and 52% reduction through the application of mass trapping, Bt, and Indoxacarb, respectively. Other tests have also demonstrated less effective biological control than alternatives. However, when contrasted with the outcomes of individual treatments, the synergistic use of two methods (mass trapping combined with Bt) demonstrated a remarkable enhancement in efficacy, ranging from 1.5- to 2.5-fold. Similarly, the fusion of mass trapping with Indoxacarb showcased a 1.8-fold escalation in effectiveness, relative to the effects of the treatments when implemented independently. Thus, the results obtained by the researchers showed that despite the relatively low efficiency of biological control, in combination with other methods, it has a significant negative impact on the pest population. The use of a combination of biological and non-biological control methods in the analyzed study was more effective than a combination of different non-biological methods, as well as their separate implementation.

Another study by S. Shahini et al. presents the outcomes of an experiment conducted within a vineyard situated in Durres, Albania, spanning the years 2004 to 2006[9)]. The primary objective was to assess the efficacy of two distinct strains of *Bacillus thuringiensis* Berliner, namely vars kurstaki and aizawai, in combating the grapevine pest, *Lobesia botrana*. This moth is known to inflict significant damage to grapevines. The experimental findings unveiled a substantial increase in effectiveness for both strains when compared to the control group. Furthermore, the application of *Bacillus thuringiensis* offered enhanced protection for grape bunches during the second generation, in contrast to the third generation. This discrepancy underscores the relatively brief duration of action of the active ingredient, indicating its limited persistence over time. In summary, their findings strongly support the efficacy of biological methods of pest control in managing the grapevine moth across both its second and third generations, highlighting its pivotal role in pest control. The utilization of pheromone traps emerged as indispensable for monitoring insect flight activity, aiding in identifying optimal timings for Bt treatments. The researchers found that there are peaks in moth activity during certain months, as shown in Fig. 2.

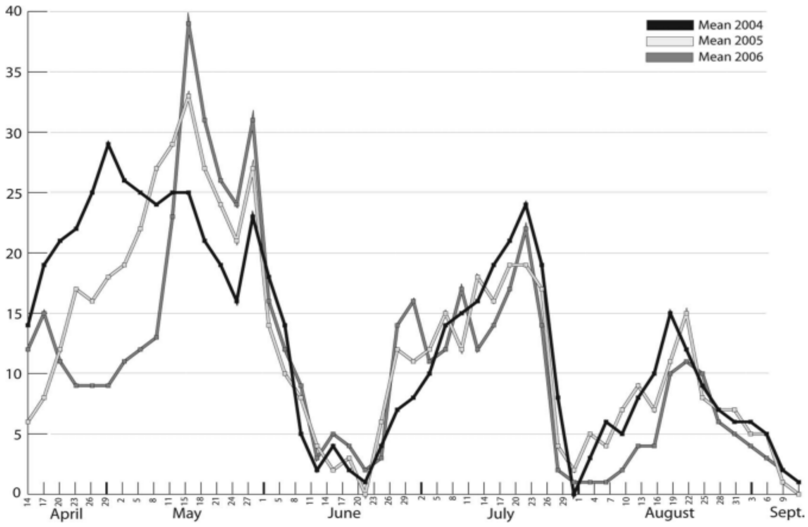


Fig. 2: Seasonal fluctuations in the population of grapevine moth

Source: [9].

However, it is important to note that population levels did not consistently correlate with the levels of damage. Interestingly, investigation of the researchers revealed a lack of significant variation between the damage caused by the third generation and that of the second. This phenomenon was attributed to a complex interplay of factors. On one hand, reductions in vegetative and reproductive growth created a less conducive micro-climate for the third generation's development. The thinner skin of ripened grapes rendered them more vulnerable to damage from the third generation. Furthermore, their study underscores the influence of cultural practices, such as leaf removal enhancing grape coverage with Bt, as well as favorable weather conditions and precise treatment timing. These factors collectively contribute to the efficacy of biological control. The impressive success of Bt should serve as a catalyst for broader adoption of environmentally friendly methods and biological products in vineyard management practices across Albania. Thus, the research analyzed emphasizes the effectiveness of biological methods of controlling insect pests, and also demonstrates the higher efficiency of using combined control methods.

