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BIOLOGICAL CONTROL OF PESTS IN CUCURBITACEOUS VEGETABLES: AN OVERVIEW

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Key words: *biologic control, cucurbitaceous crops, cucurbit pests from Romania, pests of cucurbits*

INTRODUCTION

The Cucurbitaceae is a huge plant family consisting of hundreds of plant species (Messelink et al. 2020) but economically the most important cultures are cucumber (*Cucumis sativus* L.), melon (*C. melo* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai), pumpkin/squash (*Cucurbita spp.*), bottle gourd (*Lagenaria siceraria*) and bitter gourd (*Momordica charantia*) (Zheng et al. 2019). In general, Cucurbita species prefer warm weather, temperatures of 18–27 °C, can be grown in a wide range of soil varieties but favors well-drained fertile ground (Salehi et al. 2019). In 2019, over two million hectares of cucurbits were harvested in the world, and Romania had produced over a hundred thousand tonnes of cucurbits (table 1). A lot of money, time and natural resources are invested to grow these vegetables (Sharma, Rana, and Sukhwal 2016). Still, cucurbita species are very predisposed to pests and diseases, and the attack of some pathogens has a strong economic impact on crops (Messelink et al. 2020). To maintain good quality and high commercial yield for cucurbits, it is important to protect them (Salehi et al. 2019). There are various methods for controlling pests, including physical, chemical, cultural, and biological methods (Parajuli et al. 2020). Chemical insecticides, for the most part, are very effective in controlling pests, however, few pesticides are safe for use and storage (Sharma, Rana, and Sukhwal 2016). But, repeated treatments led to the development of pathogens and pests that are resistant to chemical pesticides (Rur et al. 2018). All types of biological control – *natural, classical, conservation*, and *augmentative* – can be used to prevent pest density where they become damaging (Van Lenteren and Nicot 2020). Even though that biological control has been used for centuries, the first big wave of activity in the modern era followed the spectacular success of the introduction of the parasitic fly (*Cryptochaetum iceryae* Williston) and the vedalia beetle (*Rodolia/Novius cardinalis* Mulsant) to control cottony-cushion scale (*Icerya purchasi Maskell*) in California citrus orchards in the late 1880s (Barratt et al. 2018). More than 90% of the natural enemy species used in greenhouses belong to arthropods and less than 10% belong to nematodes. Is important to find and evaluate new biocontrol agents in the biological combat of pests, their mass production, their storage, and liberation in vegetable cultures are vital (Van Lenteren et al. 2020). EU agriculture is currently in transition from conventional crop protection to integrated pest management (IPM). Because biocontrol is a key component of IPM, many European countries recently have intensified their national efforts on biocontrol research and innovation (Lamichhane et al. 2017). The biological control of vegetable pests also involves an active human management role. That is why the purpose of this review is to search in the publications available in the scientific databases of the last years (mainly Google Academic, ScienceDirect.com and Springer), pests from cucurbita vegetables crops and to underline the most important and effective methods of biological control that can be used by producers as more sustainable forms of pest management.

Table 1. The agricultural production of cucurbits in 2019 (http://faostat.fao.org)

Region	Area harvested (ha)	Yield (hg/ha)	Production (tonnes)
World	2231402	393497	87805086
Europe	160484	374678	6012986
Romania	6910	171679	118630

MATERIALS AND METHODS

We have compiled data from specialized studies from last years, studies that address pest management for cucurbitaceous crops (cucumber, melon, watermelon, pumpkin/squash etc.). We searched the databases in Google Academic, ScienceDirect, Springer using the following keywords "cucumber cultivars"; "pests of cucumber"; "insects pests of cucumber"; "biological control pests of cucumber"; "biological control agents" and "Integrated pest management". The main pests of cucurbits crops from the world and Romania has been identified.

We have identified 251 papers that have been analyzed. The studies selected for this review had to

meet the following criteria: (1) publication period, recent years; (2) to present the pests of the plant species in question; (3) to present the microbial biologic control agents, parasites, and predatory species for the identified pests.

