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Main directions of plants integrated protection in the conditions of organic agriculture

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Abstract. The environmental situation in the world is only getting worse every year. This is caused by an increase in air pollution, wastewater pollution, wood burning, and others. Since 2013, ammonia emissions by European Union companies have increased significantly. This was facilitated, among other things, using synthetic pesticides. That is why the transition of agriculture to organic farming standards can be considered a good alternative. The aim of the study was to analyse the effectiveness of combining known organic pesticides in one biogeocenosis. A combined treatment of the vegetable crop *Brassica oleracea* with such biological pesticides as Bacillus thuringiensis and pyrethrin, combined with mass pest trapping, is proposed in the research. When combining these three approaches, the efficiency was 93%. The total crop yield was 27 tons/ha,

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while the area of the field where pheromone and yellow sticky traps were used had a yield of 34 tons/ha. These methods were effective against the following pests: *Ceutorhynchus rapae, Aleyrodes proletella*, and *Brevicoryne brassicae*. Leaf damage was reduced by 93% on average during the study period when using the combined approach. During the two-year research, it was possible to neutralize 1882 insects by mass trapping and find out that the largest number of *Ceutorhynchus rapae* affect the crop in May and August, but the use of pheromone traps is most effective in October. The combination of individual methods increased the effectiveness of each method due to the synchronized impact on different pests. Increasing vegetable yields in Albania in the future can also solve the problem of hunger in countries with unfavourable climatic conditions by increasing the export of these crops

Keywords: *Bacillus thuringiensis*; pyrethrum; *Brassica oleracea*; biological pesticides; a natural insecticide

INTRODUCTION

Following the European Environment Agency, the concentration of nitrogen dioxide and PM10 particles in the Balkans has significantly increased, resulting in more than 30,000 premature deaths. Such statistics harm the economic situation of countries, as they lead to increased healthcare costs and a decrease in the number of working-age people. Agricultural reforms can not only help improve its environmental safety but also meet the demand of discerning consumers who care about their health and demand better food quality (Shahini *et al.,* 2022).

One of the most important vegetable crops in high demand in Europe is *Brassica oleracea*, with global production of broccoli and cauliflower totalling 25,531,274 tons in 2020 (Siomos *et al.,* 2022). Most varieties of *Brassica oleracea* are rich in vitamin C, antioxidants, and other equally important nutrients. The main pests of *Brassica oleracea* are *Aleyrodes proletella, Brevicoryne brassicae, Murgantia histrionica, Ceutorhynchus rapae, Pieris rapae*, which cause considerable damage to the leaves of the crop, which also spoils its appearance.

When comparing conventional farming methods and organic farming systems, the sustainability of such systems is primarily determined, as well as how effective they are in the conditions of the studied agrocenosis (Kalajnxhiu *et al.,* 2012, Litterick & Watson, 2017). Important factors that influence the choice of methods for plant protection to ensure their self-regulatory mechanisms can be called both climatic conditions and risk factors inherent in a given area (Teqja *et al.,* 2017). For the changing climatic conditions of Albania, biochemical and microbial plant protection will be effective. This is dictated not only by climatic conditions but also by the presence of specific pests that damage crops in this region. Previous studies by the authors on this topic primarily focused on the environmental safety of the methods used (Seidenglanz *et al.,* 2021, Shahini *et al.,* 2021, Toshova *et al.,* 2009). Thus, in this region, Sh. Shahini *et al.* (2021) in recent works have demonstrated that combinations of different environmental pesticides significantly increase the overall effectiveness of such plant protection compared to the control sample and individual methods. Analysis of the protection of tomatoes from *Tuta absoluta* showed that when using *Bacillus thuringiensis*, fruit infection decreased by 29%, when treated with Indoxacarb pesticide, this figure reached 43%, and when mass trapping – 52% (Shahini *et al.,* 2021). For our study, we replaced Indoxacarb with pyrethrum and slightly modified the previously used technology.

The use of pyrethrum in different parts of the world has demonstrated its high effectiveness against aphids (Jansen *et al.,* 2010), bedbugs, worms, and other pests (Gokturk *et al.,* 2018). Based on the research work of Daniel Lybrand from Michigan, USA, the advantage of the insecticide is its harmful effect on the nervous system of insects, while being safe for warm-blooded animals and humans (Lybrand *et al.,* 2020). It also does not require additional disposal but decomposes under the influence of sunlight and changes in the pH of the environment (Sun *et al.,* 2020).

