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THE INFLUENCE OF WEED INFESTATION AND PEA (*PISUM SATIVUM* (LINN.)) CROPPING SYSTEM ON THE BENEFICIAL AND HARMFUL ENTOMOFAUNA

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Abstract

The experiment was carried out in the conventional and organic experimental fields of the Institute of Agriculture - Karnobat, in the period 2019 - 2022. The aim of the experiment was to study the influence of weed infestation and cropping system of pea (*Pisum sativum* (Linn.)) on the beneficial and harmful entomofauna. Six and seven species of insects from seven families and three orders were found to damage pea in organic and conventional farming, respectively. Their density was higher in conventional farming. The most economically important and the most widespread pest in both types of cropping was the aphid *Acyrthosiphon pisum* (Harris, 1776). Of the beneficial insects, thirteen species were found in pea in organic and eleven in conventional farming, from eight families and five orders. Greater species diversity and higher numbers were observed in organically grown pea during all four years of the study. The absence of herbicide treatment in organic farming and the presence of more blooming vegetation stimulate the multiplication of beneficial entomofauna, regulating the population density of the aphids in pea. The correlations between the blooming vegetation and the beneficial entomofauna and between the beneficial and harmful entomofauna have been demonstrated.

Keywords: pea, beneficial and harmful entomofauna, weeds, organic and conventional farming

INTRODUCTION

The introduction of intensive agricultural practices in Europe has led to the implication of agricultural scapes and an increased use of fertilizers and pesticides (Robinson, Sutherland, 2002). Despite the increase in yields, many side effects occur, such as environmental pollution and human health risks (Baldi et. al., 2013; Devine et. al., 2007; Krebs et. al., 1999), which necessitate a transition to more sustainable food systems (Hatt et. al., 2016). Due to the excessive use of insecticides in recent years, pest resistance has further developed (Foster et. al., 2007). Increasingly stringent regulations on the pesticide use are being adopted in the European Union (Skevas et. al., 2013), encouraging the development of non-chemical practices.

In organic farming of leguminous crops (winter pea), the biggest challenge is to create a sustainable crop, with good competitive ability against available weeds. Since the use of pesticides is prohibited, the research is focused on agrotechnical, mechanical and ecological methods, helping to create a good and strong pea crop that can compete with weeds. In the survey of 119 conventional and 64 organic fields, a total of 76 weed species were recorded, with the average number of weed species per field being 10 in conventional cultivation and 18 in organic farming. The most common weed species in both farming practices were *Chenopodium album*, *Stellaria media* and *Viola arvensis* (Salnen, Terho, 2005). Plowing depth and seeding depth (Gronle et al, 2015), field pea seeding rates (Bailey-Elkin et al., 2022), comparison of pea genotypes and cultivars

(Collner, et al, 2019; Ntatsi et al, 2019), pure and mixed crops (Kristo et al., 2022).

The cropping system plays an essential role in controlling the numbers of harmful and beneficial entomofauna. The organic farming system excludes the use of chemical agents, which significantly affects the preservation of beneficial insects and the self-regulation in agrocenoses. It has been established that the reduction or exclusion of chemical agents in cultivation technologies contributes to the multiplication of beneficial entomofauna (Kornijchuk, 2013, 2017; Borzykh, Tkalenko, 2018; Sabluk et.al., 2021).

The principle of self-regulation of insect groups in agrocenoses is the basis of this process, that is, due to the optimization or exclusion of chemical plant protection measures, the beneficial insects that feed on phytophages or parasitize on them are preserved and thus maintain their numbers at a certain level (Stankevych et. al., 2016; Sabluk et. al., 2018, 2021; Vorozhko et. al., 2017). Many studies confirm that the chemical agents used in the cropping technologies in a conventional farming system reduce the population of beneficial insects in agrocenoses or destroy them. This, in turn, leads to breaking the natural connections between living organisms in agrocenoses, and also conditions are created for the mass accumulation of certain types of phytophages, and there is an urgent need to control their numbers, mainly with the help of the same chemical means, and this is repeated year after year (Pysarenkoet. al., 2002; Stankevych et. al., 2016; Vorozhko et. al., 2017; Sabluk et. al., 2021).

Numerous studies highlight the potential of habitat diversity to improve the conservation biological control (CBC), most notably showing that the increased landscape complexity contributes to increased numbers of natural enemies and reduced pests (Balzan et. al., 2016, Martin et. al., 2016, Rusch et. al., 2016). Wildflower strips (WFS) sown along field borders (Tschumi et. al., 2016) or within fields (Hatt et. al., 2017) and hedgerows (Morandin et. al.,2014) are used as well as forests (Bianchi et. al., 2008) adjacent to the fields can also improve CBC (Tscharntke et. al., 2016).

Aphids (Hemiptera: Aphididae) are a major crop pest in temperate regions (Van Emden et. al., 2007). They harm by sucking plant sap from plants, producing honeydew and transmitting viral diseases. Their natural enemies are predators and parasitoids (Katis et. al., 2007).

The aim of the present study is to investigate the influence of weed infestation and the pea (*Pisum sativum* (Linn.)) cropping system on the beneficial and harmful entomofauna.

MATERIALS AND METHODS

The experiment was conducted on conventional and organic experimental field of the Institute of Agriculture - Karnobat, in the period 2019 - 2022. Under the conditions of a conventional (CF) and an organic farming (OF) system, the pea variety Mir was grown, used for silage and harvested in the flowering phase. The trial was based on an area of 0.1 ha – 0.5 ha in a conventional and 0.5 ha in an organic field. The predecessor of the pea in both types of farming systems were cereal crops. The pre-sowing soil treatment was cultivation, and the sowing rate of pea was 100 - 140 seeds per square meter. Sowing was done as soon as possible after October. No pesticides were applied in the organic field. In the conventional – when the weed density was above the economic threshold (20-30 pcs/m2 depending on the species), they were treated with foliar herbicides with the active substance bentazoneand/orhyzalofop-P-ethyl in the recommended doses. The technological solutions were in line with the "FarmtoFork" strategy — one of the main pillars of the European Green Pact, which aims to reduce the use and risk of chemical and more dangerous pesticides in the EU by 50% by 2030.

The entomological observations in pea were carried out in the period from germination to flowering and harvesting of peas for silage in this phase, in both types of farming. The surveys were carried out by mowing with a standard entomological sweeping net. The samples were collected in bags and processed in the plant protection laboratory of the Institute of Agriculture - Karnobat.