RESULTS AND DISCUSSIONS

Biological pest control

The development and use of entomopathogens as classical, preservation and biological control agents included many successes and some obstacles in recent years (Lacey et al. 2015). The opinions about the value of biological control are often divided. Most often they refer to classical biological control, in which a species is introduced from another region to control pests, such as herbivore arthropods in agricultural or weed systems, both in managed and natural systems (Parra 2014; Roderick, Hufbauer, and Navajas 2012). For example, pest-resistant varieties are often used for pest control, this is an important and safe method of pest control. Agricultural controls (cultural controls) include agricultural operations which decrease the population densities of pests (Lou et al. 2013). Biological control is an ancient pest control strategy, specifically refers to using insects to control other insects, although its use is still limited. Biocontorl has gained acceptance in recent years (García Gutiérrez et al. 2013) since is a technique widely used throughout the world against many pests in protected crops but also the field (Calvo, Bolckmans, and Belda 2011). So, biocontrol is a method of controlling pests such as insects, mites, weeds, and plant diseases using other organisms. Natural enemies of insect pests, also known as biological control agents, include predators, parasitoids, and pathogens (Rosenheim et al. 1995; Andow et al. 2021). Despite this, natural enemies continue to provide a valuable ecosystem service; estimates rank their contribution to the management of crop pests well ahead of other measures, including pesticides (Begg et al. 2017). A small number of entomopathogenic bacteria have been developed for the control of insect pests. These include several sub-species of *Bacillus thuringiensis* Berliner, *Lysinibacillus*/*Bacillus sphaericus*, *Paenibacillus spp*., and *Serratia entomophila* Grimont. Subspecies *B. thuringiensis kurstaki* is the most widely used for control of pest insects of crops and forests, and *B. thuringiensis israelensis* and *L. sphaericus* are the primary pathogens used for control of medically important pests including dipteran vectors.

Pests of cucurbits plants

Knowledge of pests specific to cucurbits crops is very important for establishing the most effective measures to prevent attacks and reduce crop losses (Marina et al. 2018; Vinutha et al. 2017). In this paper, a summary of the most important orders of cucurbits pests in the world in recent years has been made and their feeding has been evaluated. These data have been extracted from the literature (Sarwar et al. 2011; Pym 2020; Kumar, Singh, and Sharma 2016; Ghule et al. 2014; Marina et al. 2018; Vinutha et al. 2017; Haldhar et al. 2013; Koné et al. 2019; Parajuli et al. 2020; Alao and Adebayo 2015; Lal et al. 2014; Anato et al. 2017; N'Goran et al. 2019; Araujo et al. 2013; Pitan and Esan 2014; Pitan and Filani 2014; Willis Chan and Raine 2021; Nottingham and Kuhar 2013).

In the literature of recent years, the distribution of pests according to the frequency of occurrence has shown the presence of 63 species worldwide belonging to eight orders (*Acari, Coleoptera, Diptera, Hemiptera. Hymenoptera, Lepidoptera, Orthoptera,* and *Thysanoptera*). It is observed from *Figure 1* that most pests of cucurbitaceous plants are part of the *Coleoptera* Order, like the western spotted beetles (*Diabrotica undecimpunctata* L.) (Health et al. 2020), the striped cucumber beetles (*Acalymma vittatum* Fabricius) and western striped cucumber beetles (*Acalymma trivittatum* Mannerheim). Cucumber beetles are native to North America and feed primarily on plants in the family Cucurbitaceae (Haber et al. 2021). They damage cucurbit crops across much of the growing season, can damage the foliage, flowers, fruit, and roots by vectoring pathogens of major diseases like bacterial wilt (*Erwinia tracheiphila* Smith) and squash mosaic virus (Brzozowski et al. 2016). *Hemiptera* is the second-order presenting economic importance for cultures of cucurbits. Pests like common squash bug (*Anasa tristis* De Geer) is a major pest of cucurbit crops in the United States. also is a vector of cucurbit yellow vine disease (*Serratia marcescens* Bizio) which can cause severe crop damage (Cornelius 2018).

Depending on how they were fed, the pests identified in the literature were divided into three groups: defoliating pests, sucking pests, and borers.