The data from the Balkan Reserve also indicate that *Ceutorhynchus rapae* is a serious threat to *Brassica oleracea*, against which the above methods of protection are not very effective (Toshova *et al.,* 2009). This can significantly affect the yield of *Brassica oleracea*. Pheromone and yellow sticky traps have shown good results in the control of *Ceutorhynchus rapae* (Seidenglanz *et al.,* 2022; Reddy *et al.,* 2018). The use of yellow sticky traps, although not popular in the Balkan Peninsula, has been used in the work of other scientists conducting research in similar climatic conditions. Elias Beckmann of the German Institute for Plant Protection has illustrated the effectiveness of such traps for monitoring whiteflies in recent publications, and similar work by authors from Mexico and Turkey has shown not only encouraging results but also indicated the commercial availability of this approach.

The use of traps in combination with other types of protection has broad prospects for implementation not only within organic farming but also for lands using conventional farming approaches. In general, as the literature review has shown, the number of works on similar topics in the Balkans is currently insufficient to present a complete picture of the problems that may arise at each stage of technology implementation but given the number of positive publications from other regions, further research may open up several new opportunities in this area. The research aims to combine known organic pesticides within one biogeocenosis and analyse the effectiveness of such a combination.

MATERIAL AND METHODS

The place for the research was the capital of Albania – the city of Tirana (41°19′48″N, 19°49′12″E), with a predominantly humid subtropical climate and an average annual rainfall of 1266 mm. The Broccoli Brassica oleracea Italica group was chosen as the crop under study (Table 1). The tests were carried out for 2 years (2021-2022) from August to October.

Table 1. *Characteristics of the researched plant culture*

Plant culture name	Brassica oleracea (Italica Group)
Height	from 45.7 to 76.2 cm
Width	from 30.5 to 61.0 cm
Lifetime	Two years
the pH of recommended soils	Neutral
Type of insemination	Hermaphroditic

Source: *compiled by the authors*

The *Brassica oleracea* Italica group was planted in rows at approximately 45-46 cm from each other, placed at an interval of 92 cm in the form of seedlings. The planting took place within a l-hectare plot of loamy soil, divided into two equal parts, in one of which crop protection was carried out using *Bacillus thuringiensis* and pyrethrum, and in the other, along with these methods, mass pest trapping was used. Pheromone traps were installed to prevent *Ceutorhynchus rapae*.

For the study, a solution of the pathogen pyrethrum from Syngenta was used in 8-ounce bottles with a concentration of 6-24 ml per gallon of water. *Bacillus thuringiensis* solution of the Dipel DF brand was also used. The concentration of the active ingredient was 300 g/l. A mechanical spray pump with a volume of 200 litters (flat-fan nozzle, pressure 5 atm, diameter 0.5 mm) was used to spray the pesticides.

The experiment was carried out using delta traps manufactured by Great Lakes IPM Inc. (Michigan, USA), which contained pheromone bait from ChemTica Internacional SA (Costa Rica) in the form of a grey rubber membrane impregnated with 4-methyl-3,5-heptandione. Each bait contained 10 mg of pheromone, which released 0.1 mg/day of the active ingredient.

The cup under each of the partitions was filled with 100 μL of pheromone solution in hexane, with a concentration of 0.1 mg/mL. After that, the hexane began to evaporate, simultaneously releasing the pheromone, which was in a special plastic bag. The bait was stored in aluminium bags at 4°C. Traps were placed in blocks at 8-10 m from each other. Every 2-3 days, insects were removed from the traps and their number was recorded. Yellow sticky traps (Ø 30 cm, 10 cm) were also installed, 1 trap per 0.1 ha.

To evaluate the effectiveness of the combined crop protection, the analysis of leaf damage was carried out by selecting 100 random leaves, for which the percentage of healthy and damaged leaves was calculated. The collected data were compared with the literature and data collected from the control plantation, where no pre-treatment of plants was carried out. The procedure was carried out weekly during the treatment of crops for two years. The values of adjusted efficiency were calculated based on Abbott's formula (Shahini *et al.*, 2021) (1):

$$(Ecorr)\% = [1 - (\frac{DL\ treatment}{DL\ control})] \times 100, \quad (1)$$

where DL is the average number of damaged leaves.

