Economic implications of integrated pest management against the tomato pinworm on Crete

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Οικονομικές επιπτώσεις της ολοκληρωμένης διαχείρισης εντόμων κατά του σκουληκιού της τομάτας στην Κρήτη

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Keywords:	tomato cultivation, *Tuta absoluta*, tomato pinworm, integrated pest management, business as usual, cost-benefit analysis, sustainable agriculture, Crete

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Abstract

Managing the tomato pinworm, *Tuta absoluta*, on Crete, Greece, is essential given the critical role of tomato production for the agricultural economy of Crete. Effective pest management should ensure sustainable practices and minimize economic losses. Pest management against the tomato pinworm is, however, often performed with business as usual methods and professional advisory assistance for integrated pest management is rare.

This study compared the impacts of business as usual management where pest management is based on the traditional methods that farmers use and advised pest management in which pest management follows expert instructions and recommendations to reduce the use of insecticides, through a cost benefit analysis conducted across twelve greenhouses in Ierapetra and Tympaki, with the aim to determine the effectiveness and sustainability of these approaches in tomato cultivation. Results showed that greenhouses utilizing professional advisory services had significantly lower overall cultivation costs and specific expenses related to the tomato pinworm management compared to those following business as usual. Although costs in advised pest control greenhouses were lower this did not affect profits. Furthermore, farms receiving expert advice adopt more environmentally friendly practices, such as the use of pheromone traps to monitor pest densities and the use of natural enemies for biological control, which contribute to sustainable agricultural outcomes.

These findings underscore the importance of integrating expert advice into pest management strategies as the adoption of such practices enhanced pest control efficiency. The knowledge acquired from this study should reach farmers, policymakers, and agricultural advisors, to raise awareness for a change in tomato production on Crete and beyond towards more sustainable, productive, and economically viable agricultural practices. Finally, this study contributes to the larger discourse on sustainable development in agriculture, for which the adoption of innovative solutions is needed in order to face new challenges posed by agricultural pests.

Keywords: tomato cultivation, *Tuta absoluta*, tomato pinworm, integrated pest management, business as usual, cost-benefit analysis, sustainable agriculture, Crete

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Abbreviations

ADV	Advised
AGRO	Agricultural
AMITON	Mediterranean International Association of the Processing Tomato
BUA	Business as Usual
CBA	Cost Benefit Analysis
EUREPGAP	Euro-Retailer-Produce GAP
FAOSTAT	Food and Agriculture Organization Statistical Data
GH	Greenhouse
GAP	Good Agricultural Practices
IPM	Integrated Pest Management
ToMV	Tomato mosaic virus
TBSV	Tomato bushy stunt virus

1. Background

1.1 Introduction

The cultivation of tomatoes is associated with many challenges worldwide, with pests and pest management increasing production costs and reducing yields (Ramasamy & Ravishankar, 2018). *Tuta absoluta* (Meyrick,1917) (Lepidoptera, Gelechiidae), commonly known as tomato pinworm is among the most important tomato pests and presents a high economic threat due to its feeding habits and fast reproductive cycle (Pandey et al., 2023; Roditakis et al., 2015). In this regard, effective pest management strategies are required on Crete, a region of Greece where tomato cultivation plays a crucial role for the agricultural economy (Kokkinakis et al., 2007), to reduce the losses inflicted by the tomato pinworm and guarantee sustainale production systems (Desneux et al., 2022; Pandey et al., 2023; Roditakis, Skarmoutsou, Staurakaki, et al., 2013).

Tomato pinworm management involves various management approaches, such as the use of conventional insecticides (Desneux et al., 2022) but also integrated pest management (IPM) systems with an emphasis on biological control and using fewer insecticides (Sanchez et al., 2014). Integrated pest management, has attracted attention because it can provide pest control while minimizing the environmental impact of cultivation and the development of pesticide-resistant pest populations (European Comission, n.d.).

In regions like Crete, where tomato cultivation is significant, implementing effective pest management strategies is essential not only for maintaining production but also for economic sustainability (Tayang et al., 2023). Greenhouses that integrate professional advisory services for integrated pest management might experience fewer production losses and more consistent yields due to improved pest management. Furthermore, such advisory services can aid in optimizing pest management costs, possibly leading to reduced overall cultivation expenses (Kountios et al., 2023).

Moreover, the overall profitability of tomato cultivation can be influenced by the choice of pest management strategy (Akter et al., 2016). Greenhouses utilizing advisory services with regards to integrated pest management instead of using chemical control could be more profitable by balancing the costs of pest control with the benefits of reduced damage and higher yields (Akter et al., 2016; Midingoyi et al., 2019).

The focus of this study is on the economic evaluation of different pest management strategies against the tomato pinworm in tomato cultivation on Crete. Specifically, benefits, indirect and direct costs associated with pest damage were compared between farms using professional advisory services for integrated pest management of the tomato pinworm and farms following a business as usual pest control strategy. This evaluation will help farmers, policy makers, and agricultural advisors in their work for optimizing production by considering economic viability and environmental sustainability.

1.2 Tomato

Tomato (Solanum lycospersicum Linnaeus, 1758) together with potato, eggplant, and paprika belongs to the family of Solanaceae. Being one of the most important crops, in 2022, approximately 186 million tons of fresh fruit from about 4.6 million hectares were produced worldwide (*FAOSTAT*, n.d.). China is the leading producer of tomatoes in the world, whereas in the Mediterranean basin Turkey, Egypt Italy, and Spain remain the main producers of tomato (*FAOSTAT*, n.d.).

Tomato originates from the Andes in South America and has been present in Europe since the 16th century (Dam et al., 2005). Although it is referred to as a vegetable, tomato botanically is a fruit (Gould, 1992). Tomato has great nutritional value containing minerals, vitamins, and dietary fibers, which are useful for the human body. Tomatoes, especially red ones are full of lycopene, an antioxidant that could be used by the organism for protection against carcinogenic substances (Dam et al., 2005).

In total there are three main types of tomato plants:

1. Tall or indeterminate type
2. Semi-bush or Semi-indeterminate type
3. Bush or determinate type

Tall, indeterminate plants are more productive because they keep growing and producing fruit continuously after flowering. In contrast, bushy, determinate plants stop growing after flowering, produce fruit for only two to three weeks, and ripen faster (Dam et al., 2005).

Tomato requires productive soils with good drainage and a warm climate. Factors, such as plant vigor, insect pest control, and climatic conditions also play a role in tomato production as well as choosing the right variety to grow (Gould, 1992). Field conditions are also important. Maintaining and creating uniform soil conditions, weed control, and irrigation during limited rainfall are essential. Additionally, fertilizers and transplanting solutions can promote healthy and high-yield growth of the cultivation (Gould, 1992). Furthermore, crop rotation, protected cultivation such as greenhouses, and sanitation practices, are used as methods to protect the cultivation from pests, pathogens, and unfavorable climatic conditions (Dam et al., 2005). Using greenhouses provides optimal growing conditions, which allows for year-round tomato production, unlike open field cultivation which is seasonal (Jensen, 1997).

1.2.1 Tomato production in Greece

Tomato cultivation is an important agricultural activity in Greece with a significant contribution to its economy (Sanchez et al., 2014). Based on the most recent data, Greece in 2022 produced, 752.510 tons of tomatoes on 9,430 hectares (*FAOSTAT*, n.d.). Tomatoes are used both fresh but also for processing (Kakabouki et al., 2021). Sauces, juices, and other canned products are being produced for consumption (Roussis et al., 2023). Greece is part of the Mediterranean International Association of the Processing Tomato (AMITOM) (Kakabouki et al., 2021).

The Mediterranean climate in Greece provides suitable conditions not only to grow tomatoes but also to enhance their quality (Sanchez et al., 2014). Tomato crops in Greece, are demanding in terms of water and nitrogen fertilization, which are crucial for plant growth and fruit quality (Kakabouki et al., 2021). Greek tomatoes are known for their rich flavor and color which makes them appealing and are exported to various countries (Ehler, 2006). Cultivation is being done both in open fields, as well as in greenhouses to extend the growing season, but also to protect the crop from unfavorable weather conditions (Sanchez et al., 2014). For greenhouse cultivation, there are two main growing seasons for tomatoes in Greece, with specific timelines for sowing, transplanting, and harvesting. The first one starts at the end of August or early September until December, whereas the second growing season starts mid November to early December, until early April or late June (Michalis et al., 2023).

In Greece, pest management in tomatoes is crucial for crop protection. The use of chemicals remains the main pest control method in tomato production although the extensive use has increased pest resistance (Desneux et al., 2022; Roditakis, Skarmoutsou, Staurakaki, et al., 2013). Integrated Pest Management (IPM) strategies are highly recommended although being used differently across regions and farming systems (Papadaki-Klavdianou et al., 1999). Based on the new EU regulation, farms must reduce their use of chemicals while enhancing biological control methods (European Commission, 2022) which can be achieved by a combination of resistant varieties, cultural practices, and rational pesticide use (Jensen, 1997). The same practices could also be used to manage plant pathogens (Thomidis et al., 2023).

1.2.2 Tomato on Crete

Tomato cultivation is important for the agricultural sector on Crete, Greece, particularly in the region around Ierapetra, where approximately 1,000 producers focus on growing tomatoes and peppers, contributing to an annual production of about 270,000 tons or approximately one-third of the Greek production (Kokkinakis et al., 2007). The cultivation primarily takes place in plastic-covered greenhouses, covering around 1650 acres, and produce is sold both domestically and to other European markets (Avgelis, 1986). Implementing Good Agricultural Practices (GAP) under the AGRO 2-1 & 2-2 protocols has substantially improved the microbiological quality of tomatoes, ensuring that they meet Euro-Retailer-Produce GAP (EUREPGAP) standards (Kokkinakis et al., 2007).

Despite advancements in cultivation techniques, virus diseases such as the tomato mosaic virus (ToMV) and the tomato bushy stunt virus (TBSV) have been a challenge (Avgelis, 1986).

Additionally, root-knot nematodes (*Meloidogyne spp*) are a common pest, and management strategies, including chemical applications and crop rotations with resistant cultivars, have proven effective. Studies have shown that resistant cultivars can decrease nematode populations, and *Pasteuria penetrans* (Bacilli: Pasteuriaceae), a hyperparasite of nematodes, has potential for biological control (Tzortzakakis et al., 1999).

Last but not least, one of the major pests in tomato cultivation in Greece and especially on Crete is *Tuta absoluta* (Meyrick,1917) (Lepidoptera, Gelechiidae), th tomato pinworm. The tomato pinworm was first recorded on Crete in 2009 and causes great damage to the cultivation of tomato in both greenhouses and open fields. The species is also challenging to control due to its strong potential develop resistances to insecticides (Roditakis et al., 2010).

Overall, there is still too little research regarding tomato cultivation and its pests on Crete or in Greece in general and this report aims to contribute to the knowledge around this subject.

1.3 The tomato pinworm, *Tuta absoluta*

The tomato pinworm Tuta absoluta (Figures 1 & 2), also known as tomato borer or tomato leafminer, is rapidly spreading and is considered highly destructive, leading to substantial economic losses in tomato production (Roditakis et al., 2015).

T. absoluta has been a key pest in South America for over 50 years and it was first noticed in Peru in 1917 (Pandey et al., 2023). T. absoluta is a significant pest that has invaded many countries, posing a threat to tomato production worldwide (Desneux et al., 2022). In Europe, it was first detected in 2006, and it quickly spread the same year at Spain, in 2008 in Italy and in 2009 in Greece (Roditakis, Skarmoutsou, Staurakaki, et al., 2013). Furthermore, there are also reports of T.absoluta on other continents as well, such as Africa and Asia (Biondi et al., 2018; Roditakis et al., 2010).

Figure 1. Adult Tuta absoluta. Photo: Roditakis Emmanouil

Figure 2. Larva of Tuta absoluta. Photo: Roditakis Emmanouil

It is a notorious oligophagous pest that primarily attacks solanaceous crops, mining on the mesophyll of leaves (Figure 3) and boring into tomato fruits (Figure 4) (Pandey et al., 2023). It can cause extensive damage to both developing and ripe fruits (Roditakis, Skarmoutsou, & Staurakaki, 2013).

Figure 3. T. absoluta larvae mining the mesophyll of a leaf. Photo: Roditakis Emmanouil

Figure 4. Tomato fruit damage caused by the boring of the tomato pinworm, Tuta absoluta. Photo: Roditakis Emmanouil

The tomato pinworm can easily adapt to different agroecological conditions, leading to its rapid multiplication. Up to 60% of the worldwide tomato-cultivated area have been infested within 10 years and the species is a significant threat to major tomato-producing countries like China and the United States (Biondi et al., 2018). In Europe, its rapid dispersal is lagerly based on the lack of coordinated actions among the countries (Biondi et al., 2018).

The tomato pinworm has multiple generations per year and females are laying hundreds of eggs (around 260) on tomato plants. The larvae bore into plant tissues, leading to defoliation and fruit rot, rendering infested fruits unsuitable for the market (Roditakis, Skarmoutsou, Staurakaki, et al., 2013).

As a pest, it is mainly controlled through the application of insecticides, but efforts have been made to implement integrated pest management programs to reduce reliance on chemicals (Sanchez et al., 2014). This will also contribute to reducing the resistance the pest has developed towards various insecticides (Roditakis et al., 2010).

1.3.1 The tomato pinworm in Greece

In Greece, the tomato pinworm has been a great concern for tomato growers leading to the exploration of different management strategies to control its population. Efforts are focused on studying the biology, ecology, and potential control methods of the pest to minimize its impact on tomato cultivation (Desneux et al., 2022). It poses a threat to tomato crops due to its ability to undergo multiple generations per year and survive in various climatic conditions (Biondi et al., 2018).

It was first reported for Greece in June 2009 on Crete, and has since then spread rapidly across the country, causing significant damage to the tomato industry (Roditakis, Skarmoutsou, & Staurakaki, 2013). It is worth mentioning that the distribution of the tomato pinworm in Greece is localized and scattered, indicating multiple introductions rather than a natural spread (Roditakis et al., 2010). Managing the pest has been challenging, with severe infestations resulting in substantial crop losses. The invasion of the tomato pinworm in Greece has led to cases of total crop destruction, especially during the 2009 and 2010 growing seasons (Roditakis, Skarmoutsou, Staurakaki, et al., 2013).

Various chemicals chlorantraniliprole, flubendiamide, emacetin benzoate, spinosad, indoxacarb, metaflumizone and chlorpyphos, amongst others, have been registered for tomato pinworm control and the Greek Ministry of Rural Development and Food has approved 15 commercial products for use against the pest in the growing season of 2024 (Roditakis, Skarmoutsou, & Staurakaki, 2013; Υπουργείο Αγροτική Ανάπτυξης και Τροφίμων, 2024; Table 1).

Table 1. Insecticides approved by the Greek Ministry of Rural Development and Food and their active substances (Υπουργείο Αγροτική Ανάπτυξης και Τροφίμων, 2024).

Product name	**Active substance**
Laser 480 SC	Spinosad (spinosyn)
Tracer 24 SC	
Exalt 25 SC	Spinetoram (spinosyn)
Alverde 24 SC	Metaflumizone (semicarbazone)
Affrirm 095 SG	Emamectin Benzoate (Avermectin)
Altacor 35WG	Chlorantraniliprole (Anthranilic Diamide)
Voliam Targo 063 SC	
Belpromec	Abamectin (avermectin)
Bermectine	
Voliam Targo 063 SC	
Valmec 1,8 EW	
Butik 1,8 EW	
Belpromec Gold	
Acarelte	
Minecto Alpha 10/1,25 SC	Anthranilic diamide / acibenzolar S-Methyl (benzothiadiazole)

1.3.2 The tomato pinworm on Crete

Among the regions in Greece that the tomato pinworm has been reported from, Crete was the first in June 2009 (Roditakis, Skarmoutsou, & Staurakaki, 2013). The presence of the species on Crete indicated its spread to the Mediterranean Basin (Desneux et al., 2022).

Tomato pinworm populations can be found in several locations on Crete, including the areas of Tympaki and Ierapetra covered in this report (Roditakis, Skarmoutsou, & Staurakaki, 2013).

Farmers on Crete struggle to control the tomato pinworm due to high insecticide levels, leading to severe crop losses (Roditakis, Skarmoutsou, Staurakaki, et al., 2013). However, the tomato pinworm population on Crete has been shown to have low resistance against diamide insecticides which are still used (Roditakis et al., 2015).

Further monitoring and management strategies may be necessary to control the impact of the tomato pinworm on tomato production on Crete in the future (Desneux et al., 2022). For example, based on research *Nesidiocoris tenuis* (Reuter,1895) (Hemiptera, Miridae) can effectively control the tomato pinworm in greenhouse tomatoes. If the use of predatory mirids is combined with biological agents like *Bacillus thuringiensis* (Berliner,1915), better control of the tomato pinworm infestation can be achieved (Pandey et al., 2023).

1.4 Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is a comprehensive approach to pest control that combines various strategies to manage pests effectively while minimizing risks to human health, by reducing hazards associated with chemical spraying, benefiting farmers and consumers alike, and minimizing the environmental impact as it promotes eco-friendly approaches (European Comission, n.d.; Gajanana et al., 2006).

The base of IPM are cultural practices, that make the environment less conducive to pests. Crop rotation and intercropping are significant cultural practices that help control pest infestations by promoting biodiversity and reducing reliance on chemical control. Additionally, using pest-resistant varieties can further reduce the need for chemical interventions (Tiwari, 2024).

On higher tropic levels, IPM includes biological control involving natural predators, parasitoids, and pathogens to manage pest populations. In protected cultivation such as greenhouses, the use of released predators and parasitoids is an effective method for managing pests (Ramasamy & Ravishankar, 2018). Moreover, IPM aims to increase the number of natural enemies to protect cultivation while keeping crop production costs lower and improving yields (Picanço et al., 2007).

Mechanical and physical control methods involve the use of physical barriers or manual techniques to manage pests. Monitoring and controlling pests with colored sticky traps and pheromone traps are commonly implemented in IPM for specific pests like the tomato pinworm (Ramasamy & Ravishankar, 2018).