Weed species were counted in the phase appearance of third triple leaf (103) - appearance of the first branch (201) and in the phase 4 branches with whiskers - beginning of flowering (501) according to the quantitative - weight method - number/m^2, fresh and air-drybiomass (g/m^2), in 4 plots of 0.25 m^2. Weed species were determined according to Delipavlov et al. (2003).

The mathematical processing of the results was performed with the Statistics program.

In southeastern Bulgaria, the climate is transitional-continental with an average annual precipitation of 549 mm. Winter is relatively warm, spring is short and cool, summer is hot and dry, autumn is long and warm. Weather conditions during the study period differed significantly. In the first year, they are very suitable for growing the crop. Pea thrives under conditions of sufficient rainfall and suitable temperatures. Visually, there are no differences in the habit, stemness and density of the conventional and organic crops. In the second year of the study, drought began in the winter period and continued in the spring. This had an adverse effect on the culture - the plants were small and suffered from a lack of moisture. In the third and fourth years - the conditions again were not very optimal for cultivation. Pea has grown in conditions of insufficient rainfall. Visually, there were no differences in the habit, stemness and density of crops grown in the two farming systems (Figure 1).

RESULTS AND DISCUSSION

As a result of the observations on pea, seven species of insects in the conventional and six in the organic farming, from seven families and three orders, were found to be harmful. (Table 1).

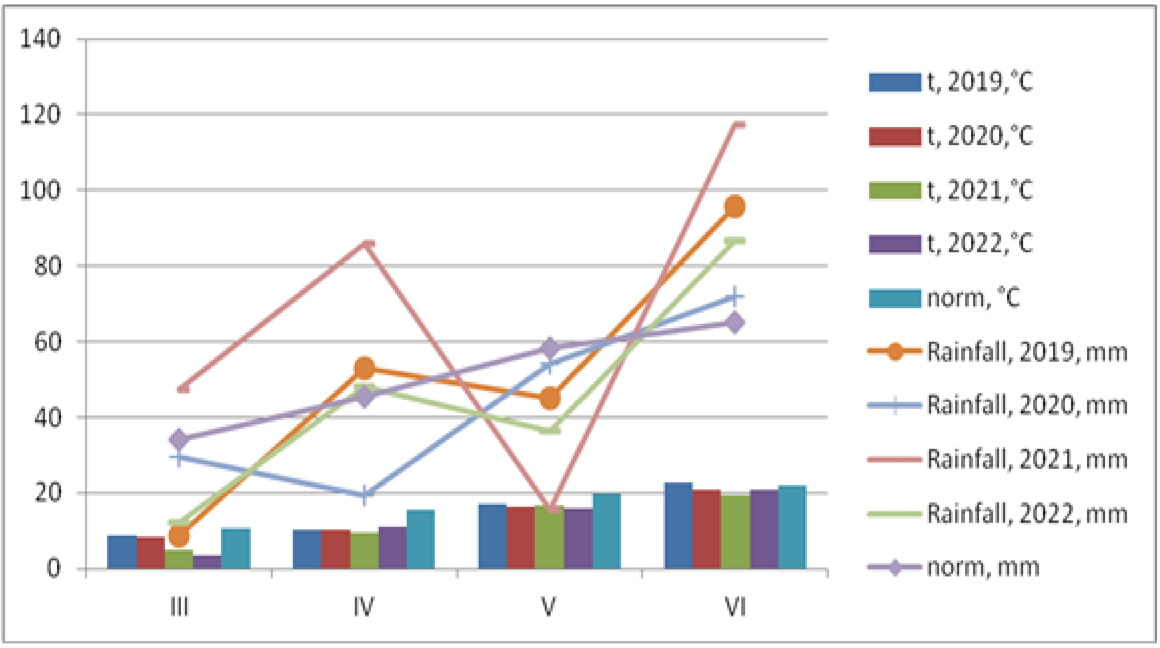

Figure 1. Agrometeorological conditions during the study period

Table 1. Species composition of pests on pea grown in two types of cropping

Order	Family / Species	Organic farming	Conventional farming
Coleoptera	Bruchidae		
	Bruchus pisorum (Linnaeus, 1758)	+	+
Hemiptera (suborder Homoptera)	Aphididae		
	Acyrthosiphon pisum (Harris, 1776)	+	+
	Cicadellidae		
	Empoasca pteridis (Dahlbom 1850)	+	+
	Aphrophoridae		
	Philaenus spumarius (Linnaeus, 1758)	+	+
Lepidoptera	Nymphalidae		
	Vanessa (Pyrameis) cardui(Linnaeus,1758)	-	+
	Noctuidae		
	Autographa gamma (Linnaeus, 1758)	+	+
	Crambidae		
	Loxostege sticticalis (Linnaeus, 1761)	+	+

The species *Acyrthosiphon pisum* (Harris, 1776) reached the highest number of pests in both types of farming (Figures 2a, 2b, 2c, 2d). It is also of the greatest economic importance. The thesis of Van Emden et al. (2007) referred to the aphids (*Hemiptera*: *Aphididae*) as the major crop pest in temperate regions. At the beginning of the reporting in 2019 the species were in a higher density in organic farming. Later, their number dramatically increased in conventional farming (Figure 2a) due to the greater number of natural regulators of pest in organic farming (Figure 3a), as reported by researchers who studied pests in organic and conventional farming (Kornijchuk et. al., 2017; Pysarenko et. al., 2002; Stankevych et. al., 2016), emphasizing that it is not the use of pesticides in organic farming that contributes to the multiplication of beneficial entomofauna. The naturally occurring interactions between living organisms in agrocenoses are restored and self-regulation of insect groups takes place, i.e. all types of insects are maintained at a certain level without destroying each other.

Towards the end of May, the numbers of *Acyrthosiphon pisum* (Harris, 1776) in both types of pea cropping decreased, probably due to the rainfall that fell at the end of the month (Figures 1, 2a). Stacey & Fellowes (2002) investigated how climate affects *Acyrthosiphon pisum* (Harris, 1776) and its attack by parasitoids, finding that a temperature difference of 5 degrees had no effect (from 18 to 23°C). The same authors found that ladybugs are not directly affected by temperature, but by the reproduction of aphids. However, there were significant interactions between louse abundance and temperature. Therefore, smaller changes in temperature do not significantly alter the pea aphid–natural enemy interactions.