All data were analysed using IBM SPSS Statistics v.20 for Windows, where the average values were compared at the 0.05 probability level.

RESULTS

An important task when choosing pesticides was not only their safety for the environment but also their effectiveness against existing pests. The experiment was conducted in the field, which reduced the efficiency of pesticide spraying, but contributed to their decomposition under the influence of sunlight and prevented contamination of crops with residual solutions during harvesting.

The protection of broccoli *Brassica oleracea* was carried out by a combination of biological pesticides with different effects, considering the characteristics of pests that pose a major threat to cabbage plantations. However, it is worth noting that climate change can also affect the insect population, so the study of combining biological pesticides for plant protection in different climatic conditions is an important step to building a realistic picture of the effectiveness of this method. The treatment of the studied vegetable crop with *Bacillus thuringiensis* and pyrethrum reduced leaf damage by 57% compared to the control sample (Fig. 1).

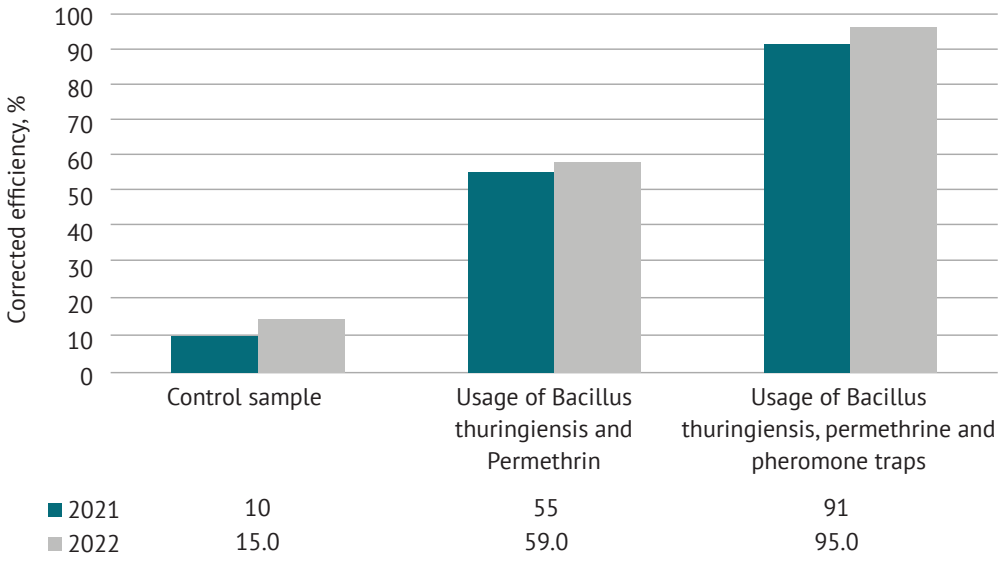

Figure 1. *Observed the effectiveness of plant protection in the period from 2021 to 2022*

Pyrethrum is a natural insecticide containing biologically active substances (Table 2) (Kawamoto *et al.,* 2020), usually obtained by drying the flowers of the chrysanthemum *Tanacetum cinerariifolium*, which does not involve the use of any synthetically produced compounds (Sun *et al.,* 2020). Its extraction is carried out through a series of sequential steps, namely: drying of flowers, dewaxing, saponification, evaporation, removal of fatty acids, and separation of pyrethric acid from chrysanthemic acid (Otienol *et al.,* 2020). The product is used in the form of a suspension in oil or water, sprays, and can also be sprayed in the air, covering large areas of land.

Table 2. *Biologically active compounds quantified from pyrethrin extraction*

Name	Abbreviation	Gross formula	Molecular mass
Pyrethrin I	Py I	$C_{21}H_{28}O_3$	328. 4
Pyrethrin II	Py II	$C_{22}H_{28}O_5$	372. 4
Serine I	C I	$C_{28}H_{28}O_3$	316. 4
Serine II	C II	$C_{21}H_{28}O_5$	360. 4
Jasmoline I	J I	$C_{21}H_{30}O_3$	330. 4
Yasmonlin II	J II	$C_{22}H_{30}O_5$	374. 4

Source: *compiled by the authors*

On the other hand, the use of *Bacillus thuringiensis* strains can reduce the level of insect nutrition, which leads to death from septicaemia. *Entomopathogenic fungi* produce endotoxins, which, when ingested by the insect stomach, destroy it from the inside (Schünemann *et al.,* 2014). The main producer of products based on various species of *Bacillus thuringiensis* in the United States, namely Valent Bioscience and Certis, while in Europe, biological pesticides are produced by Koppert Biological Systems, a company based in the Netherlands, and the Italian company Isagro.