Chemical control is used as a last resort in IPM and involves selective and reduced use of pesticides. Targeted pesticide application is a key factor, with spraying implemented only when action thresholds are reached, leading to fewer applications compared to traditional, calendar-based systems (Miranda et al., 2005). Eco-friendly inputs such as biopesticides and organic salts are preferred to control major pests, reducing environmental pollution compared to the use of conventional synthetic insecticides (Ramasamy & Ravishankar, 2018).

IPM also offers in long-term, economic benefits to the farmers, with often higher yields and lower cultivation costs (Gajanana et al., 2006). For example, the reduction in insecticide applications automatically lowers production costs while it can also be beneficial for crop yields (Picanço et al., 2007). While IPM has several benefits, it also comes with several limitations. The plethora of definitions for IPM itself created confusion for it together with the gaps in IPM concepts, practices, and policies (Deguine et al., 2021). The lack of subsidies and technical barriers are often hampering for its adoption. Education, technical support, and financial incentives are important to expand IPM implementation among farmers (Papadaki-Klavdianou et al., 2000). Additionally, governmental support from agriculture and horticulture departments is also essential together with the availability of inputs such as biopesticides (Miranda et al., 2005).

Overall, IPM is a comprehensive, sustainable approach to pest management that integrates multiple strategies and socio-economic perspectives. Successful adoption of IPM depends on overcoming these barriers, providing education and support to farmers, but also promoting eco-friendly pest control methods. This could be achieved by including the farmers in the technology development (Deguine et al., 2021).

1.4.1 IPM in Greece

The registration of pesticides in Greece has significantly improved towards ensuring safety in ecosystems. Key to this is the harmonization with European directives, which enhanced ecological safety through customized IPM approaches, based on local conditions and pest species (Vassiliou, 2006).

Farmers, play a crucial role in environmental protection through their activities. The majority of greenhouse producers in Greece, still use chemical insecticides for plant protection, despite their negative impact on nature (Papadaki-Klavdianou et al., 1999). On the other hand, younger farmer generations seem to be aware of the risks to human health and the environment and tend to be more cautious while spraying. Also, the educational level seems to impact the use of chemicals, as farmers with higher education show greater awareness of the negative impacts of agrochemicals (Papadaki-Klavdianou et al., 1999).

IPM practices in Greece, have their focus on intensive crops that require significant inputs and management to achieve high yields, particularly in greenhouses. From 1992 to 1994 an IPM program was introduced by the Greek Ministry of Agriculture and implemented to promote IPM practices by greenhouse farmers (Papadaki-klavdianou et al., 2000). The initial attempts were made in the areas of Crete and the Peloponnese, and by 1994 IPM methods were implemented on 110 hectares of greenhouse cultivations in Greece (Papadaki-Klavdianou et al., 2000).

Additional actions to enhance sustainable pest control, consumer safety, and environmental protection, take place in Greece. For example, in citrus orchards, innovative approaches like mass trapping with non-toxic attractants are being implemented to address pest issues (Bempelou et al., 2021). Another example is the pest management in tomato cultivation in Greece and the invasive tomato pinworm, which impacts both open fields and greenhouse cultivation. In this case, the importance of integrating biological control through strategic release and conservation of natural enemies is being highlighted. This approach not only effectively manages tomato pinworm populations but also minimizes the environmental impact of tomato cultivation and promotes sustainable tomato cultivation practices in the Mediterranean region (Perdikis et al., 2015).

Despite the progress, IPM faces great challenges in Greece due to a lack of means and farmer education. Continuous monitoring and evaluation are essential to ensure its effectiveness in the country (Bempelou et al., 2021).

In conclusion, although IPM is being introduced to Greek farmers and several implementations have been achieved in the country, there is still room for improvement, and new ways to make IPM more appealing to the farmers are needed.

1.4.2 IPM for the tomato pinworm in tomato cultivation

Integrated pest management strategies for controlling the tomato pinworm, have been increasingly adopted worldwide. Originally managed predominantly through intensive insecticide applications, the implementation of IPM has marked a significant shift towards more sustainable and environmentally friendly approaches (Sanchez et al., 2014).

Natural enemies, such as predators and parasitoids, play a crucial role in suppressing tomato pinworm populations while reducing the reliance of the farmer on chemical treatments and mitigating environmental risks (Picanço et al., 2007). Biological control agents used alongside *B.thuringiensis* (Table 2) and less toxic insecticides are key components for IPM (Sanchez et al., 2014).

In Greece, several predatory and parasitoids species are approved for use against the tomato pinworm: *Macrolophus pygmaeus* (Rambur, 1842) (Miridae: Hemiptera), *N.tenuis* (Miridae: Hemiptera), *Steinernema feltiae* (Cobb, 1927) (Steinernematidae: Rhabditida), *Steinernema carpocapsae* (Weiser, 1955) (Steinernematidae: Rhabditida), and *Trichogramma acheae* (Nagaraja and Nagarkatii, 1969) (Υπουργείο Αγροτική Ανάπτυξης και Τροφίμων, 2019).

Moreover, the need to sustainably manage the tomato pinworm, across different geographical regions and the need for integrated approaches, is stressed in international symposia as well as scientific papers (Roditakis, Skarmoutsou, Staurakaki, et al., 2013).

The environmental sustainability of IPM strategies is further highlighted by research into soil microbial inoculations, which have shown promise in enhancing plant resistance and reducing tomato pinworm problems without reducing crop yield or quality (Minchev et al., 2024).

In Greece, IPM practices for the tomato pinworm also emphasize the importance of the reduction of pesticide use through systematic monitoring with pheromone traps, sanitation measures, and the implementation of insect exclusion nets (Perdikis et al., 2015). These measures not only help in minimizing this pest but also in preserving beneficial insect populations and enhancing overall crop health and yield (Han et al., 2024).

Table 2. List of biopesticides approved by the Greek Ministry of Rural Development and Food, and their active substance or biological agent (Υπουργείο Αγροτική Ανάπτυξης και Τροφίμων, 2024).

Product	**Active Substance / Biological agent**
Bacillus thuringiensis	
Bactecin DP	Bacillus thuringiensis subsp. kurstaki strain abts 351
Bathikur DP	
Bactospeine WG	
Dipel 2X	
Costar WG	Bacillus thuringiensis subsp. kurstaki strain sa12
Delfin WG	Bacillus thuringiensis subsp. kurstaki strain sa 11
Belthirul 32000 WP	Bacillus thuringiensis subsp. kurstaki strain pb 54
Lepiback	
BactoIL SC	
Amcobac	
Bacillus Chemia	
Turibel	
Bacillus thuringiensis subsp. aizawai (Bt aizawai) Strains	
Agree WP	Bacillus thuringiensis subsp. aizawai strain gc-91
Xentari WG	Bacillus thuringiensis subsp. aizawai strain abts-1857
Bacillus thuringiensis subsp. kurstaki (Bt kurstaki) Strains (Additional)	
Lepinox Plus	Bacillus thuringiensis subsp. kurstaki strain eg 2348
Cordalene	
Rapax AS	
Azadirachtin (Neem)	
Azatin EC	
NeemAzal T/S	
NeemAzal ® - T/S Biogarden	
AzaGreen	
Azactiva	
Other products	
Parapin 5 SC	Pyrethins
Ecothrin	
Fatty Acids (Potassium Salts)	
Acaridoil 13 SL	Fatty acids C7-C18 and C18 unsaturated potassium salts
Clavitus 13 SL	
Synthetic Pheromone	
Isonet T	(E,Z,Z)-3,8,11-Tetradecatrien-1-yl Acetate
Tutatec®	
Tuta Pro Press	
Cloud Tuta	

Overall, the adoption of IPM for managing the tomato pinworm reflects a paradigm shift towards sustainable agriculture. Continued research and implementation of these strategies are crucial for ensuring long-term pest management efficacy and sustainable agricultural practices worldwide but also in Greece specifically.

1.5 Aim and hypotheses

This thesis aims to compare tomato cultivation costs in two different pest management strategies, in greenhouses on Crete, through a cost benefit analysis. Specifically, the study aimed to evaluate the economic impact of professional advisory assistance for integrated pest management to reduce the use of conventional, chemical insecticides compared to business as usual management following traditional management of a major tomato pest, the tomato pinworm *T.asbsoluta*. Based on this aim, four hypotheses were formulated:

1. The use of environmentally friendly practices for the tomato pinworm management is higher in advised greenhouses compared to business as usual greenhouses (H1).
2. Advised greenhouses experience lower production losses attributable to the tomato pinworm compared to the business as usual greenhouses (H2).
3. The overall cost of the cultivation and the cost of the tomato pinworm management is reduced in the greenhouses with advised pest management (H3).
4. The profitability of tomato cultivation is higher in greenhouses with advised pest management compared to business as usual greenhouses (H4).

2. Methods

In the spring of 2024, a cost-benefit analysis was conducted for 12 different greenhouses on 12 different farms in two regions of Crete, Greece: Ierapetra and Tympaki.

This study aimed to compare the costs of tomato cultivation and compare pest management efficiency in two major cultivation systems. Farmers who receive professional advisory help for pest control for the specialized tomato pest *Tuta absoluta* the tomato pinworm, within the framework of IPM (hereafter: advised pest control), and those who did not and followed a business as usual pest control approach. From the total, 4 greenhouses had advised pest control, whereas the remaining 8 followed business as usual.

2.1 Research Design

A quantitative study was designed to compare tomato cultivation costs, between farmers with access to professional pest control advisory services for the tomato pinworm (advised pest control) and those following business as usual for pest management.

Advised pest control greenhouses refer to greenhouses in which management of tomato pinworm is, advised and guided by a professional. In business as usual greenhouses, traditional practices of tomato pinworm management are implemented. This means methods are passed through generations, are based on the experience of the farmers and rely heavily on conventional insecticides.

The research design involves collecting and analyzing economic and management data to identify significant differences in the expenses regarding pest control and pest management efficiency.

For this, not only the direct pest management costs were collected from the farmers but several other cost categories that form the total cost of tomato cultivation.

2.1.1 Sampled greenhouses

The study sample consists of twelve greenhouses from twelve farmers in two regions in Crete, Greece. Specifically, five greenhouses are located in Ierapetra, and cultivate cherry tomatoes (all five had the variety Lobello; Figure 3). The rest are located in the Tympaki area where the farmers grow tomatoes from different varieties, specifically Elpida (five greenhouses; Figure 4), Tyscala (one greenhouse), and Runner (one greenhouse).

Figure 5.Greenhouse with cherry tomato cultivation (Lobello), in Ierapetra.
Photo: Lelekaki Maria

Figure 6. Greenhouse with tomato cultivation (Elpida), in Tympaki. Photo: Konstantina Alipranti

Among these greenhouses, three out of seven farms from Tympaki followed advised pest control for the tomato pinworm, whereas only one out of five greenhouse from Ierapetra followed advised pest control.

The three participants in Tympaki specifically are incorporated in measure 16 (M16), and specifically in the sub-measure 16.1-16.2 with code M16ΣYN-00074 and the name "Integrated Management of the tomato leafminer *T. absoluta* (ZERO TUTA)". The measure aims to scientifically support the control of the tomato pinworm, reduce the use of chemicals, promote alternative methods that are environmentally friendly, and reduce resistance. Last but not least, it aims to educate and inform the producers about preventive and corrective measures they can take on their farms. To achieve the above, three types of measures are implemented:

1. Preventive measures: phytosanitary measures of inspections of propagating material, use of infrastructure providing mechanical protection, close monitoring of the pest with pheromone traps (Figure 7), monitoring the population of natural enemies, and inspection of the crops.
2. Corrective measures: massive trapping of adult insects, prevent coupling through trapping of the male adult, use of beneficial insects and parasitoids, with microbial formulations, use of plant extracts and mineral oils.

3. Chemical control: Monitoring the pest population (catches per week) and the number of leaf mines. When these levels exceeded a certain threshold, chemical treatments were applied for pest control.

(Roditakis, 2024)

Figure 7. Type of pheromone trap, used in the greenhouses with advised pest control. Photo: Alipranti Konstantina

The advised greenhouse in Ierapetra is part of a study, in which the management of the tomato pinworm with a combination of the insecticide Epsilon and the natural enemy *N.tenuis is used*. The project uses the following methods in order to achieve pest control:

1. Monitoring: leaf damage, population density of the tomato pinworm, density of *N. tenuis*
2. Foliar application of special formulation: use of Epsilon, a silicon fertilizer, with insecticide effect
3. Use of natural enemies: *N. tenuis*
4. Data collection and analysis, from both the farmer and advisor together

(Roditakis, 2024)

2.1.2 Data Collection

Data were collected through structured interviews with both farmers and advisors. An Excel sheet was designed to record all relevant cost data, ensuring comprehensive and organized data selection. The cost data captured general information such as the area where the greenhouse is located, its size in acres, the type of greenhouse (whether is plastic, glass, etc.), the tomato variety, the total yield in tons, and tomato price per kilo (volume sold at full price).

For later analyses, the data sheet was divided into two sections. First, the overall costs of the cultivation were collected, providing a broad overview of the financial inputs required for tomato cultivation. These include work costs (whether family or worker labour), seed costs, utility costs which included the pesticides, biological control products, fertilizers, propagation material costs, and pollination costs. Soil and water analysis, irrigation, equipment, maintenance, electricity, production loss (product sold for a lower price as well as the price obtained for it or product that could not be sold), fuel, and other costs were also collected. Work costs were counted in payment per day. Based on this information, the days of pinworm management were also counted, as their equal to the days that the farmer paid a worker or a family member to manage the pest.

Second, all the costs that are directly linked to the management and control of *T. absoluta* were gathered for a more focused analysis. These costs included work, utility, and equipment costs, as well as the production loss due to the pest.

During the process of data collection, informal discussions with farmers were held to collect qualitative background data about farming practices.

2.1.3 Cost Calculations

In this report, a Cost Benefit Analysis (CBA) was performed. CBA is used to compare the benefits and the costs, that arise within a system through a systematic and analytical process. It helps answer questions about the feasibility and the scale of new projects or the viability of existing ones (Mishan & Quah, 2020).

In this case, an Environmental CBA was conducted. This means that the economic evaluation was about policies or projects aiming at environmental services or actions impacting the environment indirectly (Atkinson & Mourato, 2008).

For this, several calculations were made in Excel to facilitate later data analysis. All calculations were made both in total and standardized per acre. Costs were related to acres instead of hectares for convenience, as this unit is used in Greece and by the farmers of the greenhouses where the data were collected. One acre is approximately equal to 0.40 hectares. Additionally, all amounts were recorded in kilograms, and all economic values in euros (€).

Production per Acre

For each greenhouse, all production numbers were calculated per acre: the total production, A product (the product sold at full price), B product (product sold at a lower price), lost production (product not sold at all), as well as B product and Lost production due to the tomato pinworm (APPENDIX 1).

Total Cost and Total Cost for the management of the tomato pinworm

Based on the collected data first the total cost and the total cost per acre were calculated for each greenhouse. Furthermore, the total cost and total cost per acre for tomato pinworm management were calculated for all twelve greenhouses (APPENDIX 2).

The total cost included work, seed, utility, soil analysis, irrigation, equipment, maintenance, electricity, and other costs. The total cost for the management of the tomato pinworm included work, utility, and equipment costs that were spent specifically for the management of the tomato pinworm.

Total Income

The total income and the total income per acre were also calculated, including the product sold at full price and the product sold at a lower price (Figure 8).

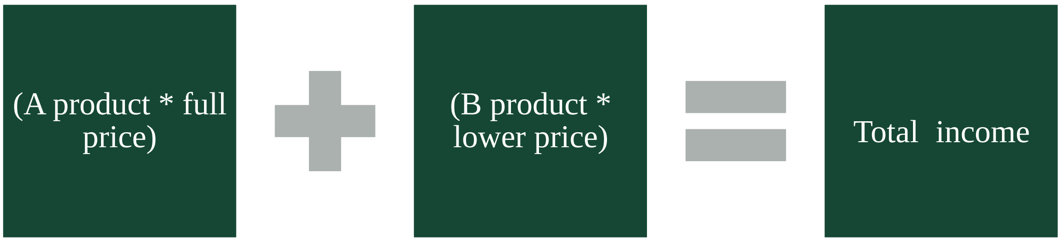

Figure 8. Total income calculation

In the next step, to calculate the ideal income, the loss due to the product not sold and the loss due to the product that was sold at a lower price were included (As if they were sold at full price (Figure 9).

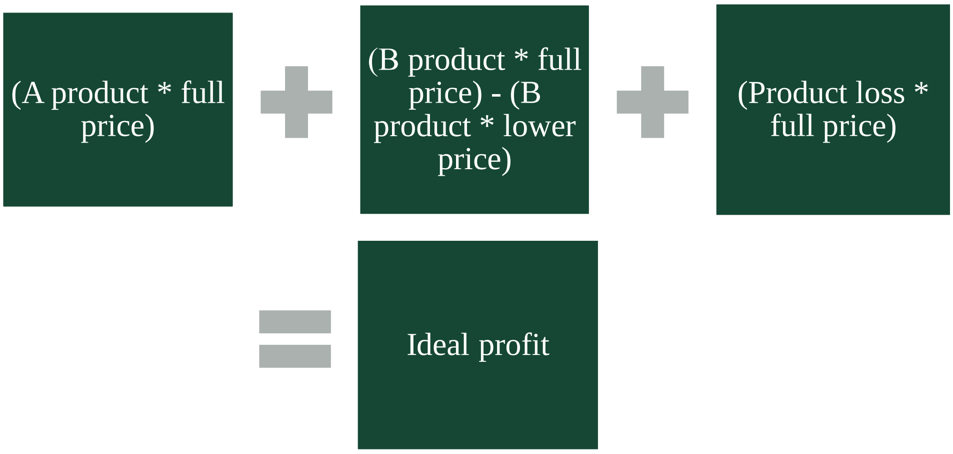

Figure 9. Ideal income calculation

Maximum Loss

The maximum loss in cultivation and the maximum loss caused by the tomato pinworm were calculated in total as well as per acre. To calculate this in all cases, the money lost from the product not sold if sold at full price and the loss from the product sold for less if sold at full price were added. The percentage of maximum loss due to the tomato pinworm out of the maximum loss in cultivation in general was also calculated (APPENDIX 4).

The maximum loss was then added to the total cost. This was done, as loss is an indirect cost to the farmer although the farmer may not realize it, as this money does not come straight from the farmer's pocket (APPENDIX 4).