The tendency for a higher number of pests in conventional farming was preserved in the following years (figures 2a, 2b, 2c, 2d). In 2022, due to unfavorable weather conditions and the later sowing, peas developed later and at the beginning of May no pests were observed. *Acyrthosiphon pisum* (Harris, 1776) again predominated in later reports, with its abundance being higher in conventional farming (Figure 2d). Other species found in pea, in both types of farming, had a very low density and when harvesting pea for silage (for green mass) they were not of economic importance.

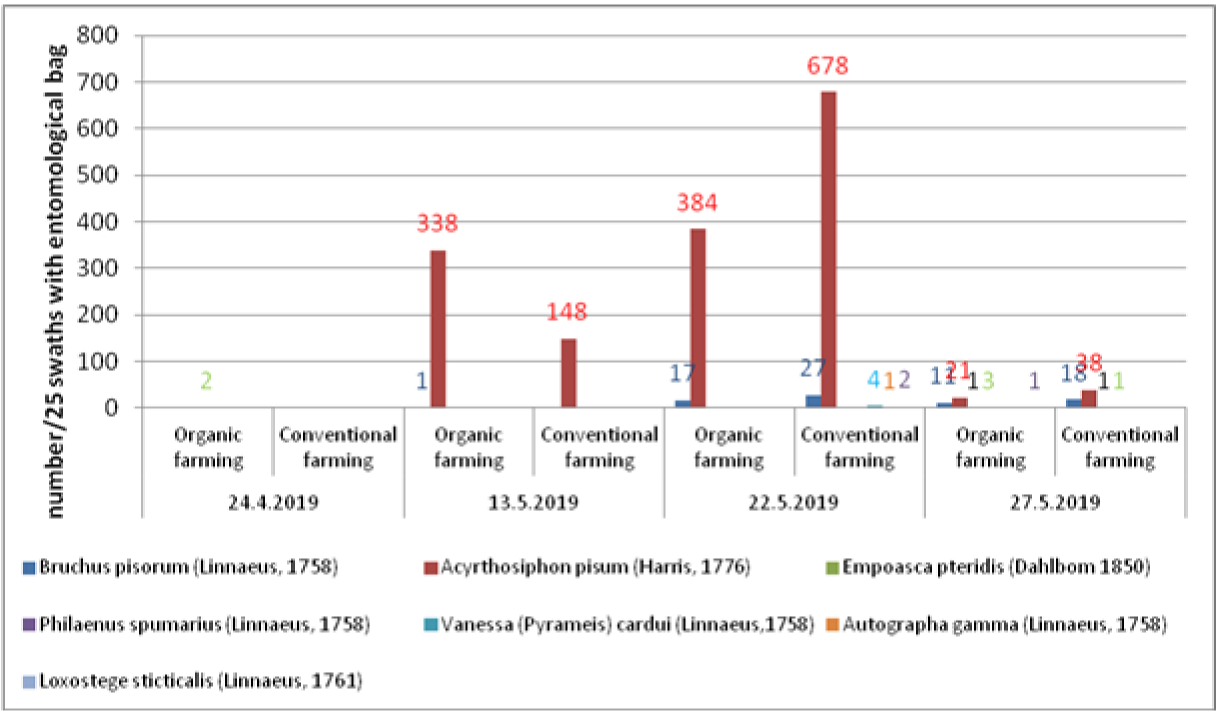

Figure 2a. Dynamics of pests on pea grown in two types of cropping systems

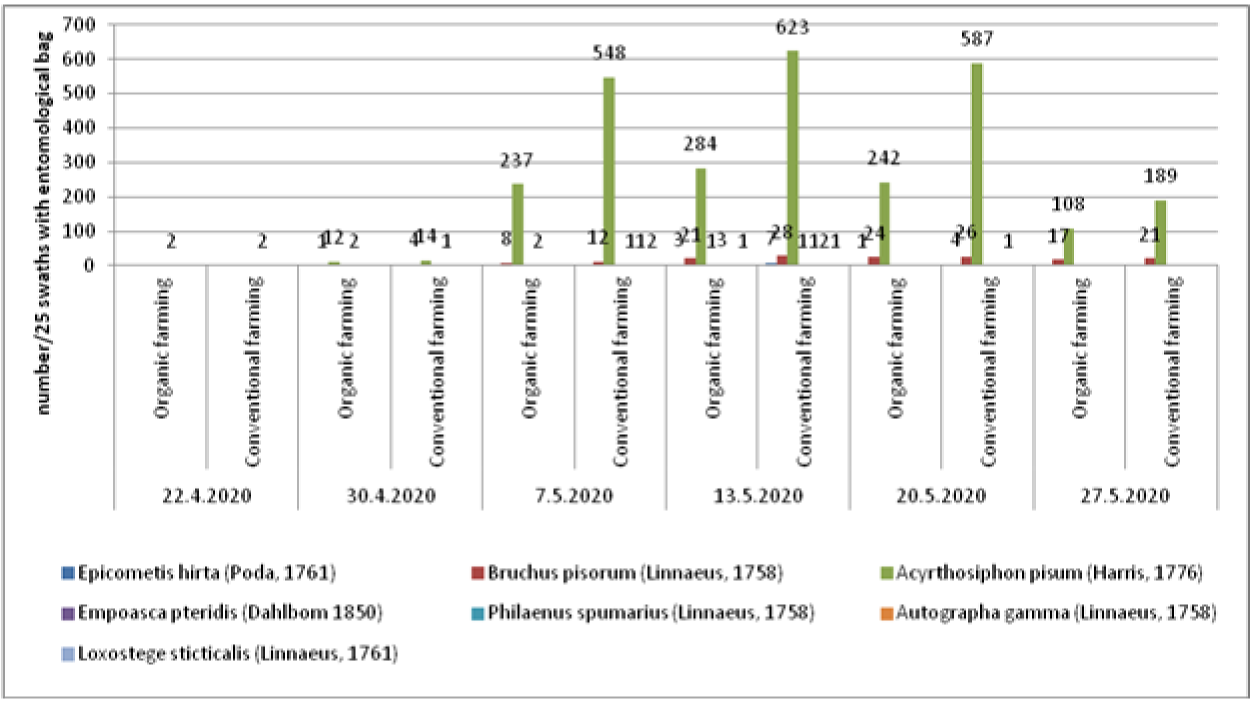

Figure 2b. Dynamics of pests on the pea grown in two types of cropping systems

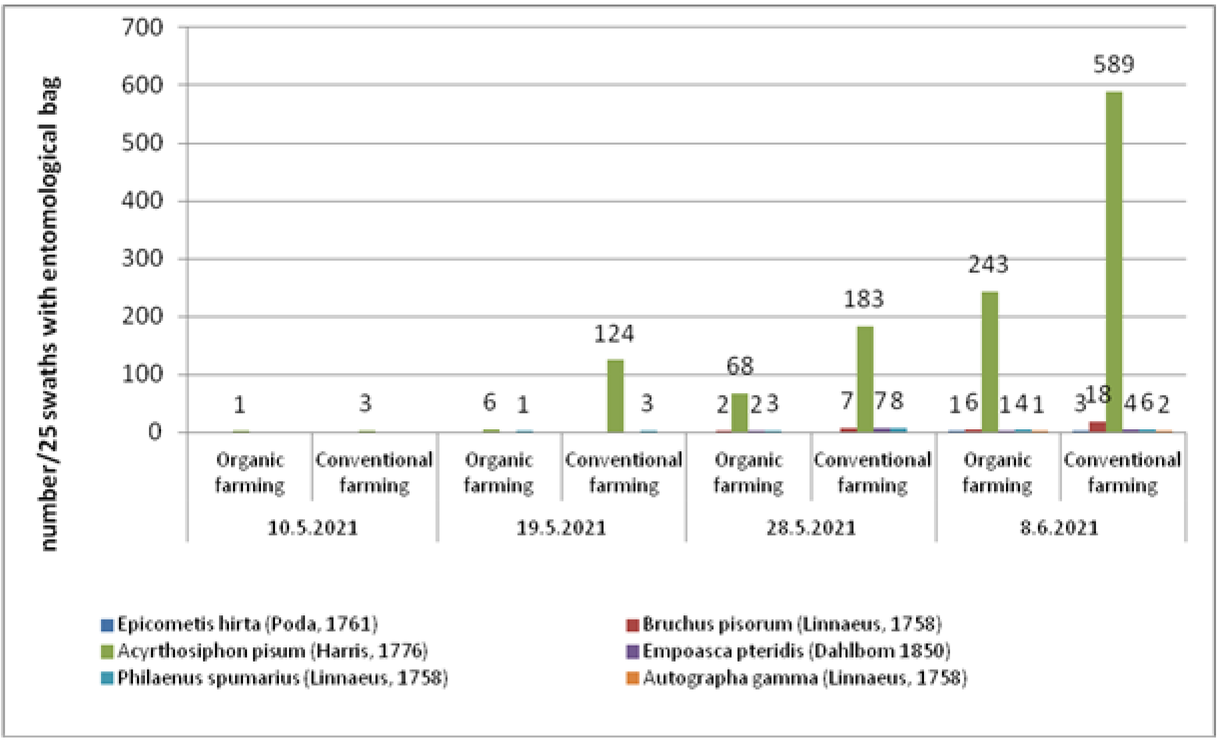

Figure 2c. Dynamics of pests on pea grown in two types of cropping systems

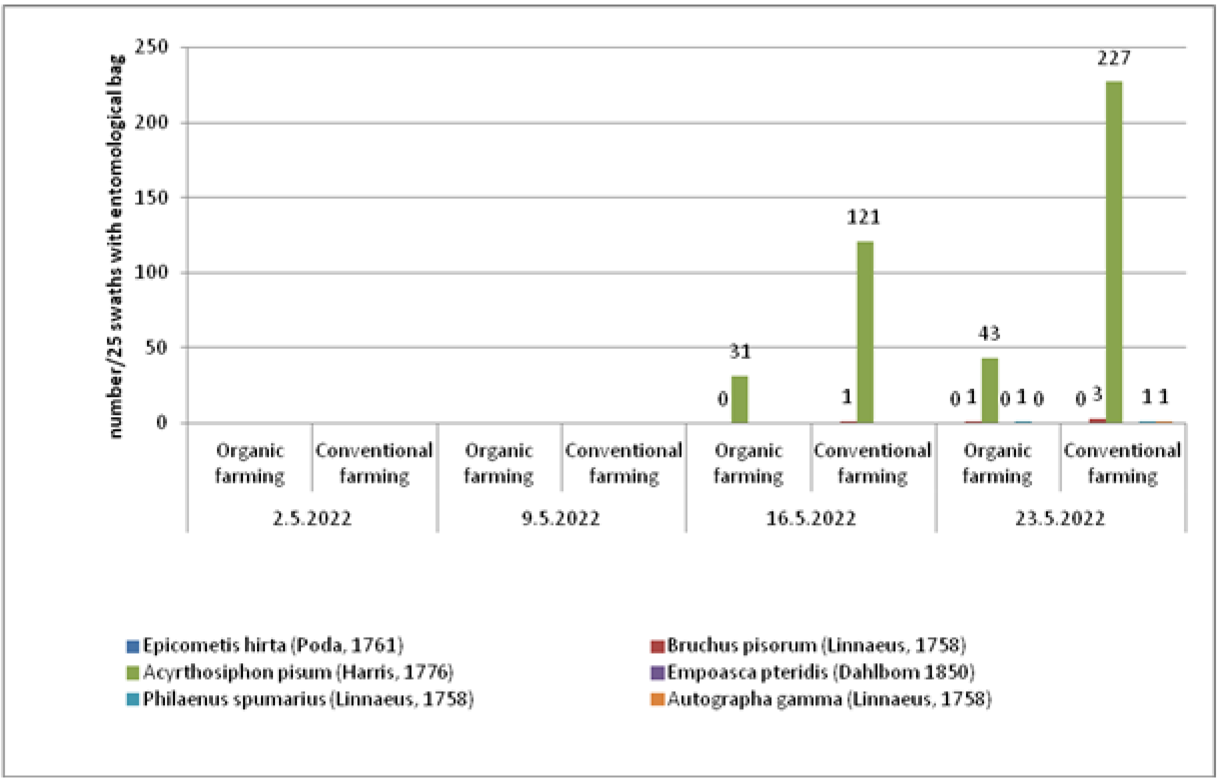

Figure 2d. Dynamics of pests on pea grown in two types of cropping systems

Of the beneficial insects, thirteen species in organic and eleven in conventional farming, from eight families and five orders, were found on pea (Table 2). A greater species diversity and higher numbers were observed in organically grown pea in all four years of the study (Figures 3a, 3b, 3c, 3d). Alignieretal (2014) compared how different natural habitats (i.e. forests, grasslands, hedgerows) affect aphids, syrphid flies (*Diptera: Syrphidae*) and parasitism at different spatial scales in fields with different crops. He found that fields bordering forests were colonized early by syrphid fly larvae, suggesting that they used the forests for overwintering. In this case, our organic field is also surrounded by a forest belt and confirms this theory. The same author found out that the overwintering syrphid flies are attracted by the presence of flowering vegetation, which was also confirmed in our field. The effect of the two different habitats surrounding the same field on CBC improvement is confirmed.