The objective of the study by E. Kullaj et al. was to evaluate a control strategy suitable for Albanian climate conditions, aiming to reduce the quantities of copper permissible in organic viticulture[10)]. This strategy revolved around the application of copper oxychloride, employing varying doses and intervals between applications. The effectiveness of this control approach was gauged through the assessment of disease incidence and severity in both grape leaves and bunches. The products employed demonstrated competent control particularly when facing moderate disease pressure. Notably, the study revealed that during seasons characterized by a minimal incidence of downy mildew attack, it was feasible to manage the fungus while adhering to the limitations stipulated by organic regulations. However, during periods of elevated fungal pressure, particularly in humid and rainy seasons, meeting these restrictions became unattainable[11)]. Thus, by opting for copper-alternatives during periods of intermediate or low downy mildew infection, growers can effectively curtail their reliance on copper in organic viticulture practices. Experiments have revealed significant insights regarding the management of downy mildew. When confronting periods characterized by low downy mildew pressure, the oomycete can be effectively suppressed. Conversely, during times of heightened *P. viticola* pressure – particularly in humid and rainy seasons. Even the use of commercial formulations featuring low copper doses fails to ensure compliance with the established limit. Additional experiments have underscored the impact of microclimate on the initial germination and epidemiology of downy mildew. These complexities suggest a compelling need to explore alternative products suitable for Mediterranean conditions. This underscores the recommendation that in organic viticulture, the use of non-biological pest control methods can be minimized by opting for alternatives during periods of intermediate or low infection. Careful selection is essential to avoid potential phytotoxic effects. All analyzed studies indicate the presence of specific periods of pest activity, as well as the importance of the timing of pest control measures[12)].

3.2 Technique and prospects for the use of *Encarsia formosa* against *Trialeurodes vaporariorum*

The optimal approach for the technology of parasite mass breeding involves adopting the standard reproduction method used for *Encarsia formosa* on bean or tobacco plants. During the autumn-winter period, this insect proves effective in controlling outbreaks of greenhouse whitefly on tomato and cucumber plants. The introduction of the parasite should be initiated at the first sign of pest infestation at any life stage (adults, eggs, larvae). The quantity of released *Encarsia formosa* individuals should be maintained at roughly 2-3 times the whitefly population. A subsequent re-release, about 8-10 days later, of 4-5 individuals per 1 m^2 across the greenhouse area is highly recommended. Data analysis suggests that following two rounds of parasite introduction within 29-35 days, pest suppression efficiency can reach up to 70%. Ongoing monitoring is essential post *Encarsia formosa* colonization to assess the insect's search capabilities. Analysis indicates that female parasites are capable of migrating up to 4-6 meters in search of hosts. Roughly 40-50 minutes post-release, they initiate the search for greenhouse whitefly larvae by flying short distances (0.5-0.8 m). *Encarsia formosa* demonstrates a preference for settling on leaves of whitefly-infested cucumber and tomato plants. On average, within 40 days, parasite density within host colonies doubles, leading to an efficiency increase of up to 80%. Notably, higher fecundity of this insect is observed under conditions of ample illumination and extended daylight hours (up to 16 hours).

The physical characteristics of plants affected by whiteflies can significantly influence the reproductive capacity and search efficiency of parasites. Leaf hairiness in gerberas, eggplants, and certain cucumber varieties can hinder parasites' quick detection of their hosts. Additionally, the presence of abundant honeydew secretions from the pests on leaves reduces *Encarsia formosa* effectiveness, as female parasites allocate a considerable portion of their time to grooming their legs, wings, and bodies. A common scenario for farmers involves the emergence of a complex of sap-sucking pests, such as spider mites, aphids, and whiteflies, within the same greenhouse crop. In such instances, the efficiency of biological control typically remains below 50%. To address this, a substantial infestation of 3-5 whiteflies per plant triggers mass *Encarsia formosa* colonization, following a release ratio of 1:8 or 1:10. A subsequent re-introduction of the parasite after 10-12 days ensures stable whitefly population regulation, resulting in an efficiency range of 80% to 90% based on analyzed data.

In industrial greenhouse settings, there are three primary methods of parasite colonization:

– spreading pupae from cucumber, tomato, or tobacco leaves in a thin layer inside Petri dishes, strategically placed for parasite emergence;
– positioning leaves containing parasite pupae within whitefly hotspots, with infection rates of 95-98%;
– affixing pupae from tobacco, cucumber, or tomato leaves onto cardboard and suspending them in areas affected by the pest.

The latter method yields the highest efficiency in focal pest areas, with parasite losses remaining minimal (2-3% of the total colonized *Encarsia formosa* pupae). Notably, a uniform dispersion of the parasite across whitefly-infested zones is also observed. This approach achieves a biological control efficiency of 92-95%. For biomaterial acquisition, asparagus beans are employed under production conditions, generating the requisite number of encarsia pupae within 50-52 days. In the autumn-winter period, cultivating whitefly-free vegetable crop seedlings in greenhouse plants proves challenging. Consequently, a sufficient quantity of biomaterial is essential for pest control. During December-January, *Encarsia formosa* development and search capabilities are impeded due to fluctuating temperature conditions. However, by late February and March, optimal daylight hours and favorable temperatures restore parasite activity.