The concentration of *Bacillus thuringiensis* was selected based on the analysis of previous studies (Shahini *et al.,* 2021). Following the experiments, the use of entomopathogenic fungi contributes to 58% to 98% of insect mortality (Biryol *et al.,* 2021), most often used to control aphids or whiteflies that can damage the stems and leaves of cabbage, which further affects the yield of the crop (Khun *et al.,* 2021). Additional treatment with a pyrethrin solution was supposed to increase the efficiency of *Bacillus thuringiensis*.

It is worth noting that insecticide spraying should be carried out with a certain frequency, since if the initial concentration of *Bacillus thuringiensis* can kill up to 97% of insects, then after 108 hours the product is only 1% effective against pests (Castro *et al.*, 2019).

Therefore, the optimal conditions were selected: treatment of plants every 24-36 hours with a concentration of 300 g/l of the active ingredient, which ensured a sufficient and controlled content of the pesticide in the crop and reduced the risk of re-infection.

To prevent the mortality of bees from pyrethrin, the spraying of the product took place at night. The use of pyrethrin as an independent insecticide, especially in the presence of many pests, is not advisable, because its effect is slow and insufficient, and at low concentrations, the nervous system of insects can even adapt to the product. On the other hand, its low toxicity and affordable cost demonstrate the advantages of pyrethrin in combination with other methods of protection, unlike synthetic pesticides that pollute groundwater.

A plot of land planted with broccoli *Brassica oleracea* Italica group treated with *Bacillus thuringiensis* and pyrethrum solution was carefully checked for damaged stems and the overall appearance of the plants was assessed. However, when the two methods were combined, *Brassica oleracea* was still affected by *Ceutorhynchus rapae*. The weevil larvae interfered with the transport of nutrients in the plant, distorting the stem tissue, which prevented its further growth.

In search of alternative solutions to increase crop yields, in addition to the above-mentioned methods, pheromone traps, and yellow sticky traps were placed on 0.5 hectares of the field. This approach allows the assessment of the impact of insect trapping on changes in the effectiveness of the combined plant protection method.

Pheromone traps were used, which can only attract weevils, while yellow sticky traps also captured whiteflies and aphids. However, in previous studies, yellow sticky traps were used only for population monitoring, and the treatment was carried out with the insecticide Proteus 110 OD, the active ingredient of which is thiacloprid (Grantiņa *et al.,* 2011). In addition to being toxic to bees, this active ingredient is also highly toxic to warm-blooded animals, with an LD50 of 40-840 mg/kg for rats and a Toxicity Category of 4 (EPPO, 2003). Therefore, this pesticide is not recommended for use, especially in the framework of compliance with organic farming standards.

During the two-year study, mass insect trapping helped neutralize 1882 pests, of which 606 were collected using pheromone traps. The pests were collected during the ripening period of the broccoli *Brassica oleracea* Italica group. The average air temperature in August was +33°C, in September – +29°C, and in October there was a decrease in the average daytime temperature to +22°C. Insects were caught using 50 traps. Following the results of the observation, many pests caught in pheromone traps were observed in October (Fig. 2).

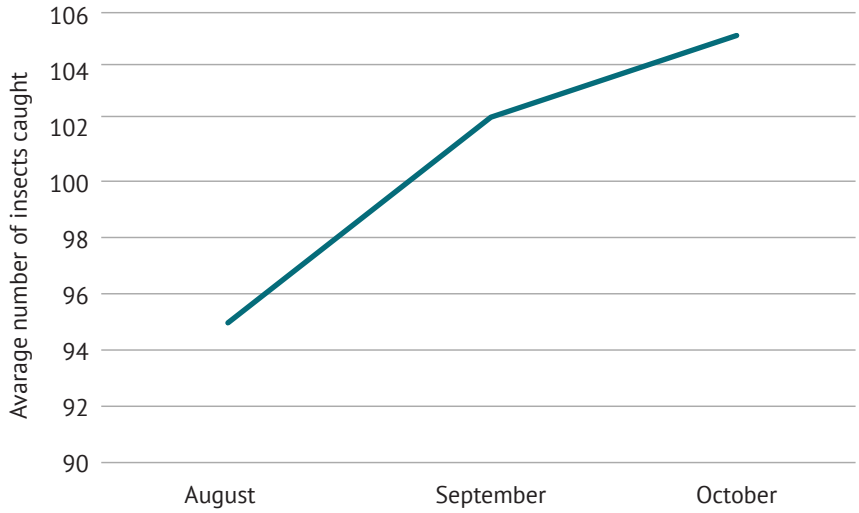

Figure 2. *The average number of Ceutorhynchus rapae captured by Great Lakes IPM Inc. traps in 2021-2022*