Table 2. Species composition of the beneficial entomofauna in pea grown in two types of cropping systems

Order	Family / Species	Organic farming	Conventional farming
Coleoptera	Cantharidae		
	Cantharis sp.	+	+
	Coccinellidae		
	Coccinella septempunctata (Linnaeus, 1758)	+	+
Hemiptera (подразред (Heteroptera)	Anthocoridae		
	Orius sp.	+	+
	Nabidae		
	Nabis sp.	+	+
Hymenoptera	Braconidae		
	Apanteles sp.	+	+
	Aphidius sp.	+	+
	Bracon sp.	+	-
	Opius sp.	+	-
	Apidae		
	Apis mellifica Linnaeus, 1761	+	+
Diptera	Syrphidae		
	Scaeva pyrastri (Linnaeus, 1758)	+	+
	Sphaerophoria scripta (Linnaeus, 1758)	+	+
	Syrphus ribesii (Linnaeus, 1758)	+	+
Neuroptera	Chrysopidae		
	Dichochrysa prasina (Burmeister, 1839)	+	+

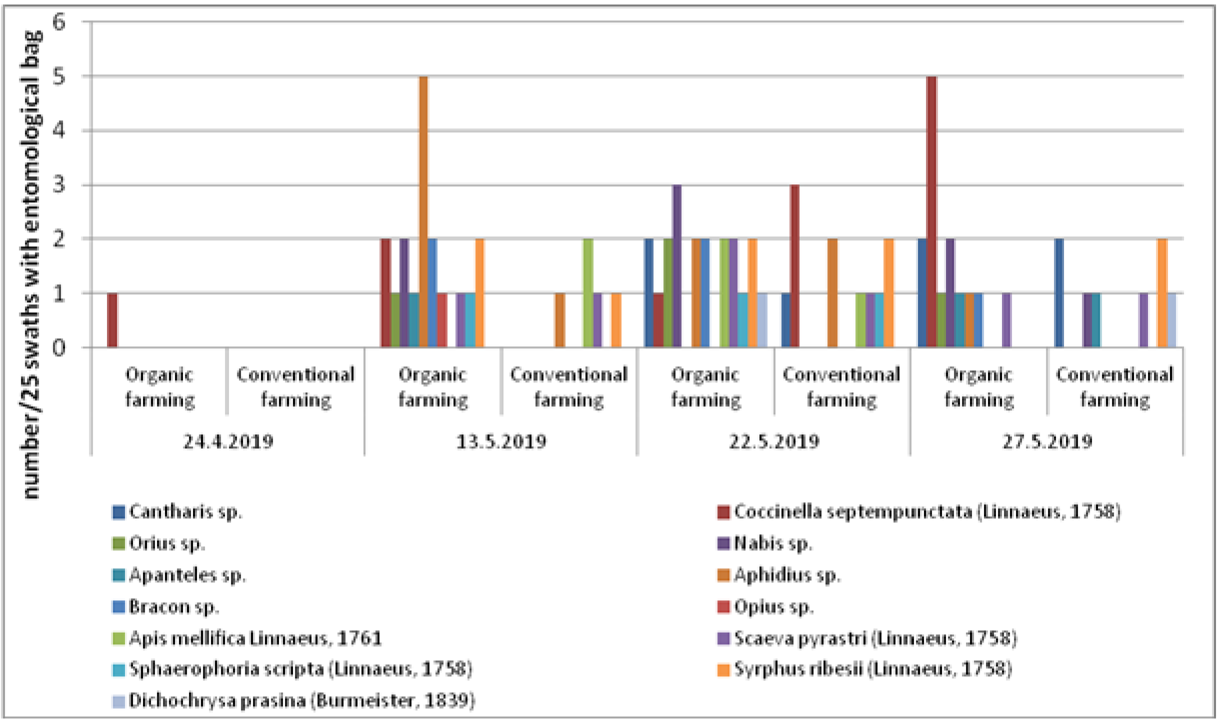

Figure 3a. Dynamics of the beneficial entomofauna in pea grown in two types of cropping systems