The seasonal inoculative release method is a specific approach within the realm of biological control. It involves the intentional introduction of beneficial organisms into an agroecosystem during specific seasons to manage pest populations. This method is particularly useful in situations where the target crop's lifecycle is relatively short, such as in greenhouses or short-term crops, and where continuous, long-term biological control is not feasible. Beneficial organisms are released into the agroecosystem for a defined period, often corresponding to the cropping season. The releases are strategically timed to coincide with the presence of the pest or at stages of the pest's life cycle when it is most vulnerable. The method is well-suited for crops that have relatively brief growth cycles, typically lasting between 6 to 12 months. In such cases, it may be challenging to establish a self-sustaining population of natural enemies over the long term. The goal of the seasonal inoculative release method is to achieve both immediate control of the current pest population and the establishment of a natural enemy population that can provide ongoing control throughout the cropping season. The number of beneficial organisms released may be higher than in the classical inoculative release method, aiming to have a more rapid and substantial impact on the pest population due to the shorter duration of the crop. The seasonal inoculative release method is often integrated with other pest management practices, such as cultural controls, use of resistant crop varieties, and limited pesticide use. This comprehensive approach enhances the overall effectiveness of pest management. The analyzed data indicate that the seasonal inoculative release method is the most optimal strategy for the biological control of greenhouse whitefly *Trialeurodes vaporariorum* using *Encarsia formosa*. For many pests in the Mediterranean region, fluctuations in their activity are observed in different seasons. Comprehensive use of biological control methods, coupled with alternative methods such as pesticides, is appropriate at peaks in *Trialeurodes vaporariorum* activity. At other times, pest control measures may be lowered, leading to more sustainable farming.

4. Discussion

The present study aimed to evaluate the effectiveness of using the parasitoid wasp *Encarsia formosa* as a biological control agent against the greenhouse whitefly *Trialeurodes vaporariorum*. In both natural ecosystems and agroecosystems that refrain from using pesticides, or adopt a selective approach, a diverse community of natural enemies typically functions to maintain whitefly populations at very low levels. The use of biological control agents has gained significant attention as an eco-friendly alternative to chemical pesticides in managing agricultural pests. The synthesis of available studies sheds light on the potential of *E. formosa* as a valuable tool in integrated pest management strategies targeting the greenhouse whitefly. The collective findings of the studies analyzed consistently suggested that seasonal inoculative release of *E. formosa* has a notable potential in controlling *T. vaporariorum* populations within greenhouse environments. This outcome aligns with previous individual studies that have reported the parasitic activity of *E. formosa* in reducing specific stages of the whitefly. The research conducted by Deeksha et al. was focused on optimizing the use of *E. formosa* against *Trialeurodes vaporariorum*[13]. It showed that the rate of parasitization was notably influenced by the developmental stage of the greenhouse whitefly, the specific host plant, and the ratio of hosts to parasitoids. This is consistent with findings regarding the importance of creating the correct parasite-to-pest ratio at target pest development periods. Researchers showed that the parasitism of *E. formosa* was more effective on whitefly nymphs of the third and fourth instars. This resulted in a reduction in development time[14]. This phenomenon highlights the preference for *E. formosa* biological control against the third and fourth instars of *Trialeurodes vaporariorum*. This observation is consistent with the results of a study by J. Huang et al.[15], who also indicated that the third, fourth, and transitional stages of whitefly development are preferred for the most successful parasitism. This contributed to the highest rate of emergence of *E. formosa* and the highest survival of parasitoids.

Current analysis also revealed that certain factors could influence the efficacy of *E. formosa* as a biological control agent. First, the timing of introduction appeared to be a crucial factor. According to F. Wan et al.[16)], *E. formosa* grown on both T. *vaporariorum* and *Bemisia tabaci* showed a preference for oviposition on third instar nymphs when all four instar nymphs were offered at the same time. This suggests that timely deployment of *E. formosa* could enhance its establishment and impact on whitefly populations[17)]. The study by L.Z. Hua et al. was completed within 18 weeks, which is approximately equivalent to two generations of whiteflies[18)]. These scientists concluded that biological control was effective. However, it is important to note that their research did not cover the full commercial production cycle, which typically takes almost a year. Therefore, in order to reliably evaluate the effectiveness of biological control, it is necessary to carry out experiments in greenhouses covering the entire period of commercial crop production.