The results obtained (Fig. 3) also showed a significant fluctuation in the number of collected pests for each of the approaches over three months, but the average number of collected individuals per seizure in both 2021 and 2022 was 7 insects. This can be explained by both the variability of weather conditions, including precipitation and air temperature fluctuations and statistical error. In addition to the expected *Ceutorhynchus rapae*, other species of weevils, such as *C. obstrictus* and *C. pallidactylus*, were also caught in pheromone traps, but the majority of the pests caught, namely, 63%, were identified as *Ceutorhynchus rapae*. Different species of insects have specific olfactory receptors, which allow them to respond to certain types of chemical compounds. Olfactory receptor neurons contain specific proteins that are located on the palps and antennae of insects and determine their sensitivity to a certain type of molecule (Witzgall *et al.,* 2010).

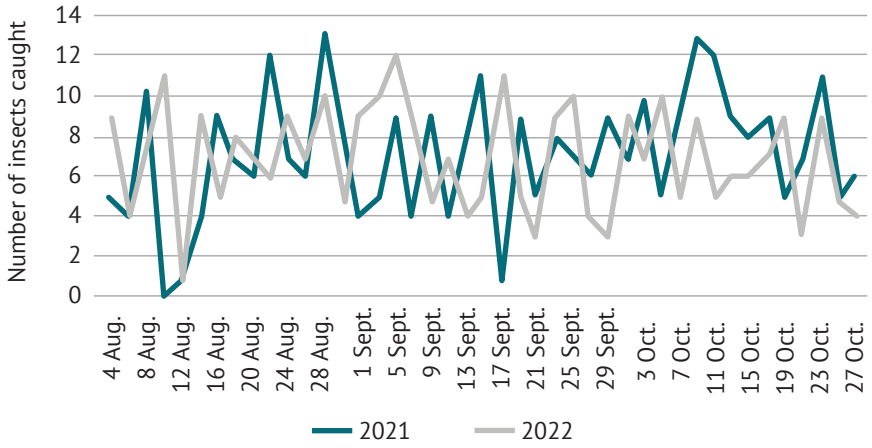

Figure 3. *The number of insects caught by Great Lakes IPM Inc. traps from August to October 2021 and 2012*

It is worth noting the influence of the average air temperature on the number of individuals caught. A decrease in temperature contributed to an increase in the number of insects collected during the month. It can be assumed that this pattern is due to the increased activity of weevils before hibernation, but this hypothesis requires further study. At the same time, the increase in humidity also partially reduces the effectiveness of the measures taken. Thus, in September, the number of rainy days was 14. Therefore, it should be assumed that the results of similar studies in greenhouse conditions will have significant differences from the field.

Previous studies have also indicated the significant effect of the yellow colour in attracting the attention of some pests, in particular weevils of various species (Cruz-Esteban *et al.,* 2021, Toshova *et al.,* 2009). Therefore, yellow traps were chosen as an additional type of protection for broccoli *Brassica oleracea*, which consisted of yellow plastic with a thin layer of glue. Although this type of trap has several disadvantages and should not be used for plantations with a high level of a plant infection, the feasibility of using such traps was proved by experimental values in this study. The yellow sticky traps were changed weekly for two years, and the number of insects and species was also recorded. The maximum number of caught pests was observed in May 2021, namely 103 insects (Fig. 4).