Profit

Greenhouse profit was also measured in this report. Two different profits were calculated. First, the actual profit both in total and per acre, subtracting the total cost from the total income. Additionally, the ideal profit was subtracting the total cost from the ideal income (APPENDIX 5).

Chemical and biological pest control costs

Last, the chemical and biological pest control cost for the whole cultivation per acre was calculated, together with the chemical and biological pest control cost specifically for the tomato pinworm (APPENDIX 6). Chemical and biological pest control costs include the costs for chemical, microbial, and invertebrate biological control agents such as mirids or parasitoids. For convenience, these costs are referred to as total pest control cost and total tomato pinworm pest control cost, respectively.

2.2 Statistical Analysis

The statistical analysis was conducted with the use of R 4.3.1. for Windows and the following packages: ggplot2 version 3.5.1 (Wickham, Chang, et al., 2024), tidyr version 1.3.1 (Wickham, Vaughan, et al., 2024), dplyr version 1.1.4 (Wickham et al., 2023), DHARMa version 0.4.6 (Hartig & Lohse, 2022), car version 3.1.2 (Fox et al., 2023), performance version 0.12.1 (Lüdecke et al., 2021), easystats version 0.7.2.3 (Lüdecke et al., 2024), emmeans version 1.10.3 (Lenth et al., 2024), ggpubr version 0.6.0 (Kassambara, 2023), ggeffects version 1.7.0 (Lüdecke et al., 2024), glmmTMB version 1.1.9 (Brooks et al., 2017).

All analyses were performed using Generalised Linear Models ('glm') and Generalised Linear Mixed Models ('glmmTMB). All models included two predictors: Type (cherry tomato or other tomato) and Treatment (advised or business as usual). The type of cultivation was included as fixed effect instead of as random intercept due to the small sample size. For most analyses, Generalized Linear Models with Gaussian distributions were used, to evaluate the significance of the predictors. Models for proportions data were fitted with Generalised Linear Mixed Models using a beta regression as error distribution. As proportion data sometimes contained the values 0 or 1 for which beta regressions are not defined, these values were replaced by 0.000001 or 0.999999 before model fitting. In one case, in the share of product sold at a lower price caused by the tomato pinworm out of all product sold at a lower price, the Generalised Linear Mixed Model could not be fitted and Generalised Linear Models with binomial distribution were used. The presence and absence of sticky or pheromone traps and natural enemy use in the cultivation were coded 0 (absence) and 1 (presence) and analysed with Generalised Linear Models with binomial distribution. The days spent for tomato pinworm management were analysed with a Generalised Linear Mixed Model with lognormal distribution. Last, for the total amount of product sold at a lower price, a Generalised Linear Mixed Model with Gamma distribution was used, as it achieved the best fit.

Before analyses, I changed the contrast settings to ‘contrast=c(‘contr.sum’, ‘contr.poly’) as the command ‘Anova’ from the car package computes wrong Null hypotheses by default (Al-Sarraj & Forkman, 2023).

ANOVA type II sums of squares Wald chi^2 tests (‘Anova’function) from the car package were used to obtain p-values while for R^2 values, the performance package was used (performance (model_name)). Estimated marginal means predictions were calculated with emmeans package (‘emmeans’function).

Visualizations were created with the use of ‘ggplot2’ to depict the distributions and the comparisons made. All model predictions are depicted with their 95% confidence intervals, except all predictions from binomial models which are depicted with standard error.

3. Results

All the data collected were compared among two different treatments, greenhouses with advised pest control and greenhouses that followed business as usual for pest control. While doing so, the type of tomato, whether normal tomato or cherry tomato was taken into account, as costs differ between tomato types due to plant's needs, susceptibilities to pests and diseases, and different selling prices.

Cherry tomato had a higher total and ideal income as the full selling price is almost one and half times higher than the one of the other tomatoes, while the price of B product is even four times higher (APPENDIX 3). In addition, cherry tomato cultivation had a higher total and ideal profit, despite higher cultivation costs (APPENDIX 5). Cherry tomato cultivation, however, also required almost twice as many pesticide applications during the cultivation than the other tomatoes. B product amount and production loss were higher in other tomatoes than in cherry tomato cultivation (APPENDIX 1).

The results part focuses on the effects of treatment on tomato pinworm management, costs, and profits. All monetary costs used in the analysis were standarised per acre.

3.1 Tomato pinworm management

3.1.1 Use of traps

Two types of traps were evaluated in this analysis, sticky traps and pheromone traps. The assessment was made whether these two types were used for the monitoring and control of the tomato pinworm in greenhouses with advised pest control and/ or in business as usual greenhouses.

Sticky traps were used in all greenhouses but one of the business as usual greenhouses (Table 3 & 4).

All greenhouses with advised pest control used pheromone traps, but none of the business as usual greenhouses used pheromone traps (Tables 3 & 4).

3.1.2 Use of natural enemies

All greenhouses with advised pest control used natural enemies, but only one greenhouse with business as usual management (Tables 3 & 4).

3.1.3 Days spent on tomato pinworm management

In business as usual greenhouses, significantly more days were spent on tomato pinworm management than in greenhouses with advised pest control, with 18.9 ± 14 days spent in business as usual greenhouses and 2 ± 7 days spent in greenhouses with advised pest control (Figure 10, Tables 3 & 4).

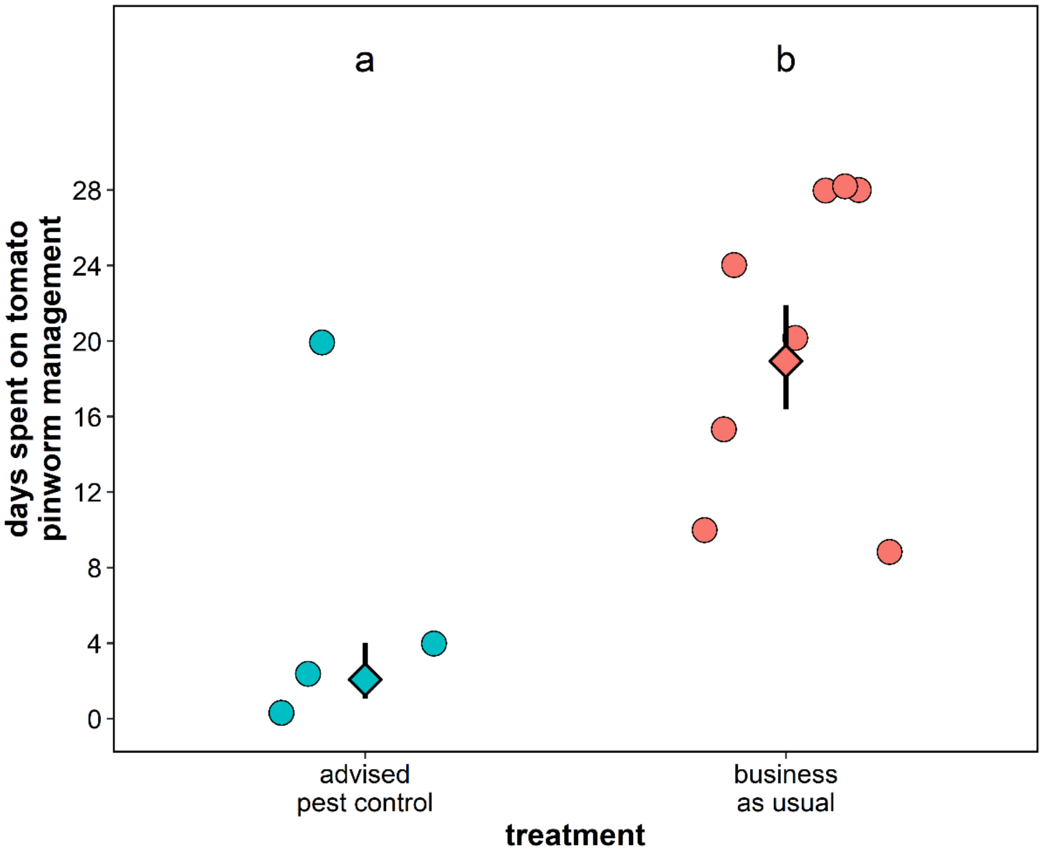

Figure 10. Days spent on tomato pinworm management in the two treatments advised pest control and business as usual. Points represent individual observations, and the diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

3.1.4 Number of insecticide applications against the tomato pinworm

The number of insecticide applications against the tomato pinworm was not significantly affected by treatment, with greenhouses with advised pest control having 20.6 ± 3 applications and business as usual greenhouses 24.2 ± 2 applications (Figure 11, Tables 3 & 4). While there was no significant difference in the number of applications, the informal background interviews revealed that the nature of the agents used did differ. The farmers followed the business as usual management mentioned that in almost all insecticide applications against the tomato pinworm, chemical-based insecticides were used as they are believed to work better and faster. In contrast, the farmers of the greenhouses with advised pest control are using biopesticides more often for the management of the tomato pinworm. Specifically, for the greenhouses GH1 to GH3 with advised pest control (APPENDIX 2), 31 to 50 % of all applications comprised of only biopesticides, 27 to 32 % were purely chemical insecticides and the remaining 21 to 38% were a combination of both. In greenhouse GH4 (APPENDIX 2), almost all applications were biopesticides.

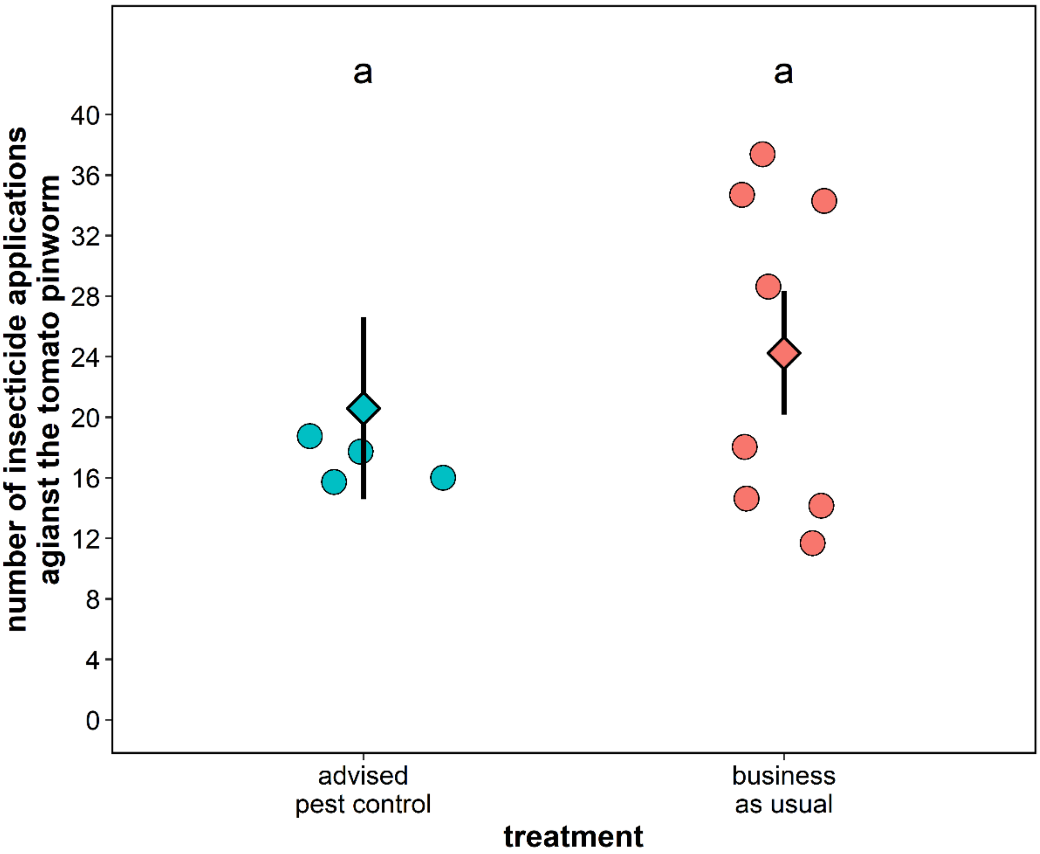

Figure 11. Insecticide applications against the tomato pinworm in two treatments advised pest control and business as usual. Points represent individual observations, the diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

3.1.5 Pest control cost for the tomato pinworm in relation to the total pest control cost.

The pest control costs for the tomato pinworm were divided by the total pest control costs of the cultivation, which results in a fraction of the total pest control cost attributed to the control of the tomato pinworm.

This fraction was not significantly affected by treatment with 78.6 ± 4.0 % in greenhouses with advised pest control and 73.2 ± 2.9 % in the business as usual greenhouses (Figure 12, Tables 3 & 4).

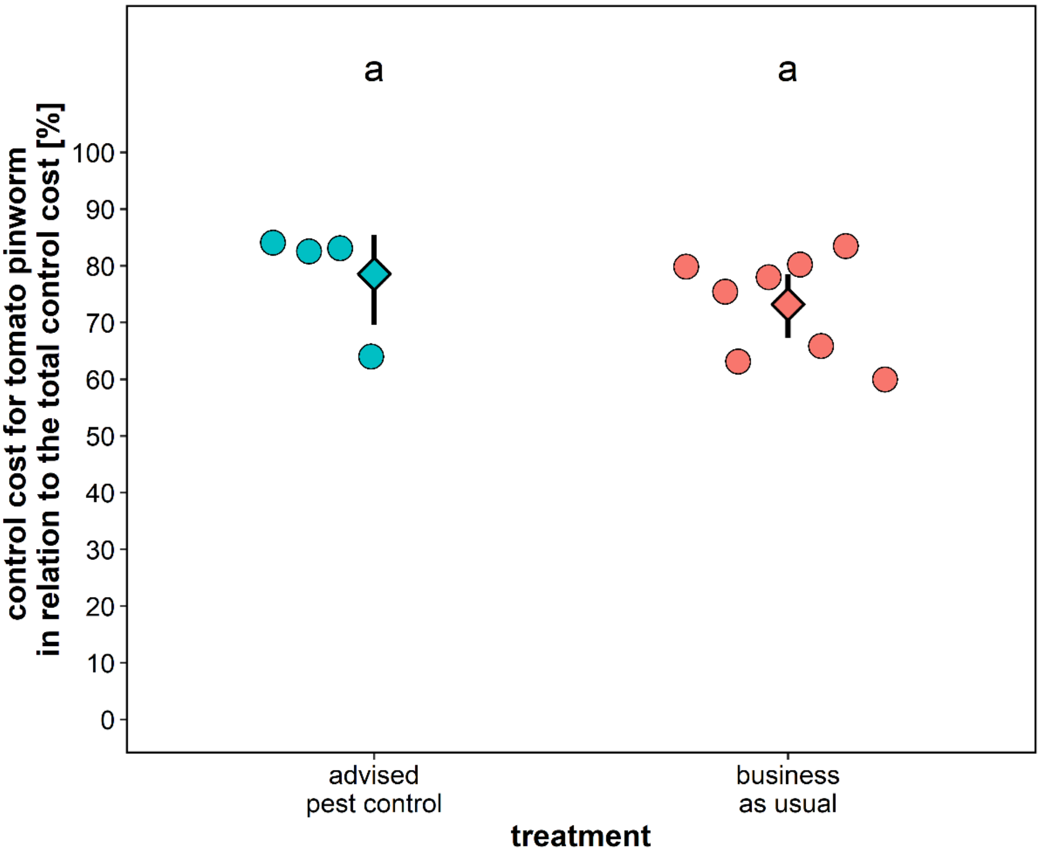

Figure 12. Comparison of the tomato pinworm chemical and biological control costs as a share of the total chemical and biological pest control costs. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p <0.05).

3.2 Crop damages

3.2.1 Product sold at a lower price (B product)

First, the total amount of the product sold at a lower price (B product) of the cultivation was assessed. The total B product amount was not significantly affected by treatment, with 70.6 ± 160kg in greenhouses with advised pest control and 576.8 ± 956kg in business as usual greenhouses (Figure 13, Tables 3 & 4). That this difference was not statistically significant is likely due to the large variation in business as usual greenhouses. Several greenhouses, managed with business as usual produced considerable amounts of B product (Figure 13).

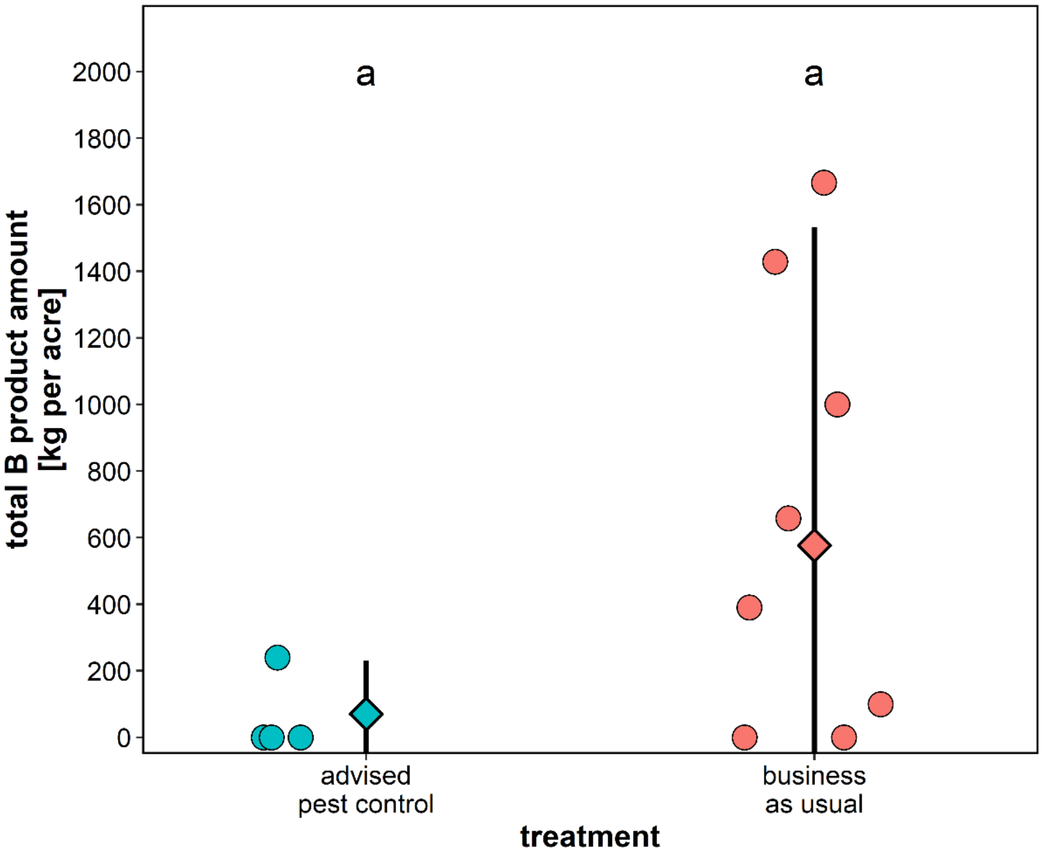

Figure 13. Comparison of the total amount of product sold at a lower price (B product) of the cultivation per acre between greenhouses with advised pest control management and business as usual. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment, and the error bars indicate the 95% confidence interval. Different letters above each group indicate significant differences between the two treatments (p<0.05).