- Defoliating pests – are pests who consumed the leaves;
- Sucking pests – are pests who sting and suck the sap in the leaves and flowers;
- Borers – pests whose larvae feed by digging galleries in leaves or fruit.

As can be seen in figure 2, the most pests of cucurbitaceous crops are defoliators followed by sucking pests and borers.

In Romania, there have been described in the literature, in the last few years, 7 species of main pests of cucurbitaceous crops that are part of 5 orders (*Acari, Hemiptera, Thysanoptera, Coleoptera,* and *Diptera*). The main pests are part of *Hemiptera* and *Thysanoptera* orders (figure 3) and are pests that feed mainly by sting and sucking (figure 4). The main species of pests from Romanian cucurbitaceous crops are shown in table 2. Also, other species of pests that could attack cucurbitaceous crops are: grey field slug (*Deroceras agreste* L.), and european mole cricket

(*Gryllotalpa gryllotalpa* L.) (Șovărel Gabriela et al. 2020; Călin 2005; Cîndea 1984).

In the experimental polygons of the Vegetable Research and Development Station Bacau, in 2021, the following pests were observed: *Aphis gossypii* Glov. (figure 5) and *Thrips tabaci* (figure 6).

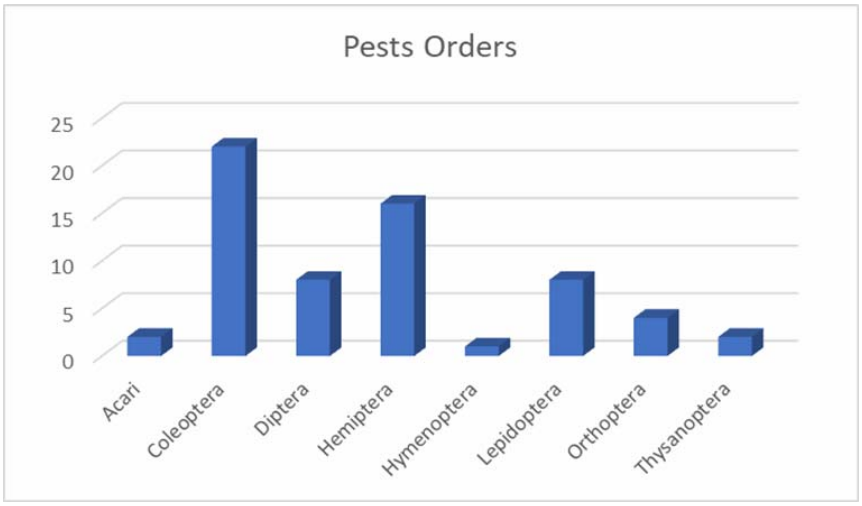

Figure 1. The main orders of cucurbitaceous pests in the world

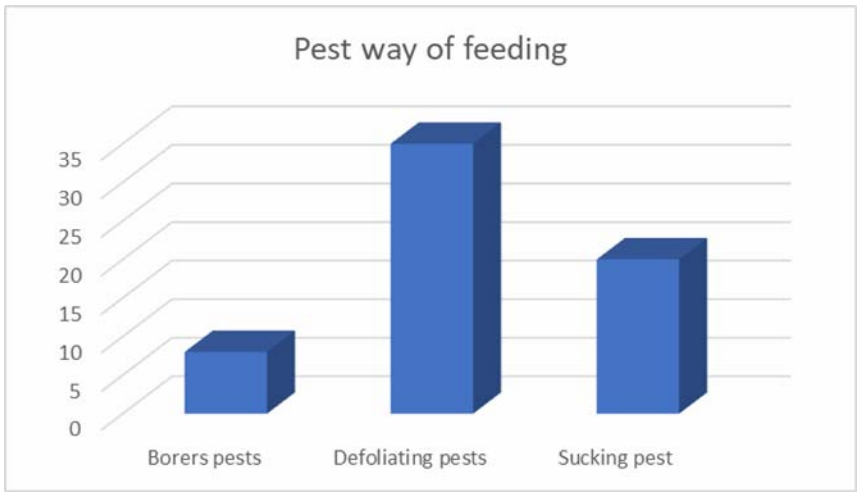

Figure 2. The main ways of feeding pests in cucurbitaceous crops

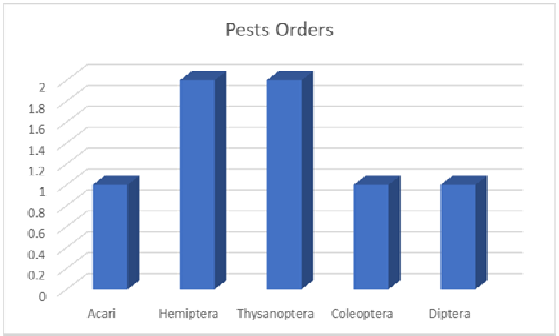