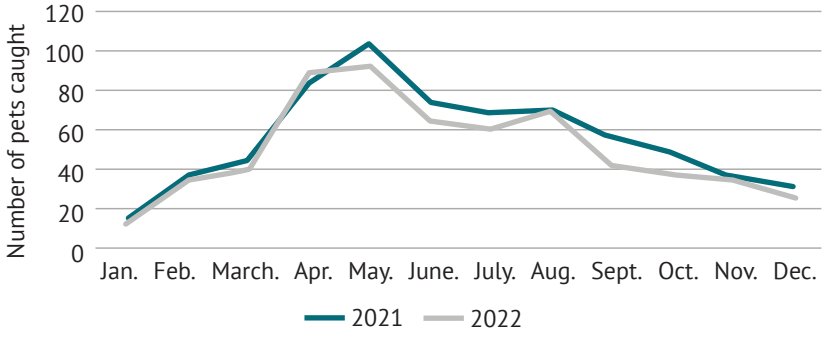

Figure 4. *Number of insects caught by yellow sticky traps from January 2021 to December 2022*

As expected, other insects were identified in addition to weevils (Table 3). That is, this method can be effective for crop protection in the combined type of plant protection. Its significant advantage is not only simplicity and commercial availability, but also safety compared to traditional plant protection products.

Table 3. *Species caught with yellow sticky traps during 2021-2022*

Types	Number of beetles caught, pcs	Number of beetles caught, %
Aleyrodes proletella	446	35.0
Brevicoryne brassicae	178	14.0
Ceutorhynchus rapae	548	43.0
Others	102	8.0

Source: *compiled by the authors*

Yellow sticky traps demonstrated high efficiency in catching whiteflies, which, in combination with the use of *Bacillus thuringiensis*, helped to prevent the impact of insects on the plant culture under research. The yield of cabbage was 27 tons/ha, with yields in the area where pheromone traps were installed significantly different from those where no traps were installed. The yield of the area where the combined approach was used was 67.8% of the total yield, which indicates a great potential for the introduction of mass pest trapping in combination with other methods of protection.

Damage to the leaves with the simultaneous use of three types of protection decreased by 91% in 2021 and by 95% in 2022 (Fig. 1). Visual evaluation of broccoli during the study helped to assess the prospects of using biological pesticides.

It is worth noting the influence of the average air temperature on the number of individuals caught. A decrease in temperature contributed to an increase in the number of insects collected during the month. It can be assumed that this pattern is due to the increased activity of weevils before hibernation, but this hypothesis requires further study. At the same time, the increase in humidity also partially reduces the effectiveness of the measures taken. Thus, in September, the number of rainy days was 14. Therefore, it should be assumed that the results of similar studies in greenhouse conditions will have significant differences from the field.

The results showed the feasibility of using a combined method of plant protection but also illustrated several issues that require further consideration. In particular, it concerns population control and selective trapping of *Ceutorhynchus rapae*. Although this study managed to reduce the number of pests on the plantation, this approach needs to improve the level of selectivity.

DISCUSSION

Indoxacarb is one of the most popular synthetic pesticides, but its toxicity, although not sufficiently studied, may pose a potential threat to humans and mammals along with other synthetic agents. Recent studies have demonstrated the advantages of *Bacillus thuringiensis* over Indoxacarb, which is a much safer analogy and can demonstrate good results in pest control (Nazarpour *et al.,* 2016). On the other hand, a study of *Tuta absoluta* control in tomato plantations showed the opposite results (Shahini *et al.,* 2021). Therefore, a good idea for further experiments would be to compare the effectiveness of combining these pesticides with safer ones and analyse the resulting efficiency.

An interesting approach to protecting rapeseed from *Brevicoryne brassicae* was discovered by scientists from Iran, who treated the crop with the proteobacterium *Pseudomonas putida* and acetylsalicylic acid. Their goal was to give the crop resistance to this type of pest to reduce the use of synthetic insecticides, but as the authors note, such an intervention can change the chemical composition of plants by increasing the content of some secondary metabolites (Khoshfarman-Borji *et al.,* 2020).

A study of the effect of directly colonized *Bacillus thuringiensis* on pak choi (*Brassica campestris var. chinensis*) leaves on whiteflies showed that the concentration of insecticide obtained in this way is insufficient to kill all individuals and leads to the mortality of only 35% of insects (Prabhakar and Bishop, 2009). On the other hand, the use of ready-made solutions is more effective, causing mortality of up to 80% of pests (Moxtarnejad *et al.*, 2014; Eski *et al.,* 2022).

A group of scientists from Karadeniz Technical University analysed the effect of *Bacillus thuringiensis* on individuals of the cicada family, namely *Orosanga japonica*, and managed to find an insecticide concentration that caused mortality of more than 97% of pests (Biryol *et al.,* 2021). However, in this study, such results were not achieved even when combining the treatment of crops with *Bacillus thuringiensis* and pyrethrum. This can be explained by the greater diversity of insects on the plantation.