Two fractions related to the B product amount were also assessed. The share of B product caused by the tomato pinworm out of the total B product amount and the share of B product of the total production. The share of B product caused by the tomato pinworm was significantly affected by treatment, with 45 ± 0% in business as usual greenhouses and 0% in greenhouses with advised pest control (Figure 14, Tables 3 & 4).

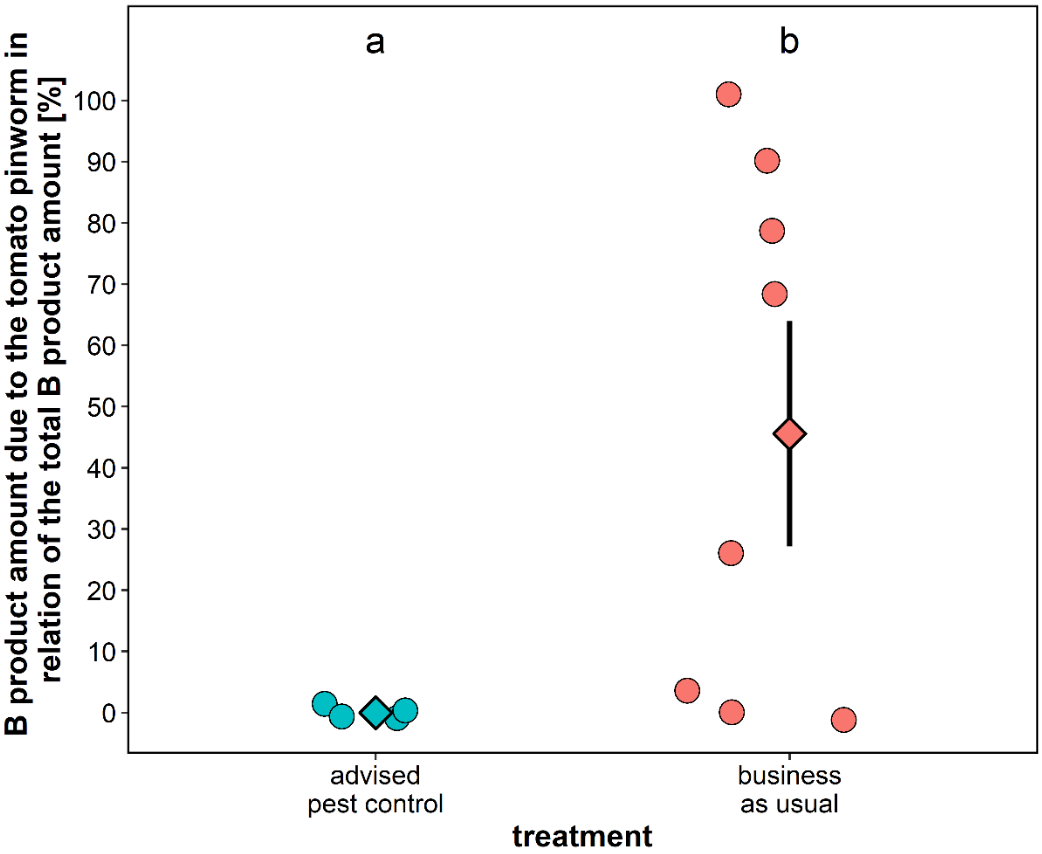

Figure 14. Share of B product caused by the tomato pinworm out of the total B product amount. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and with error bars indicating the standard error. Different letters above the categories indicate significant differences between the treatments (p<0.05).

The share of B product of the total production was also significantly affected by the treatment with 2.9 ± 1.2% in business as usual greenhouses and 0.2 ± 0.2%, in greenhouses with advised pest control (Figure 15, Tables 3 & 4).

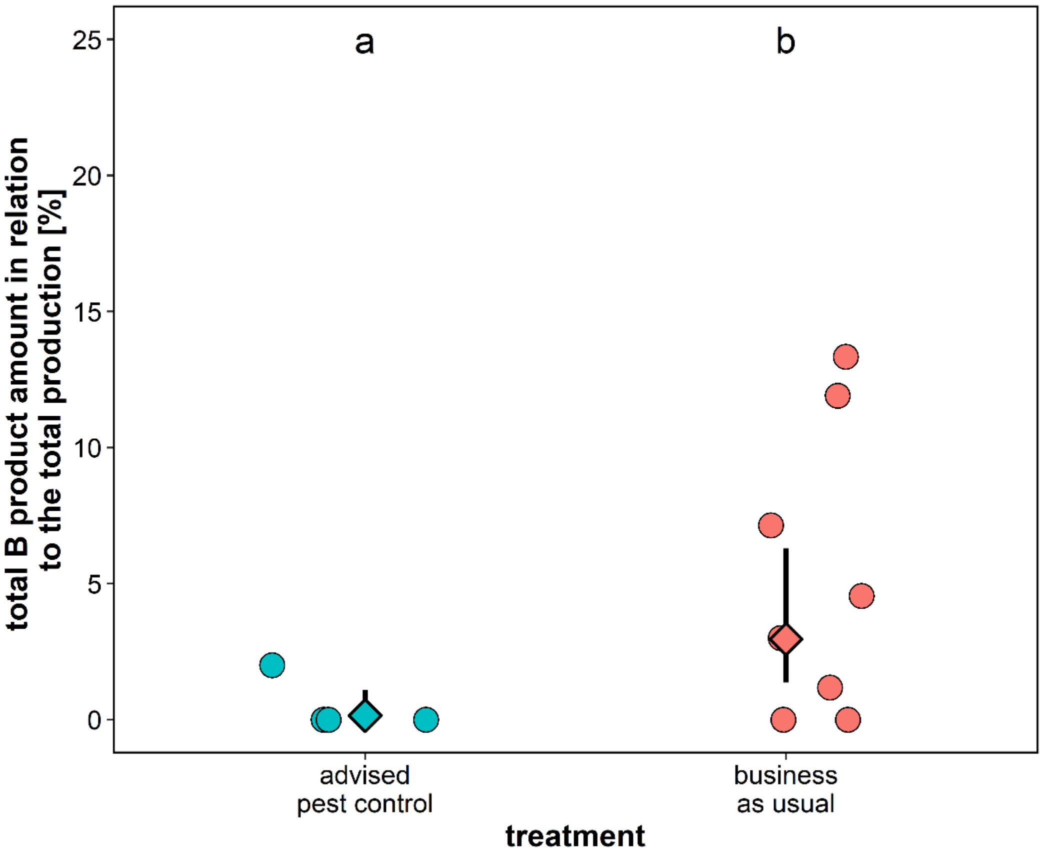

Figure 15. B product amount as a fraction of the total production of the cultivation. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment group and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

3.2.2 Production Loss

Production loss was assessed in the same way as the B product. The total production loss was significantly affected by treatment, with 782 ± 215kg lost in greenhouses with advised pest control greenhouses and 391 ± 145kg lost in business as usual greenhouses (Figure 16, Tables 3 & 4).

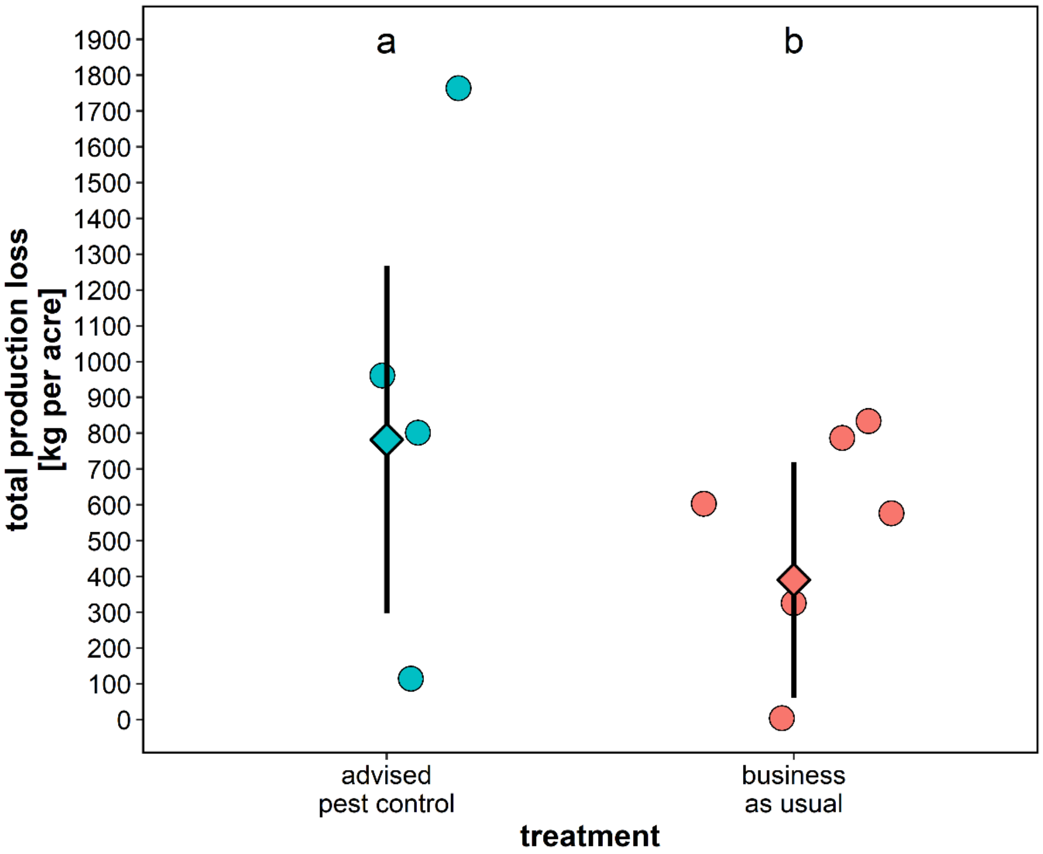

Figure 16. Comparison of the total amount of lost production of the cultivation per acre between greenhouses with advised pest control and business as usual. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment, and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

Two fractions were assessed: The production loss due to the tomato pinworm as a share of the total production loss and the total production loss as a share of the total production of the cultivation.

The production loss due to the tomato pinworm as a share of the total production loss was not significantly affected by the treatments, with 55 ± 17.8% in greenhouses with advised pest control and 45.9 ± 12.5% in business as usual greenhouses (Figure 17, Tables 3 & 4).

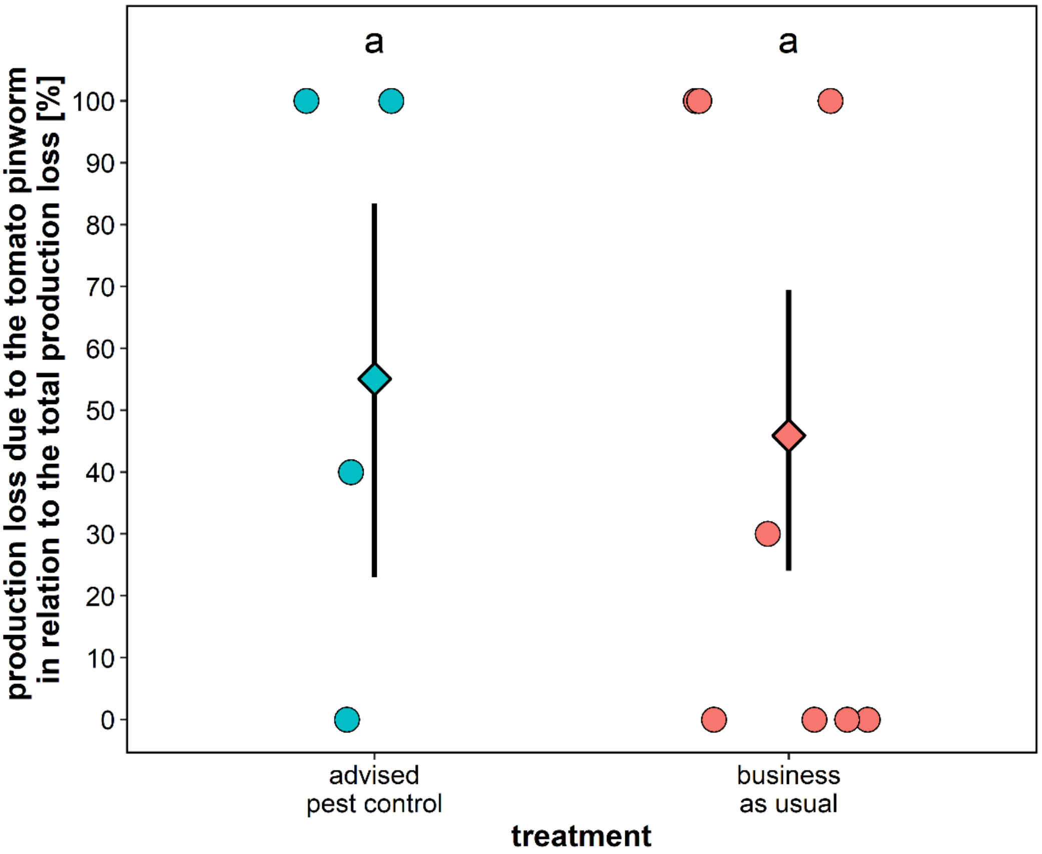

Figure 17. Product loss due to the tomato pinworm as a share of the total production loss. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

The production loss as a share of the total production was significantly affected by the treatment, with a roughly 7 percent point higher loss in greenhouses with advised pest control (8.7 ± 3.4%) than the business as usual greenhouses (1.8 ± 1.0%; Figure 18, Tables 3 & 4).

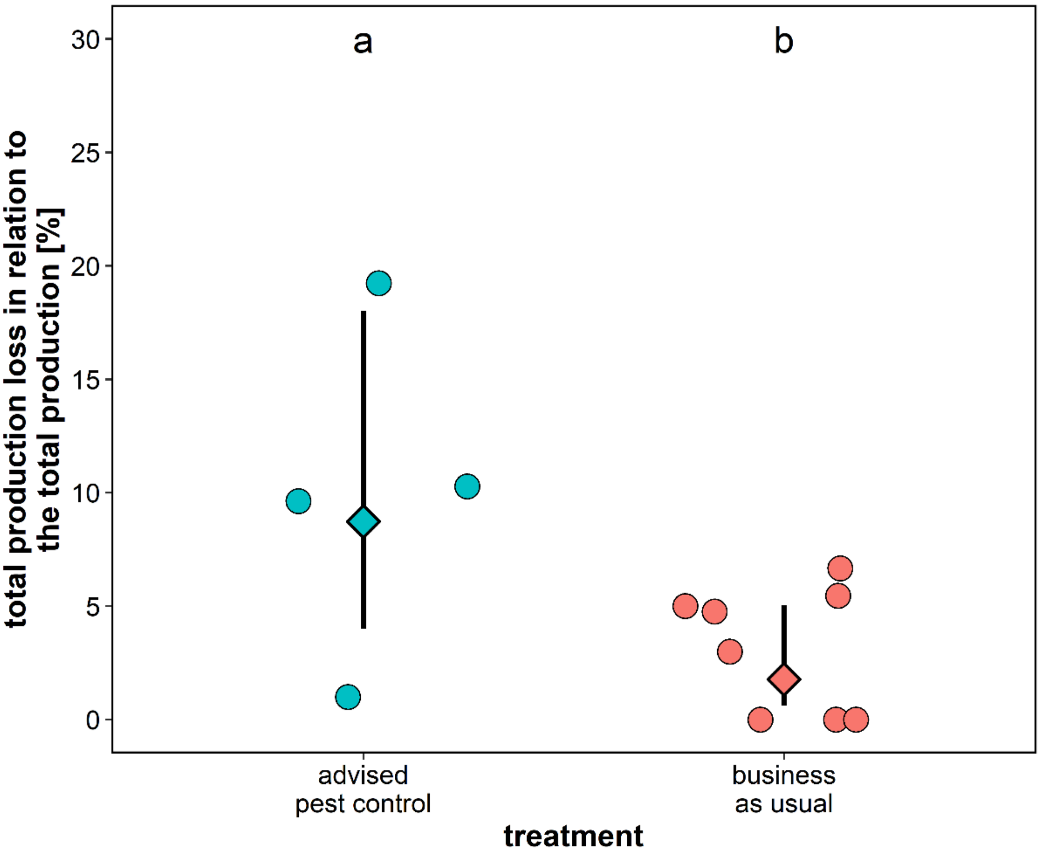

Figure 18. Production loss of the cultivation as a fraction of the total production. Points represent individual observation, diamond shapes represent the model prediction (estimate marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

3.3 Costs

3.3.1 Total cultivation cost

The total costs in the greenhouses were compared based on the treatment used. The total cost of the cultivation was significantly affected by the treatment, with production costs in business as usual greenhouses higher (11599 ± 770 Euro per acre) than in greenhouses with advised pest control (8807 ± 1137Euro per acre; Figure 19, Tables 3 & 4).