Figure 3. The main orders of cucurbitaceous pests in Romania

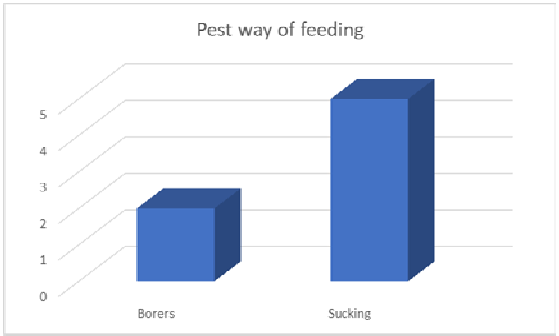

Figure 4. The main ways of feeding pests in cucurbitaceous crops from Romania

Table 2. Main pest species of cucurbits in Romania

Pests	***Order***	***How they fed***	***Cucurbitaceous vegetable***	***Authors***
Aphis gossypii Glov.	*Hemiptera*	Sucking	Cucumis sativus; Cucurbita pepo;	(Iosob 2021; Cîndea 1984; Şovărel Gabriela et al. 2020; Călin 2005)
Tetranychus urticae Koch	Acariformes / Trombidiformes	Sucking	Cucumis sativus; Cucumis melo; Cucurbita pepo; Citrullus lanatus	(Iosob 2021; Cîndea 1984; Şovărel Gabriela et al. 2020; Călin 2005; Călin et al. 2017)
Thrips tabaci Lindeman	Thysanoptera	Sucking	Cucumis sativus; Cucumis melo;	(Iosob 2021; Cîndea 1984; Şovărel Gabriela et al. 2020; Călin 2005)
Agriotes spp. Eschscholtz	Coleoptera	Borers	Cucumis sativus; Cucumis melo; Citrullus lanatus	(Iosob 2021; Cîndea 1984; Şovărel Gabriela et al. 2020; Călin 2005)
Delia platura Meigen	Diptera	Borers	Cucumis sativus; Cucumis melo; Cucurbita pepo; Citrullus lanatus	(Cîndea 1984; Călin 2005; Şovărel Gabriela et al. 2020)
Frankliniella occidentalis Pergande	Thysanoptera	Sucking	Cucumis sativus	(Iosob 2021; Cîndea 1984; Şovărel Gabriela et al. 2020; Călin 2005)
Trialeurodes vaporariorum Westwood	Hemiptera	Sucking	Cucumis sativus; Cucurbita pepo	(Iosob 2021; Cîndea 1984; Şovărel Gabriela et al. 2020; Călin 2005)