It is also worth noting that the above experiments were conducted in greenhouse conditions, which allowed better research on the selective effect of individual pesticides and their combinations on plant crops, but in this study, the realistic conditions were attempted to be recreated to analyse the impact of additional factors that may affect the effectiveness of such methods in their practical implementation. In particular, for field conditions, due to constant weather changes and the lack of additional UV protection, the effectiveness of plant protection is significantly reduced.

Pyrethrin was also chosen as an additional environmentally friendly pest control agent. One of the research objectives was also to reveal new opportunities and prospects for this insecticide. Treatment of plants with pyrethrin can solve the problem of impact not only on the existing offspring of insects but can also reduce the number of larvae hatching from eggs. In previous studies, the number of hatched larvae after pyrethrin treatment decreased by 52% (Yang *et al.,* 2012). An interesting solution for further study could be the cultivation of pyrethrum directly near vegetable-keeled crops, as Albania's climatic conditions and soils are favourable for *Tanacetum cinerariifolium* (Sladonja *et al.,* 2014). To obtain a bioinsecticide concentrate, essential oils are separated by preparative high-performance liquid chromatography, and pyrethrins I and II, cinerin II, and jasmonin II, in addition to insecticidal properties, can affect the olfactory receptors of insects, thereby repelling them (Yan *et al.,* 2021). Pyrethrin also has the effect of reducing insect appetite, which helps to reduce the number of damaged leaves and stems (Takikawa *et al.*, 2022).

The literature review revealed a lack of studies comparing the impact of pesticides such as Indoxacarb

and pyrethrin on crop yields, their combination, and their toxic effects on the environment.

When combining different crop protection products, there is also a need to diagnose pest types and predict the adaptability of different insect species to each pesticide. For broccoli *Brassica oleracea* planted in subtropical climates, *Ceutorhynchus rapae* will pose a significant threat (Seidenglanz *et al.,* 2022). *Ceutorhynchus rapae* are common in areas with high humidity and feed on the leaves and stem of broccoli *Brassica oleracea*, so when growing this crop in a subtropical climate, the issue of controlling this pest has arisen. Among the known safe methods of plant protection against weevils, pheromone traps are highly effective. This approach not only helps save crops from the harmful effects of weevils but also allows for the analysis of the species diversity of insects in the study area. Pheromone traps have demonstrated good results in previous studies, but yellow sticky traps were more effective against the cabbage weevil (Toshova *et al.,* 2009). The addition of allyl isocyanates to the traps can further increase the weevil catch, but the goal of our work is to ensure minimal harm and maximum environmental friendliness of the methods, and these compounds, although not to a large extent, have toxicity for warm-blooded animals and humans.

In this research, the combination of the use of pheromone traps against *Ceutorhynchus rapae* with other methods of protection played an important role. The work of Samuel Cruz-Esteban *et al.* (2021) is also worthy of great attention, as they studied the effect of colour on the lure of *Drosophila suzukii* and *Zaprionus indianus*. In the field, on a blackberry plantation *Rubus ulmifolius*, the scientists found that yellow cards help to carry out high-quality monitoring and catching of insects. Such traps work due to the biological instincts of insects (Böckmann *et al.,* 2021, Takikawa *et al.,* 2022). And although, as noted, the effectiveness of this approach is somewhat inferior to that of synthetic pesticides, it is a good alternative solution to further increase crop yields. Using a similar technology in this study, it was possible to analyse the ratio of pests affecting *Brassica oleracea*. Thus, a clear understanding of the existing dangers will allow us to improve the methods of integrated broccoli protection in the future and demonstrate high exports of this vegetable crop for Albania. At the same time, an additional advantage of using simple traps is the availability of their implementation in conditions of a limited budget.

Combining different biological pesticides not only helps to increase the number of undamaged plants for further harvesting and sale but also has several other equally important benefits. Every year, farmers and other professionals working with synthetic pesticides put their health at risk, risking endocrine disruption due to chemical poisoning. That is why the integrated approach to crop protection discussed in this article will help to modify the approach to agriculture and pave the way for the introduction of new regulations aimed at simplifying, systematizing and, most importantly, protecting the environment from the harmful effects of toxic pesticides.