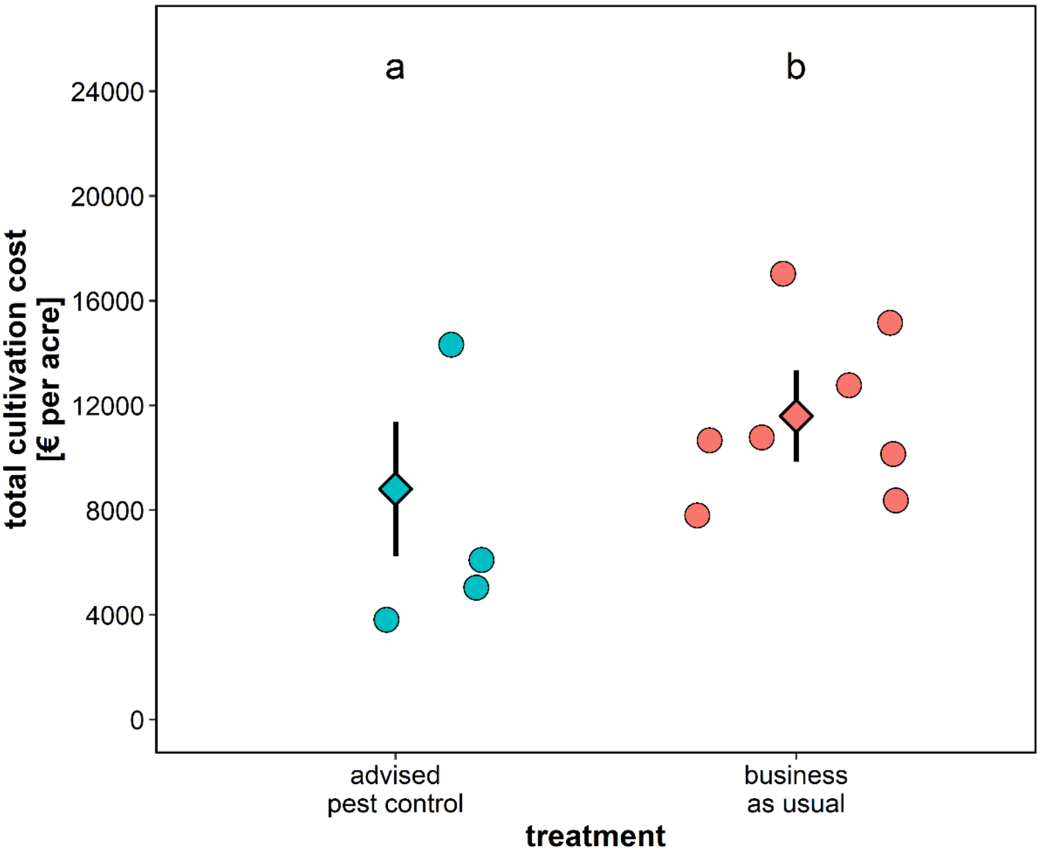

Figure 19. Total cost of the cultivation per acre in greenhouses with advised pest control and business as usual. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the two treatments (p<0.05).

3.3.2 Total tomato pinworm cost

Regarding only the costs that are directly linked to the management of the tomato pinworm, business-as-usual greenhouses had significantly higher costs, with 1910 ± 157 Euro spent per acre than greenhouses with advised pest control with 937 ± 232Euro (Figure 20, Tables 3 & 4). It should be mentioned that the greenhouse with advised pest control cultivating cherry tomatoes had more than 50 % lower tomato pinworm management costs than the business as usual cherry tomato greenhouses.

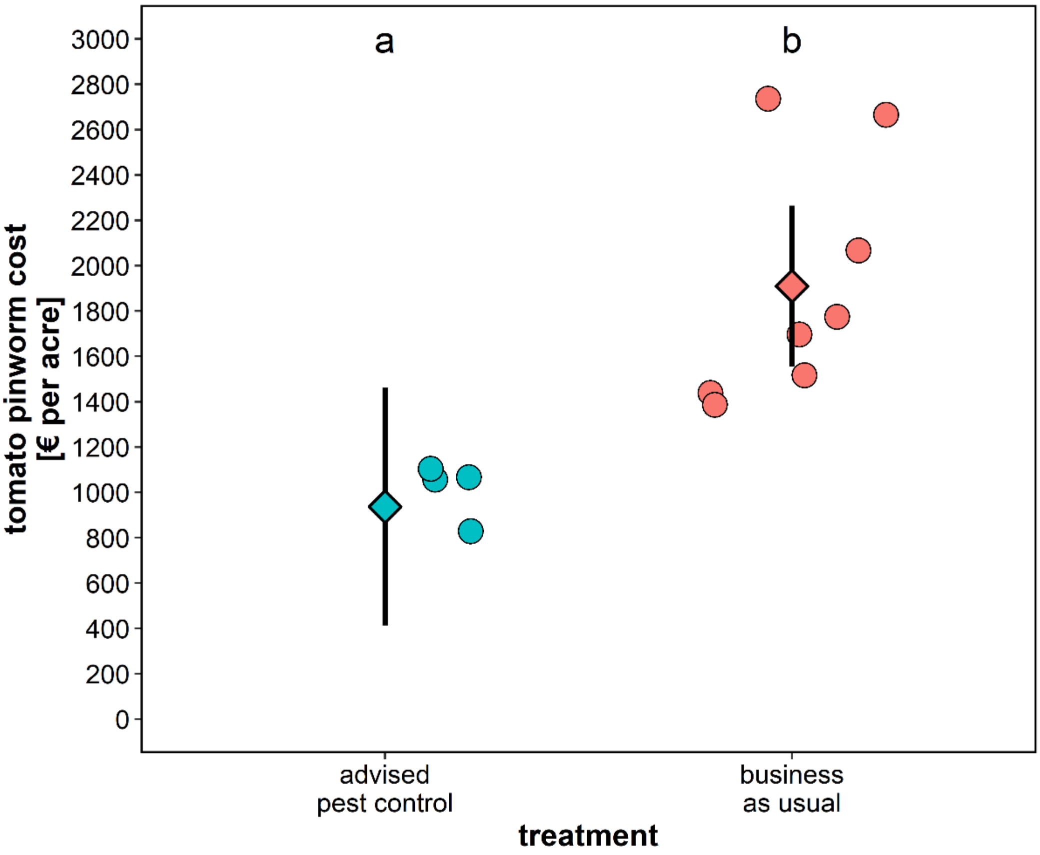

Figure 20. Total cost of tomato pinworm management per acre in greenhouses with advised pest control and business as usual treatments. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment, and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the two treatments (p<0.05).

3.3.3 Tomato pinworm management cost in relation to the total production cost

The fraction of the total production cost that can be attributed to the cost of tomato pinworm management was obtained by dividing the cost of the tomato pinworm management by the total cost of the cultivation.

This fraction was not significantly affected by treatment, being at 16.6 ± 1.3% in business as usual greenhouses and at 14.6 ± 1.7% in greenhouses with advised pest control (Figure 21, Tables 3 & 4).

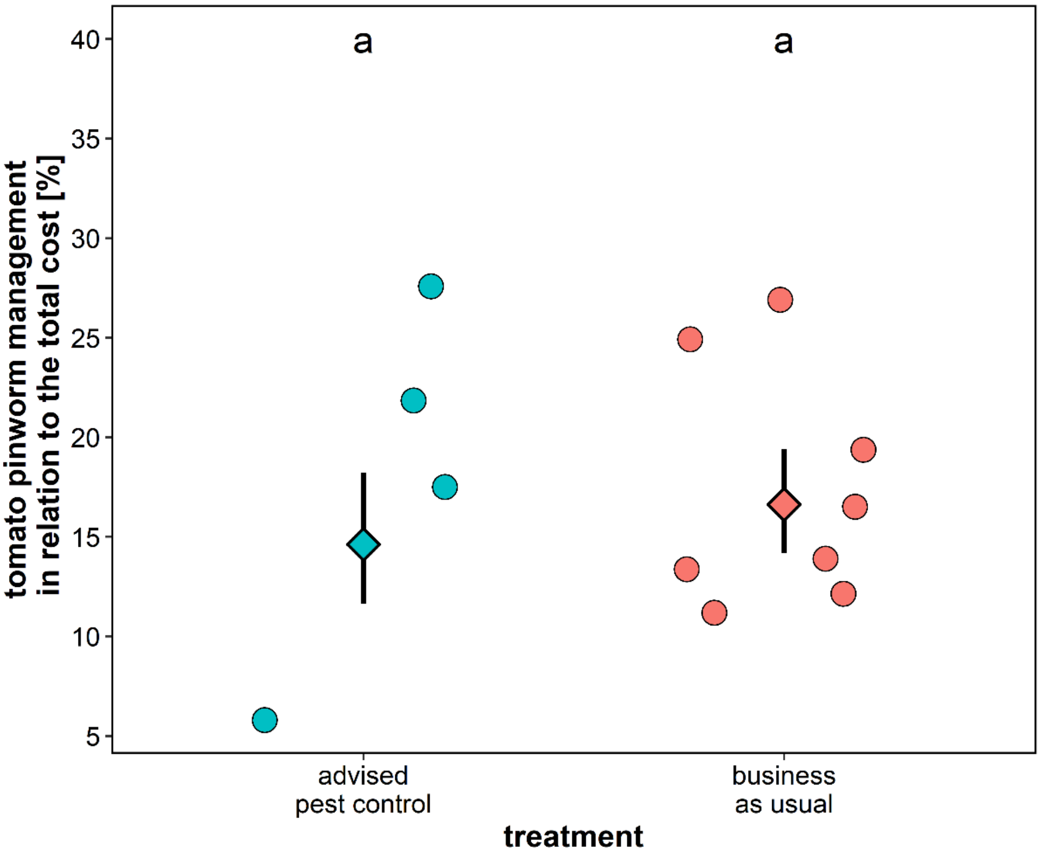

Figure 21. Cost of tomato pinworm management as a fraction of the total production cost for the two treatments, advised pest control and business as usual. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

3.4 Profit in relation to ideal profit

The total profit and the ideal profit were assessed separately within the two treatments. The total profit was not significantly affected by the treatments, with 10445 ± 1252 Euro earned per acre in greenhouses with advised pest control and 8011 ± 848 Euro in business as usual greenhouses (Figure 22, Tables 3 & 4).

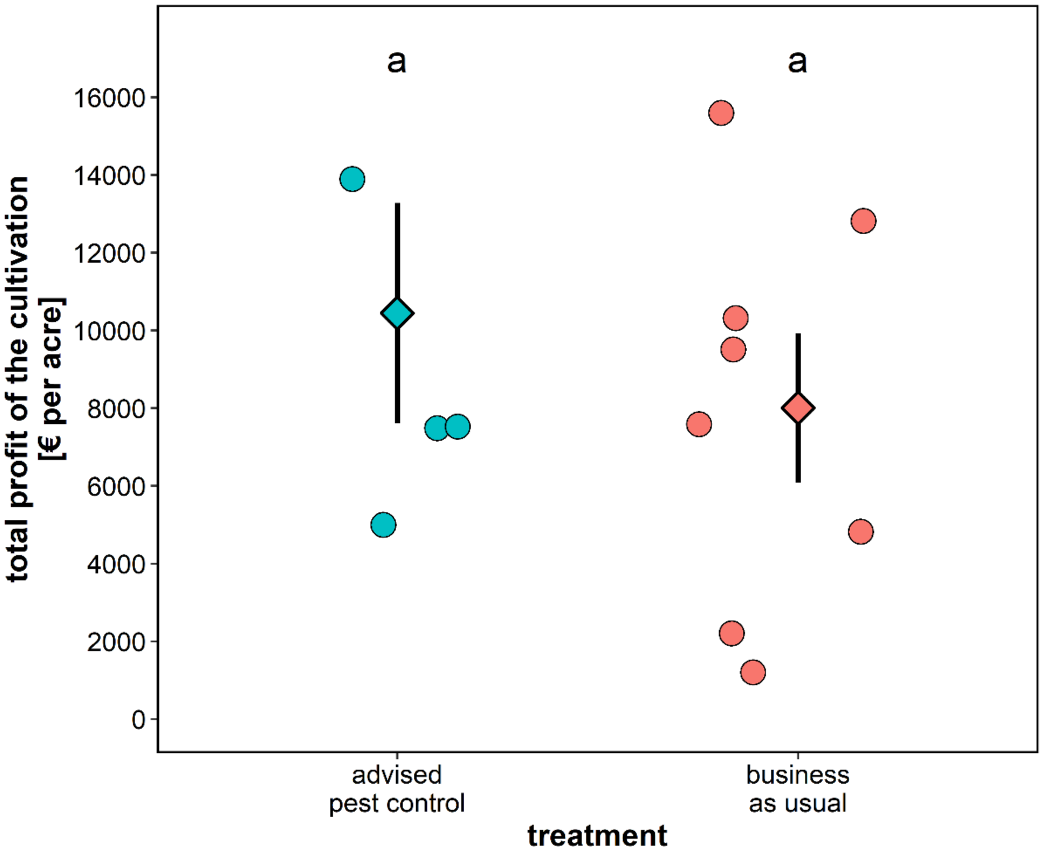

Figure 22. Total profit per acre in greenhouses with advised pest control and business as usual. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

The ideal profit was also not significantly affected by treatments, with possible earnings in business as usual greenhouses of 9280 ± 995 Euro per acre and possible earnings in greenhouses with advised pest control of 11625 ± 1470 Euro (Figure 23, Tables 3 & 4).

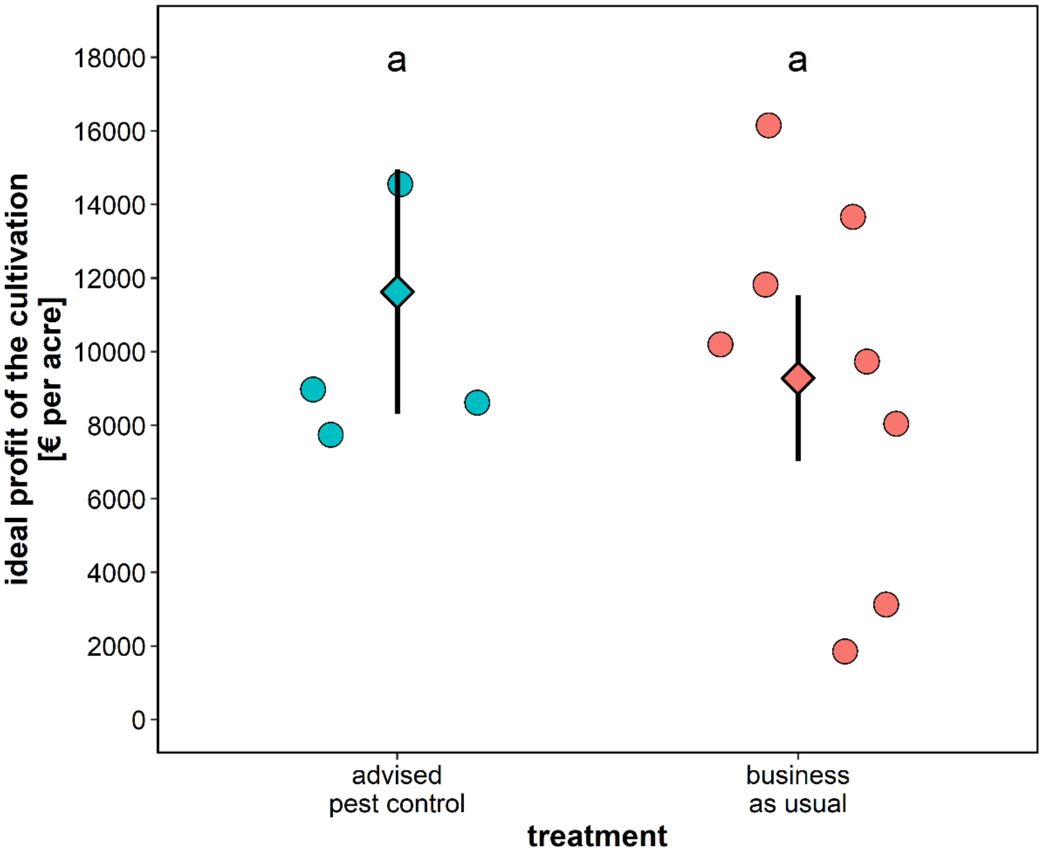

Figure 23. Ideal profit per acre in greenhouses with advised pest control and business as usual. Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments. (p<0.05).

Last, the total profit of the cultivation was compared to the ideal profit both with the relative and the absolute value difference. Neither the relative nor the absolute differences were significantly affected by treatment (Table 3), with 91 ± 2.3% of the possible profits earned in greenhouses with advised pest control and 85.7 ± 2.2% in business as usual greenhouses (Figure 24, Table 4). In absolute numbers, this translates to 1180 ± 464 Euro per acre in greenhouses with advised pest control and 1269 ± 314 Euro per acre in business as usual greenhouses (Figure 25, Table 4).