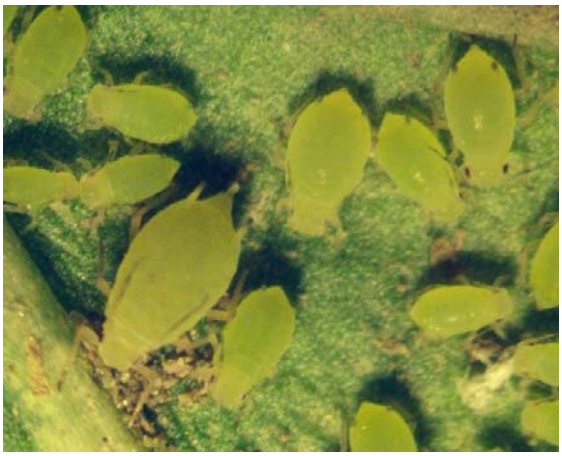

Figure 5. *Aphis gossypii* Glov. colony on cucumber leaf

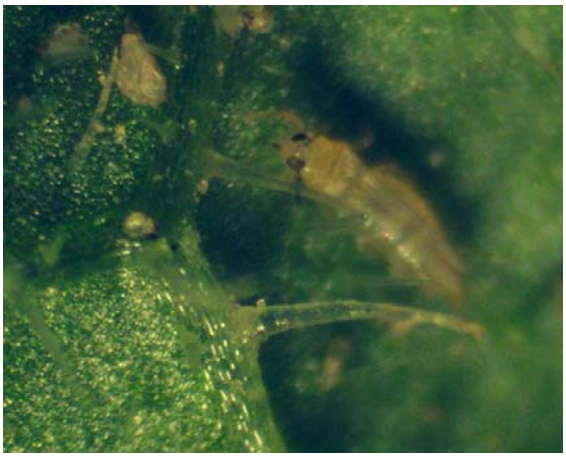

Figure 6. *Thrips tabaci* Lindeman on cucumber leaf

Biological pest control for cucurbitaceous crops

In this paper we will refer to the biological control of pests from our country:

For aphids, we can use natural extracts, of which the most efficient can be pyrethrin extracted from the *Chrysanthemum cinerariifolium* and *C. coccineum* flowers. There are many products based on this substance on market and they are allowed in ecological cultures. Other natural insecticides used against aphids can also be made with garlic, hot pepper, or nettle, but the insecticides based on pyrethrin are more efficient. Insects used for biological control of aphids are predators (*Adalia bipunctata* L.– larvae and adults; *Chrysoperla carnea* Stephens – larvae and adults; *Episyrphus balteatus* De Geer – larvae and adults; *Aphidoletes aphidimyza* Rondani – larvae and adults) (Monica et al. 2014) and parasitoids (*Lysiphlebus testaceipes* Cress; *Aphidius ervi* Hal.; *Trioxys angelicae* Hal.) (Hopkinson, Zalucki, and Murray 2013; Călin 2005).

Two-spotted spider mite (*Tetranychus urticae* Koch) is one of the most dangerous pests for this crop (Georgescu et al. 2016). The predator, *Phytoseiulus persimilis* At.-H. has a very good efficiency in the control of two-spotted spider mites (Calin et al. 2018; Călin et al. 2017), other predators with high effectiveness in the control of this pest are: *Allothrombium fuliginosum* Herm.; *Typhlodromus pyri* Schaeut.; *T. soleiger* Rib.; *Oligota flavicornis* Boisd.; *Stethorus punctillum* Weise; *Scolothris sexmaculatus* Perg.; *S. longicornis* Pr.; *Aeolothrips melalencus* Hal.; *Cryptothrips nigripes* Reut.; *Chrisopa perla* L.; *Chrysoperla carnea* Stephens; *Anthocoris nemorum* L. (Călin 2005). Biopreparations based on bacteria can have high efficacy like bio-preparations with complex activity based on *Bacillus thuringiensis* Berliner; *Streptomyces aureus* Manfio et al, 2003; (Prischepa 2013; Călin 2005)

Onion thrips (*Thrips tabaci* Lindeman) is one of the key pests of onion, *Allium cepa* L. (Muvea et al. 2014), and cucumber in field and greenhouse conditions (Jafari, Abassi, and Bahirae 2013). Traditionally, controlling thrips is conducted via the usage of chemical applications, which may explain the widespread chemical-resistance development in onion thrips (Azazy et al. 2018) but we can apply treatments with biopesticides based on: entomopathogenic fungi (*Beauveria bassiana* (Bals.-Criv.) Vuill.; *Isaria fumosorosea* Wize; *Saccharopolyspora spinosa* Mertz & Yao), and preparations based on repellent plants and insecticides (garlic extracts, chilli extracts, pyrethrum, and neem-based products). Combating thrips populations can also be achieved by launching zoophagous such as species of *Amblyseius cucumeris* Oudemans; *Chrysoperla carnea* Stephens; *Coccinella septempunctata* L.; *Orius* spp.; *Steinernema* spp. (Călin 2005; Cîndea 1984; Iosob 2021).