This method eliminates the use of synthetic pesticides, replacing them with biological pesticides, which significantly reduce environmental damage. However, for further study, it is important not only to select the right biological objects that will become safe analogues of popular insecticides but also to implement several measures that will ensure comprehensive plant protection against seasonal pests. The combination of biochemical and microbial protection is the most successful and cost-effective choice. Further research and implementation of new technologies for agricultural land in Albania will illustrate the possible disadvantages of these methods and help expand their scope of application globally.

In other words, this way it was possible to significantly reduce the level of toxic substances in the soil, increase crop yields, and this study illustrated the difficulties and benefits of implementing organic farming technologies on a specific example, ensuring the relationship between crops and organisms, as well as directing and controlling biosystems with minimal modification.

CONCLUSIONS

As a result of the research, the efficiency of the combined approach to plant protection against pests was obtained from the example of the broccoli *Brassica oleracea* Italica group. When using pyrethrin and *Bacillus thuringiensis*, the efficiency of the method was 57%, but the installation of pheromone and yellow sticky traps increased the efficiency to 93%. No synthetic pesticides and poisons were used in the process of crop treatment, and a combination of environmentally friendly and simple methods inherent in organic farming allowed for high yields without harming the environment. The massive trapping of insects, namely weevils, allowed not only influence the potential yield reduction but also to assess of the population of *Ceutorhynchus rapae* in the humid subtropical climate of Tirana. Of the 1882 insects recorded in the traps, 1276 were *Ceutorhynchus rapae*.

Further research into biological pesticides and the successful implementation of their use will both simplify and improve access to quality, safe food for a wide range of consumers. On the other hand, such an approach will increase the effectiveness of plant protection and find applications for less potent agents that, in combination with others, will show a high level of efficiency. It is also important to study the combination of these methods on the example of other crops to expand the scope of their application. At the same time, one of the methods can be replaced, because the pests of broccoli *Brassica oleracea* may be absent on other

crops but have their specific representatives that spoil the appearance of the plant or lead to its death.

When analysing all the possible hazards that can affect crop yields, massive insect trapping allows us to form a clear picture of the number of pests of each species. In addition, additional visual observation of the leaves, stem and general appearance of each plant helps to better select the means and ways to care for the plantation. In other words, the introduction of organic farming not only simplifies the process of plant protection but also increases crop yields with minimal additional resources.

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CONFLICT OF INTEREST

None.

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Основні напрямки інтегрованого захисту рослин в умовах органічного землеробства

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Анотація. Екологічна ситуація у світі з кожним роком лише погіршується. Це спричинено збільшенням забруднення повітря, стічних вод, спалюванням деревини тощо. З 2013 року викиди аміаку компаніями Європейського Союзу значно зросли. Цьому сприяло, зокрема, використання синтетичних пестицидів. Саме тому перехід сільського господарства на стандарти органічного землеробства можна вважати хорошою альтернативою. Метою дослідження було проаналізувати ефективність поєднання відомих органічних пестицидів в одному біогеоценозі. У дослідженні запропоновано комбіновану обробку овочевої культури *Brassica oleracea* такими біологічними пестицидами, як *Bacillus thuringiensis* та піретрин, у поєднанні з масовим відловлюванням шкідників. При поєднанні цих трьох підходів ефективність склала 93 %. Загальна врожайність склала 27 т/га, тоді як на ділянці поля, де використовували феромонні та жовті клейкі пастки, врожайність становила 34 т/га. Ці методи були ефективними проти наступних шкідників: *Ceutorhynchus rapae*, *Aleyrodes proletella* та *Brevicoryne brassicae*. Пошкодження листя було зменшено в середньому на 93 % за період дослідження при використанні комбінованого підходу. За два роки досліджень вдалося знешкодити 1882 комахи шляхом масового відлову і з'ясувати, що найбільша кількість *Ceutorhynchus rapae* пошкоджує культуру в травні та серпні, а використання феромонних пасток є найбільш ефективним у жовтні. Поєднання окремих методів підвищило ефективність кожного з них завдяки синхронізованому впливу на різних шкідників. Підвищення врожайності овочевих культур в Албанії в майбутньому може також вирішити проблему голоду в країнах з несприятливими кліматичними умовами за рахунок збільшення експорту цих культур

Ключові слова: *Bacillus thuringiensis*; піретрум; *Brassica oleracea*; біологічні пестициди; природний інсектицид