Second, variations in environmental conditions within different greenhouse settings could affect the success of *E. formosa* establishment and activity. M.-J. Li et al. showed that factors such as temperature, humidity, and plant species may influence the survival and reproductive capacity of the parasitoid[19)]. Therefore, it is essential to tailor biological control strategies to specific greenhouse conditions to optimize the efficacy of *E. formosa*. L.Z. Hua et al. set the temperature control parameters at 7ºC at night[18)]. Calculations show that, depending on the length of the day, this leads to an average daily temperature of 11.6ºC at the beginning and 13.1ºC at the end of the experiment. R. De Vis and J. van Lenteren conducted a similar study in greenhouse conditions, where the temperature was much higher[20)]. However, in their experiment, nighttime temperatures in most cases were between the threshold temperatures for *E. formosa* (11.4ºC) and *T. vaporariorum* (7.5ºC), according to T. Wang et al.[21)]. Under such conditions, *E. formosa* had a pronounced advantage over *T. vaporariorum*.

The integration of *E. formosa* with other pest management strategies holds promise for maximizing its impact on *T. vaporariorum* populations. L. Ons et al. showed that combining biological control with cultural practices, such as pruning and sanitation, and compatible chemical interventions could lead to a synergistic effect in reducing pests' infestations[22)]. Additionally, according to M. Pérez-Hedo, C. Riahi and A. Urbaneja the use of *E. formosa* in conjunction with other natural enemies, such as predators and entomopathogens, could create a more comprehensive and resilient pest management program[23)]. The study by A. Chailleux et al. demonstrated that inoculative release of *E. formosa* increased the effectiveness of non-biological pest control methods such as insecticide application and mass-trapping[24)]. Thus, the conclusions about the prospects of using this parasitoid as an element of integrated control are confirmed by the researchers' data.

While the current study highlights the potential of *E. formosa* as an effective biological control agent against *T.*

vaporariorum, several challenges remain. The effectiveness of *E. formosa* might be compromised in situations where chemical pesticides are still in use, as these substances can negatively impact parasitoid populations[25)]. Moreover, the potential for resistance development in whitefly populations over time raises concerns about the long-term sustainability of this approach. Future research endeavors should focus on addressing these challenges and refining our understanding of *E. formosa* ecology and behavior within greenhouse systems. Investigating the interaction between *E. formosa* and other pest control methods, as well as optimizing release rates and timing, could lead to enhanced pest suppression. Long-term studies assessing the persistence and efficacy of *E. formosa* under different greenhouse conditions will provide valuable insights into its role as a reliable component of integrated pest management strategies.

This study, while shedding light on the potential of *Encarsia formosa* as a biological control agent in Albania, has several limitations. First, it largely focuses on the greenhouse whitefly *Trialeurodes vaporariorum*, potentially neglecting other pests and interactions that might affect the results. Moreover, the effectiveness of biological control methods was analyzed predominantly in the context of the Mediterranean region, which may not be generalizable to other regions or climatic conditions. Additionally, while various biological control methods were discussed, the study does not deeply investigate the full spectrum of factors influencing the efficacy of *E. formosa*, including potential resistance among pests and interactions with pesticides.

5. Conclusions

In this study, the main approaches to pest control in Albania were analyzed, as well as the optimal conditions for the use of *Encarsia formosa* against *Trialeurodes vaporariorum* were established. It was found that, despite the fact that biological control methods are less effective than conventional methods when applied separately, their effectiveness is maximum when they are used in an integrated manner. This study underscores the potential of *Encarsia formosa* as a promising biological control agent for managing the greenhouse whitefly *Trialeurodes vaporariorum*. It was found that for many pests of fruit and vegetable plants there are seasonal peaks of activity. Various methods of biological control were considered, such as inoculative release, inundative release, and seasonal inoculative release. The obtained results indicate that the timing of biological control is crucial. The data suggest that seasonal inoculative release of *Encarsia formosa* in a pile with mass use of traps and limited use of insecticides is the most optimal method of greenhouse whitefly control from the point of view of long-term agriculture.

The obtained data are of practical importance for understanding the prospects for the application of biological control methods in the Mediterranean region, as well as the factors affecting their effectiveness. However, careful consideration of factors influencing *E. formosa* efficacy, as well as challenges associated with resistance and pesticide interactions, must guide future research and practical applications. Further practical studies of direct methods of applying this biological control and its interaction with other methods are necessary. By harnessing the strengths of *E. formosa* and addressing its limitations, farmers can develop more sustainable and environmentally friendly solutions for greenhouse pest management.

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