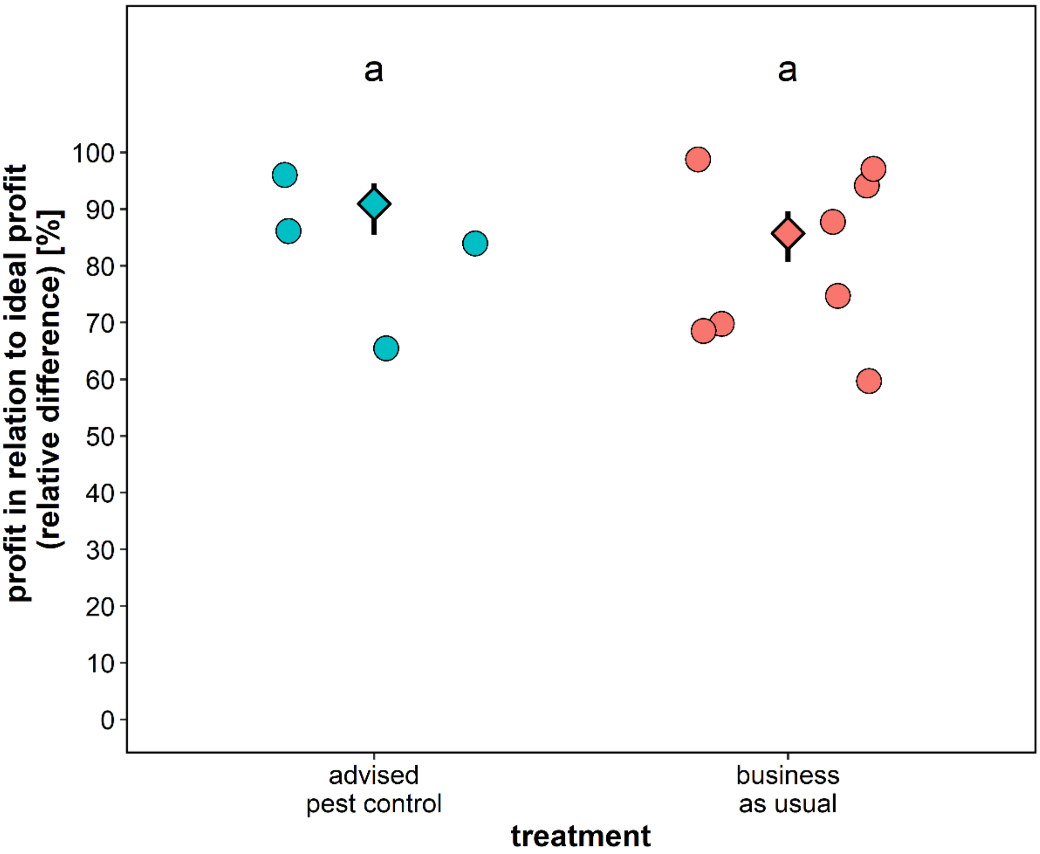

Figure 24. Actual profit (Total cultivation profit) as a share of the potential profit (ideal cultivation profit). Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

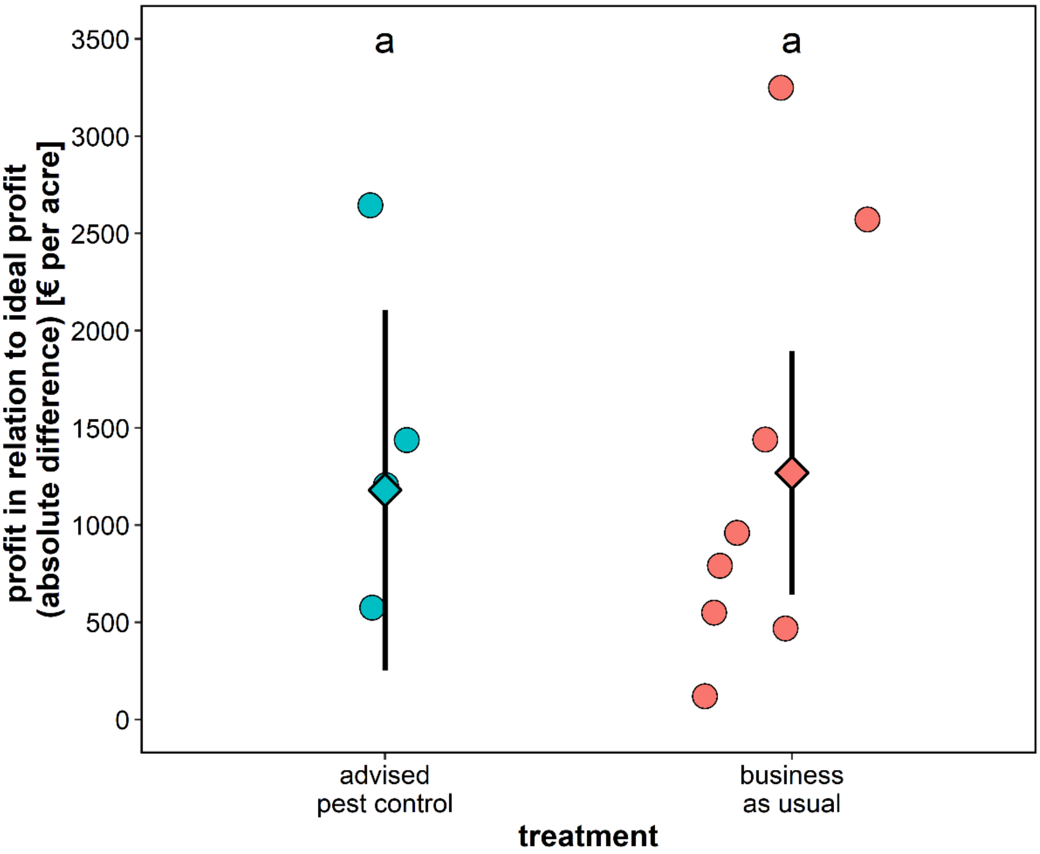

Figure 25. Absolute difference between actual profit (Total cultivation profit) and potential profit (ideal cultivation profit). Points represent individual observations, diamond shapes represent the model prediction (estimated marginal mean) for each treatment and the error bars indicate the 95% confidence interval. Different letters above the categories indicate significant differences between the treatments (p<0.05).

Table 3. Statistical results for the generalised Linear Models (GLM) and Generalised Linear Mixed Models (GLMM) fitted for assessing the effects of tomato type and treatment (advised pest control or business as usual) on different responses related to greenhouse management cost and profits. Df=degrees of freedom, $\chi2$ = chi-square value derived from the Wald chi-square tests, p-value = prob*ability of observing $\chi2$ as extreme as, or more extreme than, the one observed if the null hypothesis is true at the given number of replicated, R^2 = measures how well the model explains the variability of the response data (*) indicates p<0.1, *indicates p<0.05,**indicates p<0.01, ***indicates p<0.001*

response	model	error distribution	fixed effect	Df	χ^2	p-value	R^2
Use of sticky traps	GLM	binomial	type	1, 8	1.53	0.261	0.74
			treatment	1, 8	11.79	**<0.001*****	
Use of pheromone traps	GLM	binomial	type	1, 8	0	1	1
			treatment	1, 8	14.56	**< 0.001 *****	
Use of natural enemies	GLM	binomial	type	1, 8	1.53	0.261	0.74
			treatment	1, 8	11.79	**< 0.001*****	
Days spent on tomato pinworm management	GLMM	lognormal	type	1, 8	27.60	**< 0.001*****	0.74
			treatment	1, 8	48.22	**< 0.001*****	
Number of insecticide applications against the tomato pinworm	GLMM	Gaussian	type	1, 8	19.66	**< 0.001*****	0.67
			treatment	1, 8	1.35	0.245	
Control cost for tomato pinworm in relation to the total control cost	GLMM	beta regression	type	1, 8	0.01	0.900	0.09
			treatment	1, 8	1.07	0.299	
Total B product amount	GLMM	Gamma	type	1, 8	<0.01	0.921	0.58
			treatment	1, 8	037	0.544	
B product amount due to the tomato pinworm in relation to the total B product amount	GLM	binomial	type	1, 8	0.67	0.411	NA
			treatment	1, 8	4.30	**0.038***	

Total B product amount in relation to the total amount	GLMM	beta regression	type	1, 8	11.15	**<0.001*** **	0.23
			treatment	1, 8	14.21	**<0.001*** **	
Total production loss	GLM	Gaussian	type	1, 8	4.35	**0.037(*)**	0.49
			treatment	1, 8	2.28	0.131	
Total production loss due to the tomato pinworm in relation to the total production loss	GLMM	beta regression	type	1, 8	0.13	0.714	0.68
			treatment	1,8	0.17	0.676	
Total production loss in relation to the total production	GLMM	beta regression	type	1, 8	3.22	**0.072(*)**	0.27
			treatment	1, 8	8.13	**0.003** **	
Total cultivation cost	GLM	Gaussian	type	1, 8	20.46	**<0.001*** **	0.77
			treatment	1, 8	4.13	**0.042***	
Tomato pinworm cost	GLM	Gaussian	type	1, 8	1.31	0.253	0.58
			treatment	1, 8	12.11	**<0.001*** **	
Tomato pinworm cost in relation the total cost	GLM	Gaussian	type	1, 8	25.50	**<0.001*** **	0.70
			treatment	1, 8	0.93	0.334	
Total profit of the cultivation	GLM	Gaussian	type	1, 8	15.68	**<0.001*** **	0.64
			treatment	1, 8	1.74	0.186	
Total ideal profit of the cultivation	GLM	Gaussian	type	1, 8	29.60	**<0.001*** **	0.77
			treatment	1, 8	2.60	0.107	
Profit in relation to ideal profit (relative difference)	GLMM	beta regression	type	1, 8	34.34	**<0.001*** **	0.75
			treatment	1, 8	0.01	0.063	
Profit in relation to ideal profit (absolute difference)	GLMM	Gaussian	type	1, 8	6.08	**0.013***	0.34
			treatment	1, 8	3.45	0.855	

Table 4. Estimated marginal means with their standard errors (rounded to two decimals) and the range of the data for both treatments, advised pest control or business as usual, and all models.

model	treatment	estimated marginal mean	standard error	range
Use of sticky traps [presence / absence]	advised pest control	1	0	[1, 1]
	business as usual	1	0.09	[0, 1]
Use of pheromone traps [presence / absence]	advised pest control	1	<0.001	[0, 1]
	business as usual	0	<0.001	[0, 1]
Use of natural enemies [presence / absence]	advised pest control	1	0	[1, 1]
	business as usual	0	0.09	[0, 0]
Days spent for tomato pinworm management [days]	advised pest control	2.08	0.70	[0.5, 20]
	business as usual	18.94	1.40	[9, 28]
Number of insecticide applications against tomato pinworm [applications]	advised pest control	20.60	3.01	[16, 19]
	business as usual	24.2	2.04	[12, 37.5]
Control cost for tomato pinworm in relation to the total cost control [proportion]	advised pest control	0.79	0.04	[0.64, 0.85]
	business as usual	0.73	0.03	[0.60,0.84]
Total B product [kg per acre]	advised pest control	70.6	160	[0, 240]
	business as usual	576.8	956	[390, 1667]
B product amount due to tomato pinworm in relation to the total B product amount [proportion]	advised pest control	0	<0.001	[0, 0]
	business as usual	0.46	<0.001	[0.04, 1]
Total B product amount in relation to the total production [proportion]	advised pest control	<0.01	0.03	[0, 0.02]
	business as usual	0.03	<0.01	[0, 0.14]
Total production loss [kg per acre]	advised pest control	782	215	[120, 1764]
	business as usual	391	145	[0, 833]
Production loss due to the tomato pinworm in relation to the total production loss [proportion]	advised pest control	0.55	0.18	[0, 0.99]
	business as usual	0.46	0.12	[0, 1]
Total production loss in relation to the total production [proportion]	advised pest control	0.09	<0.01	[0.01, 0.2]
	business as usual	0.02	0.01	[0, 0.07]
Total cultivation cost [€ per acre]	advised pest control	8807	1137	[3820, 14332]
	business as usual	11599	770	[7831, 17039]
Tomato pinworm cost [€ per acre]	advised pest control	937	232	[832, 1100]
	business as usual	1910	157	[1387, 2732]
Tomato pinworm cost in relation to the total cost [proportion]	advised pest control	0.15	0.02	[0.06, 0.28]
	business as usual	0.17	0.01	[0.11, 0.27]
Total profit of the cultivation [€ per acre]	advised pest control	10445	1252	[5010, 13891]
	business as usual	8011	848	[1196, 15590]
Total ideal profit of the cultivation [€ per acre]	advised pest control	11625	1470	[7656, 14467]
	business as usual	9280	995	[1746, 16058]
Profit in relation to ideal profit (relative difference) [proportion]	advised pest control	0.91	0.02	[0.65, 0.97]
	business as usual	0.86	0.02	[0.59, 0.99]
Profit in relation to ideal profit (absolute difference) [€ per acre]	advised pest control	1180	464	[576, 1205]
	business as usual	1269	314	[120, 2571]

4. Discussion

In line with hypothesis (H1), advised pest control in greenhouses increased the use of environmetally friendly practices. Pheromone traps and natural enemies were almost exclusively used in greenhouses with advised pest control, while business as usual greenhouses showed almost no use of these methods. Additionaly, I found no difference in the total pest control cost related to the tomato pinworm which only includes, the costs of chemical and biological control products, although less days were required for its management in the greenhouses with advised control pest. However, contrary to hypothesis (H2), the production loss attributable to the tomato pinworm was not significantly reduced by advised pest control and neither was the proportion of production lost due to the tomato pinworm. Interestingly, greenhouses with advised pest control, had a significantly lower amount of B product, indicating a reduction of lower-quality produce, which partially supports the hypothesis. As expected (H3), the overall cultivation costs and the total costs for tomato pinworm management were significantly lower in greenhouses with advised pest control. Despite that, profitability (H4), was not significantly different between business as usual greenhouses and greenhouses with advised pest control. While many studies suggest that professional advice enhances profitability and sustainability (Ainembabazi, 2024; Tayang et al., 2023) the results of this study present a more complex relationship, in which advised pest control management increases environmentally friendly practices, reduces costs but did not statistically significantly increase profitability. This indicates that while advisory services are beneficial, other factors may influence the overall economic outcomes.

4.1 Tomato pinworm management

My study revealed that environmentally friendly practices for tomato pinworm management were more prevalent in greenhouses with advised pest control than in those following business as usual, in line with hypothesis (H1). These findings align with previous research indicating that professional advisory services can significantly enhance the adoption of sustainable agricultural practices (Ainembabazi, 2024; Tayang et al., 2023). For instance, (Ainembabazi, 2024) demonstrated that greenhouses receiving regular advisory input showed higher integration of sustainable land management practices.

Several factors contribute to the higher adoption rate of environmentally friendly practices among greenhouses with advised pest control. For example, guidance from professional advisors and access to information on effective and sustainable pest control methods shaped pest control in advised greenhouses, whereas in business as usual greenhouses the methods used are empirical, passed from generation to generation, and based on the experience of the farmer. This includes the use of biological control agents, pheromone traps, and the use of biological insecticides. My findings support this, as greenhouses with advised pest control were observed to implement a broader range of integrated pest management strategies compared to business as usual greenhouses.

Pheromone traps, for example, offer significant environmental benefits over sticky traps, as pheromone traps attract male individuals by mimicking the natural pheromones emitted by female individuals, whereas sticky traps can also catch beneficial insects and non-target insects (Carrillo-Arámbula et al., 2022; Sabbahi & Azzaoui, 2022).

Natural enemies as a biological control method were also being used to a larger extent in the greenhouses with advised control. Introducing predators or parasitoids helps control pest populations sustainably and non-toxically while reducing chemical residues in the environment and, in the long-term, preserving biodiversity (Pandey et al., 2023). These biological control agents not only provide pest suppression but they can also have a positive economic impact for the farmers (Martínez-Sastre et al., 2020). Contrary to my expectations, some business as usual greenhouses also implemented environmentally friendly practices such as the use of sticky traps for monitoring or the use of natural enemies for pest control but these were not consistently applied like in the greenhouses with advised pest control. This inconsistency could be attributed to a lack of comprehensive knowledge and support, which advisory services are designed to provide (*FAS - European Commission*, 2024).

The environmental practices in greenhouses with advised pest control were also reflected by the pesticide applications. For example, for the three greenhouses with advised pest control greenhouses in Tympaki, although the number of applications was not significantly different from the business as usual greenhouses, fewer chemical insecticides were used during those applications, and a wider range of biological agents were selected instead. On the other hand, in the advised pest control greenhouse in Ierapetra, applications were reduced by 50 percent and mostly the agent Epsilon was used . This is important for the sustainability of tomato cultivation, as it mitigates the negative impacts of chemical pesticides on soil health, water contamination, non-target organisms, and overall ecosystem balance (Bonabana-Wabbi & Taylor, 2008).

Although I observed several differences regarding the chemical and biological control of the tomato pinworm, this did not translate to reduced costs, as the pest control cost for the tomato pinworm as a fraction of the total pest control was comparable between both treatments used in the greenhouses.

4.2 Crop damages

The results for crop damages also supported my hypothesis (H2) that crop losses due to the tomato pinworm are lower in the greenhouses with advised pest control than in the business as usual greenhouses.

The amount of product sold at a lower price (B product), was not significantly affected by the treatment, with 70.6 ± 160 kg in greenhouses with advised pest control and 576.8 ± 956kg in business as usual greenhouses. This suggests that although the overall B product amount varies, the absence of advisory services can lead to a more substantial and potentially more consistent B product amount. In addition, the share of B product due to the tomato pinworm out of the total B product amount was 45 percent points higher in business as usual greenhouses, which indicates that advised greenhouses mitigate the damage caused by the tomato pinworm, resulting in a significantly lower proportion of B product attributed to pest damage.

This can be seen as well in the total B product amount as a share of the total production of the cultivation, which was also significantly higher in business as usual, with almost 3% in contrast to 0% in the greenhouses with advised pest control, illustrating that advised farms have a much lower proportion of their total production impacted by lower quality B product.

The total production loss was another measure that was taken into account to support the hypothesis (H2). Although the total production loss was almost two times higher in the greenhouses with advised pest control than in the business as usual greenhouses, the proportion of loss attributed to the tomato pinworm was not significantly different between the treatments. Furthermore, the loss of production as a fraction of the total production was also significantly affected by the treatments, with a roughly seven percent points higher loss in greenhouses with advised pest control. This could be due to various reasons, such as climate factors, pests, diseases, soil quality, and water availability, as well as the tomato variety (Liliane & Mutengwa, 2020).

Different pests and diseases may not have been treated with the same diligence by the farmer and the advisor, as the advisory help was specifically focused on tomato pinworm management.

Regarding, the losses caused by the tomato pinworm it could be that the farmers did not follow the instructions meticulously from the beginning or during the process, or that it took time to trust the advisor and change their usual cultivation practices which they had been following for years.

4.3 Costs

The economic analysis of the tomato pinworm management revealed that the total production costs and the total costs associated with tomato pinworm management differed significantly between advised and business as usual greenhouses which correspond with my hypothesis (H3).

For the total cultivation costs, business as usual greenhouses spent an average of 11599 ± 770 Euro per acre, while greenhouses with advised pest control spent significantly less with 8807 ± 1137 Euro per acre.

Focusing even more on the results and taking a look at the costs directly linked to the management of the tomato pinworm, it becomes evident that business as usual had significantly higher expenses. Specifically, business as usual greenhouse spent 1910 ± 157 Euro per acre on tomato pinworm management, whereas the greenhouses with advised pest control spent 937 ± 232 Euro per acre. This significant cost reduction in advised pest control greenhouses underscores the effectiveness of IPM strategies in lowering pest management expenses as stated in previous research (Bale et al., 2007; Boussemart et al., 2016).

To understand the economic impact of tomato pinworm management within the broader context of total cultivation cost, I also looked at the total tomato pinworm management cost as a fraction of the total cultivation cost. In this case, there was no significant difference between the treatments, in which the same proportion of money from the total cost is spent on tomato pinworm management, in greenhouses with advised pest control and business as usual greenhouses.