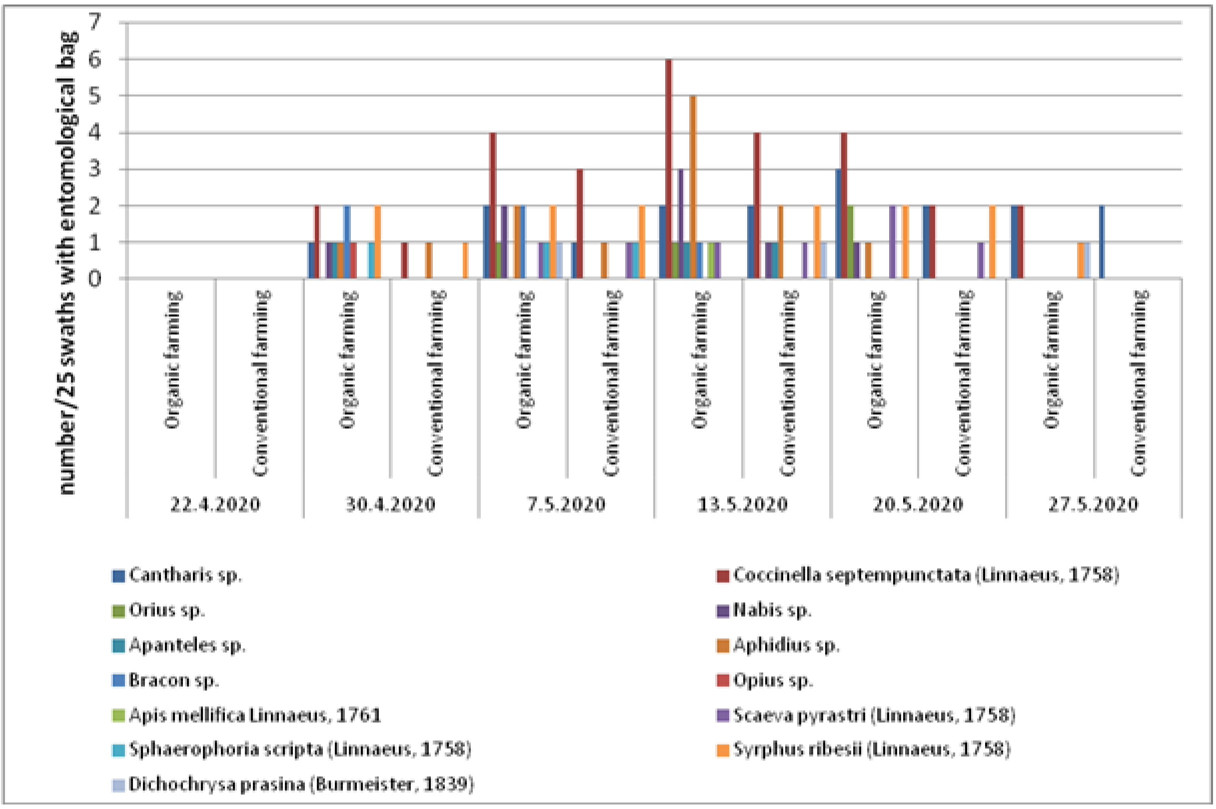

Figure 3b. Dynamics of the beneficial entomofauna in pea grown in two types of cropping system

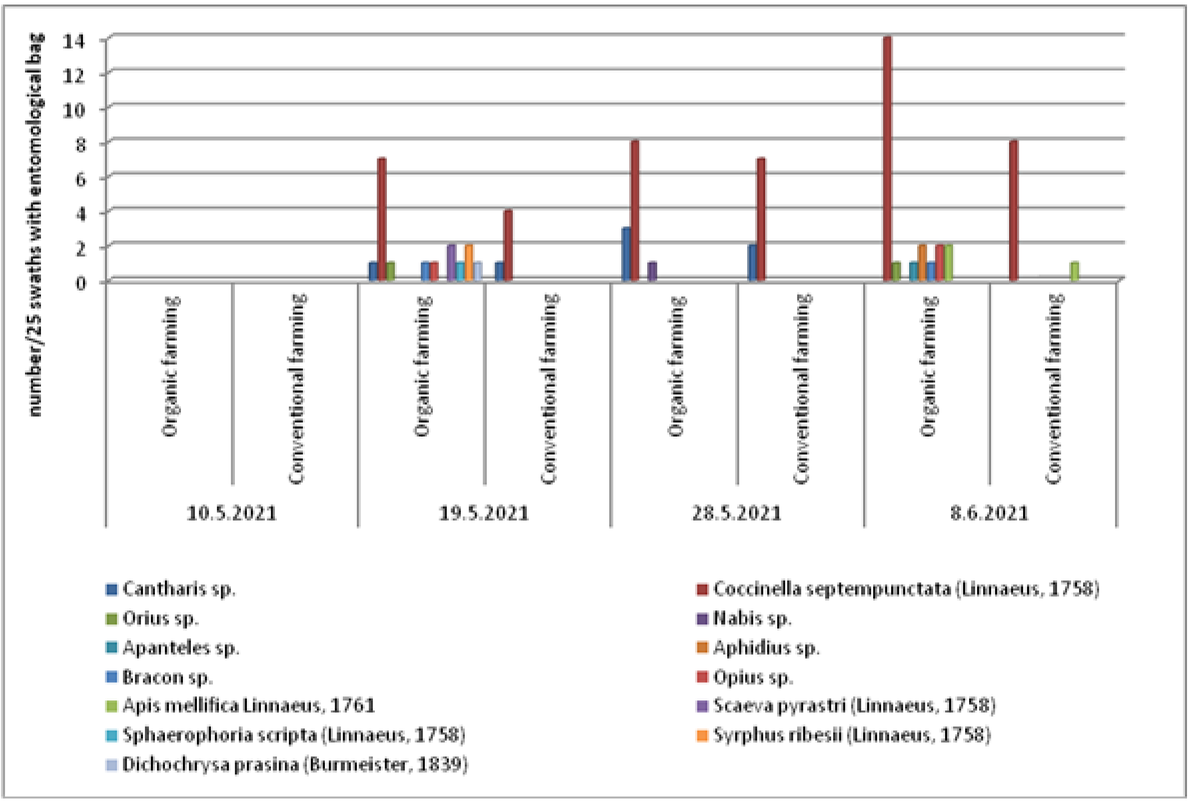

Figure 3c. Dynamics of the beneficial entomofauna in pea grown in two types of cropping system