Biological pest control of wireworms *Agriotes spp*. in cucurbits crops includes biopesticides based on entomopathogenic fungi like *Metarhizium brunneum* Petch, and *Beauveria spp*.. It is also possible to use traps with pheromones, Also, important are natural predators such as spiders, amphibians, shrews, and moles that feed on both larvae and adults (Iosob 2021; Călin 2005).

Some species of the genus *Delia*, commonly called root maggots, attack economically important crops. These insects cause large economic losses to agriculture in temperate regions (Nava-Ruiz et al. 2021) where attacks a wide range of horticultural crops including cucumber (*Cucumis sativus*), melon (*Cucumis melo*), onion (*Allium cepa*), pepper (*Capsicum annuum*), potato (*Solanum tuberosum*), and other vegetables (Gill, Goyal, and Gillett-Kaufman 2013) Much of the life cycle of worms is carried out underground, so it does not seem to have many natural enemies. However, isolated incidents have been reported in which spiders, ants, and birds have fed on adults, and some fungal diseases have infected the larvae. However, none of these predators or pathogens are considered significant in controlling worm populations (Gill, Goyal, and Gillett-Kaufman 2013; Călin 2005).

The predatory mites *Neoseiulus barkeri* Hughes and *Stratiolaelaps scimitus* Womersley are used for control of *Frankliniella occidentalis* Pergande in China (Wu et al. 2016). Apply treatments with biopesticides based on: entomopathogenic fungi (*Beauveria bassiana* (Bals.-Criv.) Vuill.; *Isaria fumosorosea* Wize; *Saccharopolyspora spinosa* Mertz & Yao), also we can apply preparations based on repellent plants and insecticides (garlic extracts, chilli extracts, pyrethrum, and neem-based products) (Călin 2005), and by launching zoophagous such as species of *Amblyseius cucumeris* Oudemans; *Chrysoperla carnea* Stephens; *Coccinella septempunctata* L.; *Orius* spp.; *Steinernema* spp. (Călin 2005; Cîndea 1984; Iosob 2021).

The greenhouse whitefly *Trialeurodes vaporariorum* Westwood is a polyphagous pest, to control them we can use entomopathogenic nematodes (EPN) like *Steinernema feltiae* and *Heterorhabditis bacteriophora* (Rezaei et al. 2015; Laznik, Znidarcic, and Trdan 2011). Also, parasitic wasps such as *Encarsia formosa* Gahan provides typically effective biological control (Iosob 2021).

CONCLUSION

Cucurbitaceous crops are very important both in the world and in Romania. In 2019, over two million hectares of cucurbits were harvested in the world, and Romania had produced over a hundred thousand tonnes of cucurbits. Uncontrolled development of pests in cucurbitaceous plants can lead to large losses due to cosmetic injury, death, or regulatory actions. Therefore, investments in better pest management are useful for all growers.

The inventory of pests associated with cucurbitaceous crops made in this work determined 63 species worldwide belonging to eight orders. In Romania, only 7 species are the main pests of cucurbitaceous crops that are part of 5 orders have been described. The use of predators, parasites, pathogens in the biological control of cucurbitaceous pests is challenging but possible and many successful examples of biological control exist.

Future studies in plant protection, especially in Romania, should focus more on the biological combat of pests and other biological strategies to reduce the use of chemical pesticides with harmful effects on human health and the environment.

ABSTRACT

This paper is a review of the literature in recent years that focuses on the determination of the main pests in the cucurbitaceous cultures in the world and Romania. Following the investigation, the distribution of pests according to the frequency of appearance showed the presence of 63 world species belonging to eight orders (*Acari, Choleoptera, Diptera, Hemiptera. Hymenoptera, Lepidoptera, Orthoptera* and *Thysanoptera*). In Romania, there have been described in the literature, in recent years, 7 major pests of cucurbitaceous crops that are part of 5 orders (*Acars, Hemiptera, Thysanoptera, Colestera* and *Diptera*). The use of predators, parasites, pathogens in the biological control of cucumbers is a challenge, but there are also many successful examples of biological control.

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