The economic advantages observed in greenhouses with advised pest control are closely linked to their adoption of environmentally friendly practices. As previously discussed, the implementation of a broader range of IPM strategies is advised, including the use of pheromone traps to monitor the pest's abundance, natural enemies, and biological insecticides, which can reduce the reliance on chemical pesticides and mitigate negative environmental impact. These practices, not only contribute to sustainable agriculture but as shown here and similar studies can translate into economic savings as well (Bale et al., 2007; Lefebvre et al., 2015).

4.4 Profit

To test the hypothesis that the profitability of tomato cultivation is higher in greenhouses with advised pest control compared to business as usual greenhouses (H4), the total profit and ideal profit were assessed separately for each treatment.

The results of the study do not support the hypothesis (H4), as both total profit and ideal profit were comparable between the treatments, and the profit as a fraction of ideal profit also showed no significant differences.

While the total and ideal profits were not significantly different between advised pest control and business as usual greenhouses, the profit in the greenhouses with advised pest control was not lower than the profit in business as usual greenhouses either. The lower costs associated with tomato pinworm management, the reduced crop damage, and the fewer labour days for tomato pinworm management in greenhouses with advised pest control suggest a reduced pressure on biodiversity and the environment, prevent insecticide resistance, and result in similar profit. The initial lack of significant profit differences could be related to the relatively short duration of the advisory programs, the way farmers implement the advisors' instructions, and the small sample size for the greenhouses with advised pest control.

As advisory programs evolve and gain more extensive implementation, as well as trust increases between farmers and advisors the financial benefits might become more pronounced, potentially leading to greater profitability over time.

Furthermore, the profit of the greenhouses is not only related to the tomato pinworm management. Thus, several other factors could affect it. Among others, the price that the product is being sold is highly connected with the profitability of the farm, as well as the total production of the cultivation. Profitability is equal to income minus the costs, where income is the produced product multiplied by the price as stated in the methods part and by Fausti et al., (2017). Integrated pest management has been shown to potentially increase tomato yield (Gajanana et al., 2006) and if pest management practices suggested by the advisors are followed thoroughly to reduce losses, an increase in income and additionally on profit can be achieved. Furthermore, financial support, such as different prices for integrated pest management products could also help the profitability of the farmers, as for now this is not the case (Lefebvre et al., 2015).

4.5 Limitations of the study

The study, although it provides valuable insights into greenhouse practices for tomato cultivation and the management of the tomato pinworm for two case scenarios, advised pest control with regards to integrated pest management and business as usual, has several limitations that need to be considered.

First, the research was conducted in two different areas of Crete, Tympaki, and Ierapetra where different climatic, soil, and water conditions occur. These varying climates could influence the growth, yield, and pest management needs of the tomatoes (Liliane & Mutengwa, 2020).

Second, the research was conducted with a very limited sample size of greenhouses with advised pest control (only four) as this management is novel and not yet widely adopted. This small sample size restricts the generalizability of the findings and may not accurately represent the broader number of greenhouse tomato cultivations (Nayak, 2010). In addition, some of the not significant differences reported here may become significant with a larger sample size.

Third, both advised programs included in the study did not run for an extended period yet. Short-term observations may not capture the full range of variables and outcomes that could influence the effectiveness and sustainability of the advised pest control greenhouse practices over longer periods.

Fourth, although the number of pesticide applications was not significantly affected by the treatments, the dose of the insecticide per acre might differ, which could not be assessed within this study. Large pesticide doses could potentially create pesticide resistance in pests, which limits the effectiveness of pest management and overall plant health, thereby potentially influencing the results of the study (Kole et al., 2019).

Fifth, in business as usual greenhouses, many of the costs reported by the farmers were estimations rather than precise records as some farmers do not keep detailed records. This includes estimates for cultivation costs and costs regarding tomato pinworm management. The lack of detailed, recorded financial data introduces a degree of uncertainty and potential inaccuracy in the economic analysis, which could affect the reliability of the conclusions drawn.

Finally, the study included different types of tomatoes, specifically normal and cherry tomatoes. Although the type was taken into account in the statistical analysis, based on the data selected, the two types had different market values, with cherry tomatoes being sold at higher prices than normal tomatoes. Additionally, management practices of the cultivation and cultivation needs could also differ between tomato types, which could also affect the economic outcomes of the study. Unfortunately, the sample size for cherry tomatoes with advised pest control was too low to investigate the potential effects of tomato type on the economic effects of advised pest management further.

By acknowledging these limitations, future research can be designed to address these issues, potentially by increasing the sample size, extending the duration of the study, and using more precise methods for cost estimation. Furthermore, conducting studies in more controlled environments or ensuring uniformity in tomato types, and climatic conditions could yield more definitive insights.

5. Conclusions

In this study, I evaluated the impact of advised pest control practices compared to business as usual methods, on the management of the tomato pinworm in greenhouse tomato cultivation. The research focused on four primary areas: adoption of environmental practices, economic efficiency, and overall profitability, as well as crop damage.

The findings revealed that greenhouses with advised pest control adopted significantly more environmentally friendly practices, such as pheromone traps and the use of natural enemies. These practices contribute to sustainable agriculture by reducing reliance on chemical pesticides and promoting biodiversity and which aligns with previous studies that emphasize the benefits of professional advisory services in enhancing sustainable agricultural practices (Ainembabazi, 2024; Tayang et al., 2023). Despite these advancements, the reduction in production loss attributable to the tomato pinworm was not significantly different between advised pest control and business as usual greenhouses. However, the quality of the produce was improved in greenhouses with advised pest control, with a significantly lower amount of lower quality B product, which indicates that while advisory services help mitigate pest damage to some extent, other factors may influence the overall production loss (Liliane & Mutengwa, 2020).

Economic analysis showed that advised pest control greenhouses had significantly lower overall cultivation costs and costs associated with tomato pinworm management. However, I did not find a significant difference in profitability between the two treatments, suggesting that factors beyond the tomato pinworm management and practices, such as sample size, market prices, and total production, play a crucial role in determining overall profitability (Fausti et al., 2017).

Nevertheless, it is important to take into account the limitations of this study. These include the small sample size, the short duration of the advised programs, and the variability introduced by different climatic conditions, estimated costs, and tomato types. Future research should address these limitations by increasing sample size, extending the duration of advisory programs, and using more precise methods for cost estimation.

Overall, the study highlights the importance of adopting environmentally friendly pest control practices as they contribute to sustainable agriculture, promote biodiversity, and, even in the short-term, result in economic benefits, with the possibility for even greater benefits in the long-term. Continuous monitoring and adaptation of integrated pest management practices are crucial for maintaining sustainable agriculture and ensuring the long-term viability of tomato cultivation. Building trust between farmers and advisors is essential, for pest management to succeed. Providing financial support to producers who implement these practices could encourage wider adoption. Further research on tomato cultivation and the economic aspects of integrated pest management is needed for the future.

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Popular science summary

Imagine you are a tomato farmer in Crete, navigating the complexities of pest management while striving for high yields and profitability. A few years ago, your methods were straightforward adhering to traditional practices passed down through generations. The business as usual approach provided predictability but also brought challenges, particularly in managing newly introduced pest, the persistent tomato pinworm, *Tuta absoluta*.

Your fields, once reliant on conventional pest control methods, faced frequent infestations that required significant time and resources to manage. The costs associated with pesticide applications, labour, and crop losses were substantial, cutting into your profits and posing risks to both the environment and your health.

In recent years, a new approach has emerged the integration of professional advisory assistance in pest management. This method brings expertise and innovative strategies aimed at improving pest management efficiency and sustainability. The promise of reduced costs, enhanced use of environmentally friendly practices, lower production losses, and increased profitability has piqued your interest.

This study delves into the economic impact of these two pest management strategies, comparing traditional business as usual management with advised pest control in greenhouses on Crete. By analysing the cost-benefit dynamics and assessing the efficacy of these treatments, I aim to provide insights that can help farmers like you make informed decisions.

My research reveals that the total cultivation costs and specific expenses related to tomato pinworm management are significantly lower in greenhouses utilizing advised pest control. Additionally, advised farms exhibit a higher adoption of environmentally friendly practices, such as the use of pheromone traps and natural enemies, which are crucial for sustainable agriculture.

Despite these advance, the journey of transitioning to advisory assistance is not without its challenges. Production losses and profitability vary, highlighting the need for continuous adaptation and learning. However, the overall findings suggest that integrating professional advice into pest management strategies can lead to a more sustainable and profitable future for tomato farmers on Crete.

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Appendix 1

Table A 1. Total production per acre. Here all production numbers were calculated per acre. Total production refers to the total yield of the cultivation, A product in the amount that was sold at full price from the total production, B product the product that was sold for a lower price from the total production, and lost production the amount that was not sold at all from the total production. B product Tuta and Lost production Tuta, are the amount sold for a lower price or not at all due to the tomato pinworm infestation.

Farm	GH1	GH2	GH3	GH4	GH5	GH6	GH7	GH8	GH9	GH10	GH11	GH12
TOTAL PRODUCTION	8345.22	9331.30	9171.75	12000.00	11000.00	12000.00	13000.00	8500.00	14473.68	12000.00	14000.00	12500.00
A PRODUCT	7540.00	8371.74	7408.50	11640.00	10670.00	11400.00	12610.00	8400.00	13026.32	10000.00	13000.00	10000.00
B PRODUCT	0.00	0.00	0.00	240.00	0.00	0.00	390.00	100.00	657.89	1428.57	1000.00	1666.67
LOST PRODUCTION	803.48	958.70	1764.00	120.00	330.00	600.00	0.00	0.00	789.47	571.43	0.00	833.33
B PRODUCT TUTA	0.00	0.00	0.00	0.00	0.00	0.00	390.00	26.32	26.32	960.00	800.00	1500.00
LOST PRODUCTION TUTA	803.48	383.48	1764.00	0.00	330.00	600.00	0.00	0.00	0.00	171.43	0.00	833.33

Appendix 2

*Table A 2. General Information of the Greenhouses. Here is some information about the area where the GH is placed, the size in acres of each one, the type of greenhouse (material is made), the variety that each cultivation has, the total production in tons, the full price of the tomato or cherry tomato, and whether is advised (ADV) or business as usual (BUA). (*average price)*

Farn	GH1	GH2	GH3	GH4	GH5	GH6	GH7	GH9	GH9	GH10	GH11	GH12
AREA	Tympaki	Tympaki	Tympaki	Ierapetra	Ierapetra	Ierapetra	Ierapetra	Ierapetra	Messara	Messara	Messara	Messara
Size	2.3	2.3	4.0	5.0	2.5	2.0	3.0	2.0	3.8	3.5	1.0	1.2
Greenhouse Type	plastic	plastic	plastic	plastic	plastic	plastic	plastic	plastic	plastic	plastic	plastic	plastic
Tomato Specie	Elpida	Elpida	Elpida	Lobello	Lobello	Lobello	Lobello	Lobello	Runner	Elpida	Tyscala	Elpida
Total Yield tons	19.19	21.46	36.69	60.00	27.50	24.00	39.00	17.00	55.00	42.00	14.00	15.00
Tomato Price *	1.50	1.50	1.50	2.40	2.40	2.40	2.40	2.40	0.80	1.50	0.85	1.50
Cultivation Method	ADV	ADV	ADV	ADV	BUA	BUA	BUA	BUA	BUA	BUA	BUA	BUA

Table A 3. Overall costs. For each category the unit was collected (measurement), the quantity (how many units), and the price of the unit, to calculate the total cost and cost per acre for each category. At the end of all data, a sum was made for each GH with the total cultivation cost and total cultivation cost per acre. The table continues on the following pages.

FARMS	GH1					GH4					GH3				
OVERALL COSTS	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
1. Work costs															
i) Family labour					0.00 €					0.00 €					0.00 €
ii)Worker’s labour	1.00	15.00	45.00	225.00 €	97.83 €	1.00	60.00	45.00	2,700.00 €	1,173.91 €	2.00	120.00	45.00	10,800.00 €	2,700.00 €
2. Seed cost	plants	6000.00	0.35	2,100.00 €	913.04 €	Plants	4000.00	0.35	1,400.00 €	608.70 €	Plants	5000.00	1.00	5,000.00 €	1,250.00 €
3. Utility costs					0.00 €					0.00 €					0.00 €
i) pesticides					0.00 €					0.00 €					0.00 €
insecticides	total	1.00	1897.17	1,897.17 €	824.86 €	total	1.00	2115.70	2,115.70 €	919.87 €	total	1.00	3217.09	3,217.09 €	804.27 €
fungicides	total		200.00	200.00 €	86.96 €	total	1.00	250.00	250.00 €	108.70 €	total	1.00	500.00	500.00 €	125.00 €
Plant regulators/biostimulants															
ii) biological control															
Registered predators release	bottles	5.00	50.00	250.00 €	108.70 €						bottles	8.00	50.00	400.00 €	100.00 €
Registered parasitoids release	1 pack	2.50	33.00	82.50 €	35.87 €	1 pack	2.50	33.00	82.50 €	35.87 €	1 pack	3.00	33.00	99.00 €	24.75 €
iv) fertilization	total	1.00	1650.00	1,650.00 €	717.39 €	total	1.00	1450.00	1,450.00 €	630.43 €	total	1.00	1780.00	1,780.00 €	445.00 €
Basic fertilisation before planting															
Crystalline drip N-P-K															
Crystalline drip (ammonium nitrate)															

Crystalline drip potassium nitrate															
Crystalline drip magnesium nitrate															
Crystalline drip calcium nitrate															
Foliar fertilisers (other)															
iv) tomato propagation material costs															
v) pollination (beehives costs)	beehives	2.00	100.00	200.00 €	86.96 €	beehives	2.00	100.00	200.00 €	86.96 €	beehives	2.00	100.00	200.00 €	50.00 €
4. Soil analysis costs / water analysis costs															0.00 €
5. Irrigation/water consumption	6 months	1.00	800.00	800.00 €	347.83 €	6 months	1.00	750.00	750.00 €	326.09 €	cubic meters	3000.00	3.33	900.00 €	225.00 €
6. Equipment Costs					0.00 €					0.00 €					0.00 €
i) traps					0.00 €					0.00 €					0.00 €
sticky traps	acre	2.30	136.00	312.80 €	136.00 €	acre	2.30	136.00	312.80 €	136.00 €	acre	4.00	136.00	544.00 €	136.00 €
light/pheromone traps	traps	(2+42+1)	68.68	68.68 €	29.86 €	traps	(2+42+1)	68.68	68.68 €	29.86 €	traps	(2+42+1)	68.68	68.68 €	17.17 €
7. Maintenance costs					0.00 €					0.00 €					0.00 €
8. Electricity costs	all year	0.50	200.00	100.00 €	43.48 €	every month	6.00	175.00	1,050.00 €	456.52 €	every month	6.00	50.00	300.00 €	75.00 €
11. Other costs					0.00 €					0.00 €					0.00 €
	TOTAL AND TOTAL/ACRE			8,786.15 €	3,820.07 €	TOTAL AND TOTAL/ACRE			11,579.68 €	5,034.64 €	TOTAL AND TOTAL/ACRE			24,408.77 €	6,102.19 €

GH4					GH5					GH6				
UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
1.00	365.00	45.00	16,425.00 €	3,285.00 €	1.00	30.00	40.00	1,200.00 €	480.00 €	2.00	300.00	40.00	24,000.00 €	12,000.00 €
2.00	330.00	45.00	29,700.00 €	5,940.00 €	2.00	200.00	40.00	16,000.00 €	6,400.00 €	-				0.00 €
plants per acre	300.00	1.10	330.00 €	66.00 €	plants	2812.50	0.95	2,671.88 €	1,068.75 €	plants	1800.00	1.00	1,800.00 €	900.00 €
barrels	29.00	90.00	2,610.00 €	522.00 €	barrels	42.75	80.00	3,645.00 €	1,458.00 €	barrels	37.50	80.00	3,875.00 €	1,937.50 €
barrels	10.00	90.00	900.00 €	180.00 €	barrels	9.00	80.00	720.00 €	288.00 €	barrels	9.00	80.00	720.00 €	360.00 €
bottles	6.00	133.33	800.00 €	160.00 €										
sacks	12.00	33.00	396.00 €	79.20 €	sacks	1.00	45.00	45.00 €	18.00 €	sack per year	1.00	38.00	38.00 €	19.00 €
sacks	200.00	32.00	6,400.00 €	1,280.00 €	sacks	72.00	33.00	2,376.00 €	950.40 €	sack	40.00	33.00	1,320.00 €	660.00 €
sacks	2.00	22.00	44.00 €	8.80 €	sacks	18.00	27.00	486.00 €	194.40 €	sack	10.00	23.00	230.00 €	115.00 €
sacks	40.00	24.00	960.00 €	192.00 €	sacks	65.00	25.00	1,625.00 €	650.00 €	sack	38.00	25.00	950.00 €	475.00 €
beehives	23.00	102.00	2,346.00 €	469.20 €	beehive	7.00	110.00	770.00 €	308.00 €	beehives	5.00	105.00	525.00 €	262.50 €

water analysis	6.00	75.00	450.00 €	90.00 €	-				0.00 €	-				0.00 €
total	1.00	2000.00	2,000.00 €	400.00 €	cubic meters	1875.00	0.25	1,171.88 €	468.75 €	cubic meters	1600.00	0.25	400.00 €	200.00 €
				0.00 €					0.00 €					0.00 €
				0.00 €					0.00 €					0.00 €
black	around the field	500.00	500.00 €	100.00 €	packet	5.00	10.00	50.00 €	20.00 €	black and yellow	10.00	10.00	100.00 €	50.00 €
per month	12.00	400.00	4,800.00 €	960.00 €	every 2 months	6.00	200.00	1,200.00 €	480.00 €	every 2 months	6.00	20.00	120.00 €	60.00 €
total	1.00	3000.00	3,000.00 €	600.00 €										
TOTAL AND TOTAL/ACRE			71,661.00 €	14,332.20 €	TOTAL AND TOTAL/ACRE			31,960.75 €	12,784.30 €	TOTAL AND TOTAL/ACRE			34,078.00 €	17,039.00 €