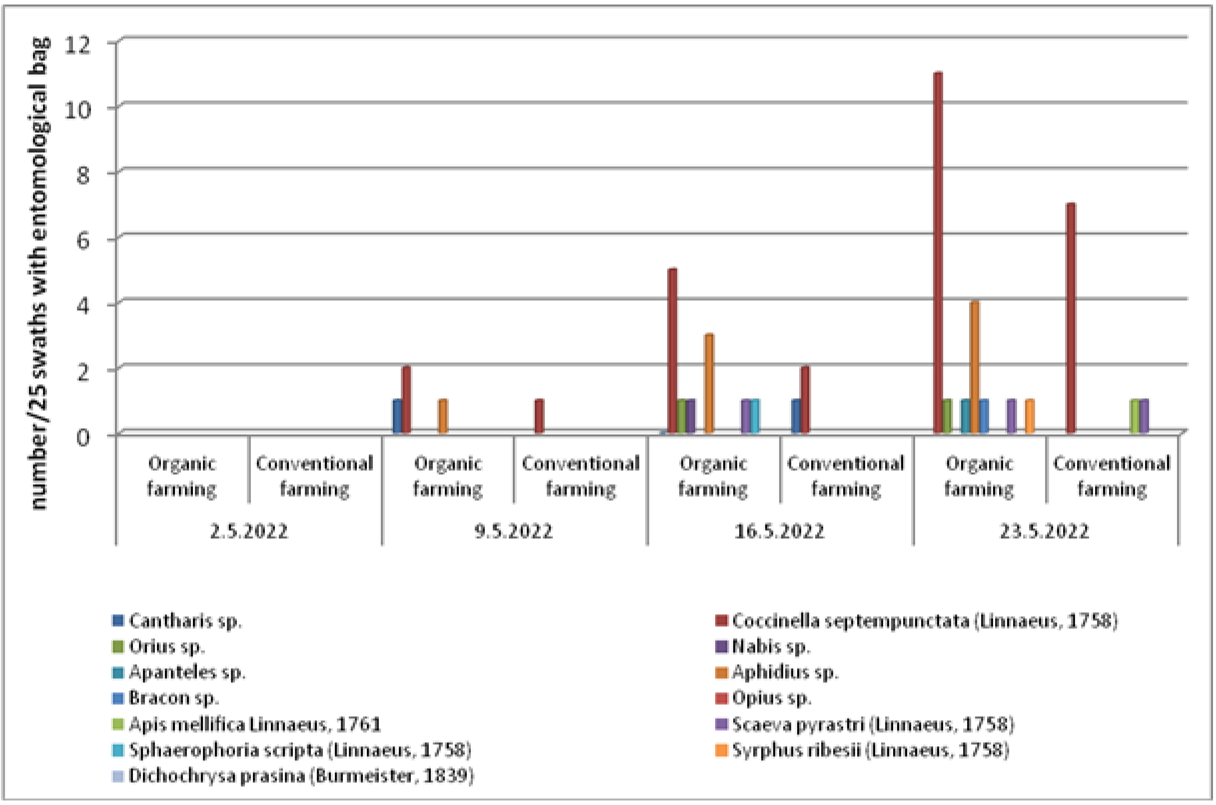

Figure 3d. Dynamics of the beneficial entomofauna in pea grown in two types of cropping system

When taking into account the species diversity and the density of weeds, the tendency for greater species diversity in organic farming (from 8 to 12 species depending on the years) compared to conventional farming (from 5 to 10 species) is clearly visible (Tables 3 and 4), in confirmation to the studies of Salnen and Terho (2005) and Arlauskienėetal (2021).

Table 3. Species composition, number and mass of weeds per m^2 in organic pea crop

Weeds	03.04.2019	22.05.2019	13.04.2020	20.05.2020	10.05.2021	28.05.2021	10.05.2022	28.05.2022
AmaranthusretroflexusL.			-	2	1	3	-	-
AnthemisarvensisL.	-	2	5	5	1	2	2	3
Anagalisarvensis L.	-	5	-	4	3	3	1	2
Avenafatua L.	-	1	2	2	-	-	1	1
Chenopodium album L.	14	1	3	6	-	1	3	-
Cirsiumarvense (L.) Scop.	1	-	-	-	1	-	2	2
Convolvulus arvensisL.	2	2	1	1	1	-	2	3
Papaverphoeas L.	-	-	5	5	-	-	-	1
Polygonim convolvulus L.	58	8	1	1	2	2	12	5
Polygonumaviculare L.	7	1	3	5	2	2	-	1
Setaria spp.	-	-	7	15	42	22	18	12
Sinapisarvensis L.	1	1	3	3	0	1	2	3
Torilisarvensis L.	-	-	-	-	-	-	1	2
Veronica hederifolia L.	4	-	2	-	-	-	-	-
Viola tricolor L.	-	2	5	5	1	-	1	2
Total weeds, (nb/m^2)	87	23	91	54	54	36	44	35
Fresh mass weeds, (g/ m^2)		162.94		158.01		72.79		84.9
Air-dry mass weeds, (g/ m^2)		32.61		45.50		18.19		24.2

The weeds in both systems were very well suppressed by the culture, especially *Polygonim convolvulus* L., *Polygonum aviculare* L., *Chenopodium album* L. There were also several types of weeds that germinated and developed during the spring growing season – *Anagalis arvensis* L. and *Veronica hederifolia* L., but they were found in the second layers of the crop and did not play a significant role. In organically grown pea, in the period April - May, a greater number of blooming weed vegetation was reported – both as species and as density per m^2 (Tables 3 and 4). These were the species – *Anthemis arvensis* L., *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L., *Papaver phoeas* L., *Sinapis arvensis* L. and *Torilis arvensis* L. Figure 4 shows the weed infestation as nb/m^2 in organic and conventional farming of winter pea. In both types of systems, at the first reading the density was higher compared to the second. In the case of organic farming this is explained by the good competitive ability of the crop, and in the case of conventional farming, the harp decrease in density was the result of treatment with herbicides.

Table 4. Species composition, number and mass of weeds per m^2 in conventional pea crop

Weeds	03.04.2019	22.05.2019	13.04.2020	20.05.2020	10.05.2021	28.05.2021	10.05.2022	28.05.2022
AmaranthusretroflexusL.	-	-	-	3	14	5		-
AnthemisarvensisL.	-	-	-	-	-	-	1	-
Anagalisarvensis L.	-	-	1	1	-	-		-
Avenafatua L.	-	1	5	1	-	-		-
Chenopodium album L.	9	5	2	8	-	1	2	5
Cirsiumarvense (L.) Scop.	1	2	-	-	-	-	2	2
Convolvulus arvensisL.	1	1	2	2	-	2	2	2
Papaverphoeas L.	-	-	-	-	-	-	1	-
Polygonim convolvulus L.	43	11	5	1	5	5	15	2
Polygonumaviculare L.	-	-	5	1	-	-	2	3
Setaria spp.	-	-	7	13	5	-	12	2
Sinapisarvensis L.	1	1	8	1	-	5	4	-
Torilisarvensis L.	-	-	-	-	-	-	-	-
Veronica hederifolia L.	1	-	2	-	-	-	-	-
Viola tricolor L.	-	-	5	2	1	-	1	-
Total weeds (nb/m^2)	56	21	42	31	25	18	42	16
Fresh mass weeds (g/ m^2)		123.95		26.32		57.48		64.2
Air-dry mass weeds, (g/ m^2)		24.08		8.24		14.37		14.8

The relationship between blooming weeds and beneficial entomofauna in organically and conventionally grown pea was investigated (Figures 5, 6, Table 5). Correlations were proven at $p < 0.05$. The theory of the predominance of beneficial entomofauna in the presence of more flowering vegetation is confirmed (Hattet. al., 2017a), and parasitoids and syrphid flies are mainly affected by the flowering vegetation (Hattet. al., 2017a).