GH7					GH8					GH9				
UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
2.00	330.00	40.00	26,400.00 €	8,800.00 €	1.00	151.00	35.00	5,285.00 €	2,642.50 €					0.00 €
1.00	84.00	40.00	3,360.00 €	1,120.00 €	-				0.00 €	2.00	6 months	5500.00	11,000.00 €	2,894.74 €
plants	3000.00	1.10	3,300.00 €	1,100.00 €	plant	1500.00	1.00	3,000.00 €	1,500.00 €	plant	7500.00	0.36	2,700.00 €	710.53 €
				0.00 €					0.00 €					0.00 €
				0.00 €					0.00 €					0.00 €
barrels	51.00	85.00	5,270.00 €	1,756.67 €	all chemicals	1.00	1856.00	1,856.00 €	928.00 €	total cost			5,000.00 €	1,315.79 €
barrels	12.75	85.00	1,083.75 €	361.25 €	all	1.00	500.00	500.00 €	250.00 €	total cost			1,000.00 €	263.16 €
					all	1.00	390.00	390.00 €	195.00 €					0.00 €
									0.00 €					0.00 €
					eggs	9.00	47.00	423.00 €	211.50 €					0.00 €
														0.00 €
										all			1,600.00 €	421.05 €
										100 cubic meters	1.00	2000.00	666.67 €	175.44 €
					all	1.00	1000.00	1,000.00 €	500.00 €					
					all	1.00	2000.00	2,000.00 €	1,000.00 €					
sacks	45.00	30.50	1,372.50 €	457.50 €	all	1.00	1375.00	1,375.00 €	687.50 €					
sacks	40.00	26.00	1,040.00 €	346.67 €	all	1.00	1000.00	1,000.00 €	500.00 €					
sacks	44.00	24.00	1,056.00 €	352.00 €	all	1.00	385.00	385.00 €	192.50 €					
per month	1.00	50.00	50.00 €	16.67 €	all	1.00	465.00	465.00 €	232.50 €					
				0.00 €					0.00 €					
beehive	7.00	95.00	665.00 €	221.67 €	beehive	7.00	85.00	595.00 €	297.50 €	beehive	8.00	100.00	800.00 €	210.53 €
analysis per year	1.00	80.00	80.00 €	26.67 €	analysis	1.00	100.00	100.00 €	50.00 €	analysis	4.00	50.00	200.00 €	52.63 €

cubic meters	1950.00	0.25	487.50 €	162.50 €	cubic meters	1900.00	0.25	475.00 €	237.50 €	cubic meters	7500.00	0.40	3,000.00 €	789.47 €
black/yellow/blue	9.00	120.00	1,080.00 €	360.00 €	trap	50.00	0.90	45.00 €	22.50 €					
										maintenance	1.00	500.00	500.00 €	131.58 €
every 2 months	6.00	30.00	180.00 €	60.00 €	month	9.00	20.00	180.00 €	90.00 €	6 months	1.00	500.00	500.00 €	131.58 €
				0.00 €	month	9.00	100.00	900.00 €	450.00 €	month	6.00	500.00	3,000.00 €	789.47 €
				0.00 €	packaging	22000.00	0.07	1,540.00 €	770.00 €	sterilized		1.00	1,960.00 €	515.79 €
TOTAL AND TOTAL/ACRE			45,424.75 €	15,141.58 €	TOTAL AND TOTAL/ACRE			21,514.00 €	10,757.00 €	TOTAL AND TOTAL/ACRE			31,926.67 €	8,401.75 €

GH10					GH11					GH12				
UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
1.00	300.00	45.00	13,500.00 €	3,857.14 €	1.00	60.00	45.00	2,700.00 €	2,700.00 €	1.00	50.00	45.00	2,250.00 €	1,875.00 €
Plant	6000.00	0.31	1,860.00 €	531.43 €	plants	1857.00	0.34	631.38 €	631.38 €	plants	2500.00	0.34	850.00 €	708.33 €
									0.00 €					0.00 €
				0.00 €										
			4,500.00 €	1,285.71 €	total cost	1.00	1.00	1,500.00 €	1,500.00 €	total cost	1.00	1.00	2,500.00 €	2,083.33 €
total cost			800.00 €	228.57 €	total cost			400.00 €	400.00 €	total cost			500.00 €	416.67 €
total cost			5,300.00 €	1,514.29 €	total cost			3,000.00 €	3,000.00 €	total cost			4,500.00 €	3,750.00 €
Beehive	4.00	100.00	400.00 €	114.29 €	beehive	2.00	100.00	200.00 €	200.00 €	beehive	2.00	100.00	200.00 €	166.67 €
										soil analysis	1.00	50.00	50.00 €	41.67 €

cubic meters	total	1.00	500.00 €	142.86 €	cubic meters	total	total	300.00 €	300.00 €	cubic meters	3000.00	0.40	1,200.00 €	1,000.00 €
				0.00 €					0.00 €					0.00 €
				0.00 €					0.00 €					0.00 €
1 barrel of glue	1.00	50.00	50.00 €	14.29 €	plastic wrap +glue	2+2	136.00	272.00 €	272.00 €	plastic wrap +glue	1+1	136.00	136.00 €	113.33 €
				0.00 €					0.00 €					0.00 €
				0.00 €	renovation	1.00	500.00	500.00 €	500.00 €	renovation			150.00 €	125.00 €
total cost	1.00	500.00	500.00 €	142.86 €	total		50.00	50.00 €	50.00 €	every 2 months	3.00	45.00	135.00 €	112.50 €
										month	7.00	50.00	350.00 €	291.67 €
					sterilize		1.00	600.00 €	600.00 €					
TOTAL AND TOTAL/ACRE			27,410.00 €	7,831.43 €	TOTAL AND TOTAL/ACRE			10,153.38 €	10,153.38 €	TOTAL AND TOTAL/ACRE			12,821.00 €	10,684.17 €

Table A 4. Costs for the tomato pinworm management. Here the respectively costs regarding the management of the tomato pinworm were calculated, the same way as in Table A3. At the end, the sum of the total cost and total cost per acre was also calculated. The table continues on the following pages.

FARMS	GH1					GH2					GH3				
COSTS FOR TUTA	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
1. Work costs															
Family labour															
Workers labour	1.00	0.50	45.00	22.50 €	9.78 €	1.00	2.00	45.00	90.00 €	39.13 €	1.00	4.00	45.00	180.00 €	45.00 €
2. Utility costs					0.00 €					0.00 €					0.00 €
i) pesticides/chemicals	All		1686.98	1,686.98 €	733.47 €	all			1,976.69 €	859.43 €				2,981.41 €	745.35 €
Drip irrigation applied insecticides															
Foliar applied insecticides															
ii)pesticides / biological															
B.t. formulation															
Silicon formulation															
iii)biological control															
Registered parasitoids release	1 pack	2.50	33.00	82.50 €	35.87 €	1 pack	2.50	33.00	82.50 €	35.87 €	1 pack	3.00	33.00	99.00 €	24.75 €
Registered predators release	pack	5.00	50.00	250.00 €	108.70 €					0.00 €	pack	8.00	50.00	400.00 €	100.00 €
3. Equipment Costs															
i) traps															
light/pheromone traps	traps	(2+42+1)	68.68	68.68 €	29.86 €	traps	(2+42+1)	68.68	68.68 €	29.86 €	traps	(2+42+1)	68.68	68.68 €	17.17 €
sticky traps	acre	2.30	136.00	312.80 €	136.00 €	acre	2.30	136.00	312.80 €	136.00 €	acre	4.00	136.00	544.00 €	136.00 €
	TOTAL AND TOTAL/ACRE			2,423.46 €	1,053.68 €	TOTAL AND TOTAL/ACRE			2,530.67 €	1,100.29 €	TOTAL AND TOTAL/ACRE			4,273.09 €	1,068.27 €

GH4					GH5					GH6				
UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
				0.00 €					0.00 €					0.00 €
1.00	20.00	45.00	900.00 €	180.00 €	1.00	20.00	40.00	800.00 €	320.00 €	1.00	10.00	40.00	400.00 €	200.00 €
				0.00 €	-				0.00 €	-				0.00 €
				0.00 €					0.00 €	-				0.00 €
				0.00 €					0.00 €					0.00 €
16 applications tuner	16.00	80.00	1280.00 €	256.00 €	barrels	42.75	80.00	3,420.00 €	1,368.00 €	-				0.00 €
applications	10.00	20.00	200.00 €	40.00 €	-				0.00 €	barrels	37.50	75.00	2,812.50 €	1,406.25 €
				0.00 €					0.00 €	-				0.00 €
application in all sprayings	16.00	30.00	480.00 €	96.00 €	once a month	9.00	25.00	225.00 €	90.00 €	barrels	35.00	25.00	875.00 €	437.50 €
total	1.00	800.00	800.00 €	160.00 €										
black around the field	1.00	500.00	500.00 €	100.00 €										
				0.00 €						black	5.00	10.00	50.00 €	25.00 €
TOTAL AND TOTAL/ACRE			4,160.00 €	832.00 €	TOTAL AND TOTAL/ACRE			4,445.00 €	1,778.00 €	TOTAL AND TOTAL/ACRE			4,137.50 €	2,068.75 €

GH7					GH8					GH10				
UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
1.00	15.00	40.00	600.00 €	200.00 €	1.00	9.00	5.00	45.00 €	22.50 €					0.00 €
					1.00	9.00	35.00	315.00 €	157.50 €	one worker per week	24.00	20.00	480.00 €	126.32 €
									0.00 €					0.00 €
									0.00 €	total cost	1.00	4792.00	4,792.00 €	1,261.05 €
					bottle (250ml)	1.00	44.00	44.00 €	22.00 €					
barrels	51.00	63.75	3,251.25 €	1,083.75 €	all	1.00	1560.00	1,560.00 €	780.00 €					
				0.00 €					0.00 €					
every spray	34.00	27.50	935.00 €	311.67 €	all	1.00	445.00	445.00 €	222.50 €					
					egg	9.00	47.00	423.00 €	211.50 €					
black	3.00	100.00	300.00 €	100.00 €	trap	50.00	0.90	45.00 €	22.50 €					
TOTAL AND TOTAL/ACRE			5,086.25 €	1,695.42 €	TOTAL AND TOTAL/ACRE			2,877.00 €	1,438.50 €	TOTAL AND TOTAL/ACRE			5,272.00 €	1,387.37 €

GH10					GH11					GH12				
UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE	UNIT	QUANTITY	UNITY PRICE	TOTAL	TOTAL/ACRE
one worker per week	28.00	45.00	1,260.00 €	360.00 €	once a week	30.00	42.00	1,260.00 €	1,260.00 €	once a week	28.00	45.00	1,260.00 €	1,050.00 €
barrels	42.00	95.24	4,000.00 €	1,142.86 €	barrels	12.00	100.00	1,200.00 €	1,200.00 €	barrels	18.00	100.00	1,800.00 €	1,500.00 €
barrel of glue	1.00	50.00	50.00 €	14.29 €	plastic wrap +glue	2+2	136.00	272.00 €	272.00 €	plastic wrap +glue	1+1	136.00	136.00 €	113.33 €
TOTAL AND TOTAL/ACRE			5,310.00 €	1,517.14 €	TOTAL AND TOTAL/ACRE			2,732.00 €	2,732.00 €				3,196.00 €	2,663.33 €

Appendix 3

Table A 5. Total Income. Here the total income and total income per acre were calculated. It includes the A product and the B product based on their amounts and prices respectively. Furthermore, it includes the ideal income which is the A product plus the B product if was sold at full price. The table continues on the following page.

FARM	GH1		GH2		GH3		GH4		GH5		GH6	
INCOME	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
Product sold full price	26,013.00 €	11,310.00 €	28,882.50 €	12,557.61 €	44,451.00 €	11,112.75 €	139,680.00 €	27,936.00 €	64,020.00 €	25,608.00 €	54,720.00 €	27,360.00 €
Product sold for less	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	1,440.00 €	288.00 €	0.00 €	0.00 €	0.00 €	0.00 €
Total income	26,013.00 €	11,310.00 €	28,882.50 €	12,557.61 €	44,451.00 €	11,112.75 €	141,120.00 €	28,224.00 €	64,020.00 €	25,608.00 €	54,720.00 €	27,360.00 €
Ideal income	28,785.00 €	12,515.22 €	32,190.00 €	13,995.65 €	55,035.00 €	13,758.75 €	144,000.00 €	28,800.00 €	66,000.00 €	26,400.00 €	57,600.00 €	28,800.00 €

FARM	GH7		GH8		GH9		GH10		GH11		GH12	
INCOME	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
Product sold full price	90,792.00 €	30,264.00 €	40,320.00 €	20,160.00 €	39,600.00 €	10,421.05 €	52,500.00 €	15,000.00 €	11,050.00 €	11,050.00 €	18,000.00 €	15,000.00 €
Product sold for less	1,404.00 €	468.00 €	240.00 €	120.00 €	750.00 €	197.37 €	1,500.00 €	428.57 €	300.00 €	300.00 €	600.00 €	500.00 €
Total income	92,196.00 €	30,732.00 €	40,560.00 €	20,280.00 €	40,350.00 €	10,618.42 €	54,000.00 €	15,428.57 €	11,350.00 €	11,350.00 €	18,600.00 €	15,500.00 €
Ideal income	93,600.00 €	31,200.00 €	40,800.00 €	20,400.00 €	44,000.00 €	11,578.95 €	63,000.00 €	18,000.00 €	11,900.00 €	11,900.00 €	22,500.00 €	18,750.00 €

Appendix 4

Table A 6. Maximum Loss. Here it is calculated the maximum loss of the total cultivation but also the one due to the tomato pinworm. Here both the loss from the product sold for less if sold full price, as well as the loss from the product not sold if sold at full price were summed. The losses were calculated both in total and per acre.The table continues on the following page.

FARM	GH1		GH2		GH3		GH4		GH5		GH6	
MAXIMUM LOSS IN CULTIVATION												
INCLUDING	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
Loss (from product sold less, if sold full price) + product not sold (if sold full price)	2,772.00 €	1,205.22 €	3,307.50 €	1,438.04 €	10,584.00 €	2,646.00 €	2,880.00 €	576.00 €	1,980.00 €	792.00 €	2,880.00 €	1,440.00 €
MAXIMUM LOSS DUE TO TUTA												
INCLUDING	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
Loss (from product sold less, if sold full price) + product not sold (if sold full price)	2,772.00 €	1,205.22 €	1,323.00 €	575.22 €	10,584.00 €	2,646.00 €	0.00 €	0.00 €	1,980.00 €	792.00 €	2,880.00 €	1,440.00 €

FARM	GH7		GH8		GH9		GH10		GH11		GH12	
MAXIMUM LOSS IN CULTIVATION												
INCLUDING	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
Loss (from product sold less, if sold full price) + product not sold (if sold full price)	1,404.00 €	468.00 €	240.00 €	120.00 €	3,650.00 €	960.53 €	9,000.00 €	2,571.43 €	550.00 €	550.00 €	3,900.00 €	3,250.00 €
MAXIMUM LOSS DUE TO TUTA												
INCLUDING	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
Loss (from product sold less, if sold full price) + product not sold (if sold full price)	1,404.00 €	468.00 €	120.00 €	60.00 €	50.00 €	13.16 €	4,932.00 €	1,409.14 €	440.00 €	440.00 €	3,660.00 €	3,050.00 €

Table A 7. Cost with Maximum Loss. Here the maximum loss of the cultivation of each greenhouse was added to the total cost of the cultivation. The calculations here were made only per acre.

Farn	GH1	GH2	GH3	GH4	GH5	GH6	GH7	GH9	GH9	GH10	GH11	GH12
COST WITH ML	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE
If we include the maximum loss into the cost	5,025.28 €	6,472.69 €	8,748.19 €	14,908.20 €	13,576.30 €	18,479.00 €	15,609.58 €	10,877.00 €	9,362.28 €	10,402.86 €	10,703.38 €	13,934.17 €

Appendix 5

Table A 8.Total Profit. In the following table the profit of each GH is calculated in total as well as in total per acre. The profit is the income of the cultivation minus the total cost of it. Furthermore, the ideal profit was calculated which is the ideal income of the cultivation minus the total cost of the cultivation. The table continues on the following page.

FARM	GH1		GH2		GH3		GH4		GH5		GH6	
PROFIT	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
PROFIT (based on the costs and sold tomatoes	17,226.85 €	7,489.93 €	17,302.82 €	7,522.97 €	20,042.23 €	5,010.56 €	69,459.00 €	13,891.80 €	32,059.25 €	12,823.70 €	20,642.00 €	10,321.00 €
IDEAL PROFIT (including Loss (from product sold less) + product not sold (if sold full price)	19,998.85 €	8,695.15 €	20,610.32 €	8,961.01 €	30,626.23 €	7,656.56 €	72,339.00 €	14,467.80 €	34,039.25 €	13,615.70 €	23,522.00 €	11,761.00 €

FARM	GH7		GH8		GH9		GH10		GH11		GH12	
PROFIT	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE	TOTAL	TOTAL/ACRE
PROFIT (based on the costs and sold tomatoes	46,771.25 €	15,590.42 €	19,046.00 €	9,523.00 €	8,423.33 €	2,216.67 €	26,590.00 €	7,597.14 €	1,196.62 €	1,196.62 €	5,779.00 €	4,815.83 €
IDEAL PROFIT (including Loss (from product sold less) + product not sold (if sold full price)	48,175.25 €	16,058.42 €	19,286.00 €	9,643.00 €	12,073.33 €	3,177.19 €	35,590.00 €	10,168.57 €	1,746.62 €	1,746.62 €	9,679.00 €	8,065.83 €

Appendix 6

Table A 9. Chemical and biological control cost. Here the total control cost of the cultivation and the one specifically for the tomato pinworm was calculated. By chemical and biological control cost, we only refer to chemical or biological pesticides used as well as the cost of using natural enemies such as natural parasitoids. The cost was only calculated in total per acre.

Farm	GH1	GH2	GH3	GH4	GH5	GH6	GH7	GH8	GH9	GH10	GH11	GH12
Control Cost	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE	TOTAL/ACRE
Total cultivation control cost	1,056.38 €	1,064.43 €	1,054.02 €	862.00 €	1,746.00 €	2,297.50 €	2,117.92 €	1,584.50 €	1,578.95 €	1,514.29 €	1,900.00 €	2,500.00 €
Total control cost due to the tomato pinworm	878.03 €	895.30 €	870.10 €	552.00 €	1,458.00 €	1,843.75 €	1,395.42 €	1,236.00 €	1,261.05 €	1,142.86 €	1,200.00 €	1,500.00 €

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