The relationship between harmful and beneficial entomofauna was also traced (Figures 7, 8, Table 5). Correlations were proven at $p < 0.05$. Snyder & Ives (2003) found that the multiplication of parasitoids does not immediately lead to a sharp decrease in the aphid population, but at a later stage when the parasitoid develops. In contrast, predators cause a rapid decline in aphid populations, but their populations continue to increase. Only when predators and parasitoids work together, the pest population control is achieved. Stacey & Fellowes (2002) established a relationship between aphid reproduction and species of the *Coccinellidae* family. This may explain the correlations between the beneficial and harmful entomofauna in both types of cropping. It is confirmed that the abundance of pests can be a significant prerequisite for the spread of natural enemies in the fields (Schellhornet. al., 2014).

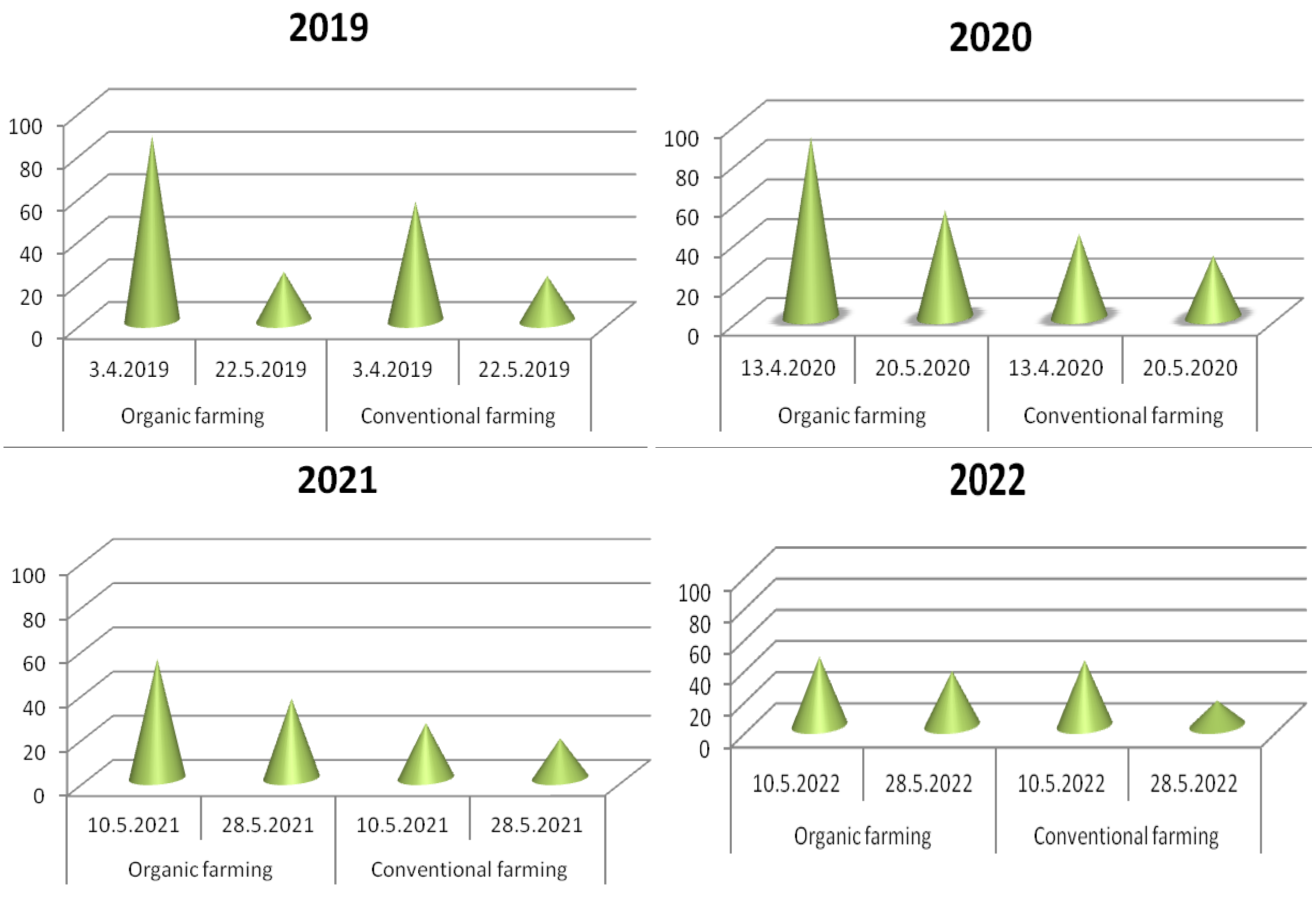

Figure 4. Total weeds per m^2 by years in pea crops

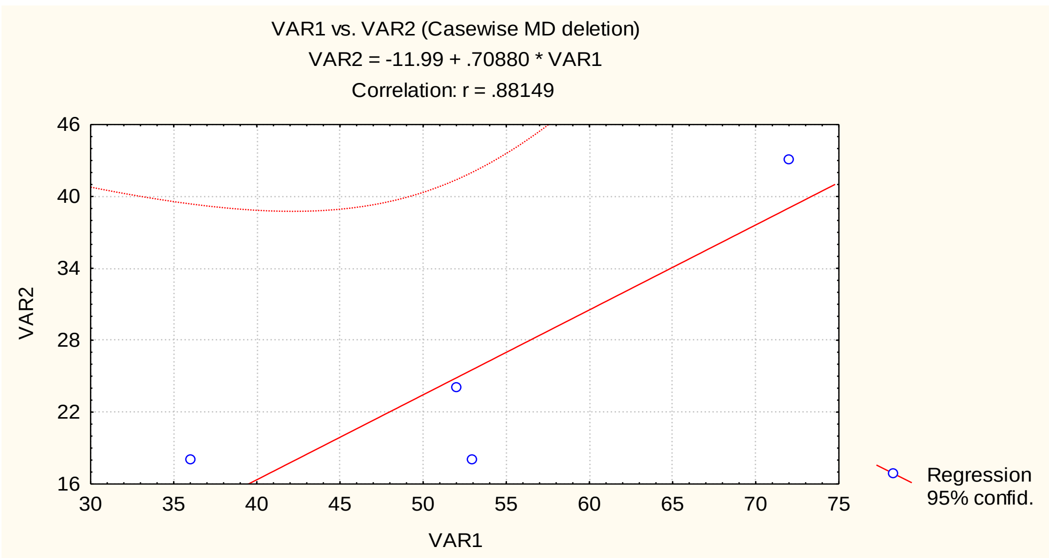

Figure 5. Relationship between the blooming weeds (VAR 1) and the beneficial entomofauna (VAR 2) in organically grown pea

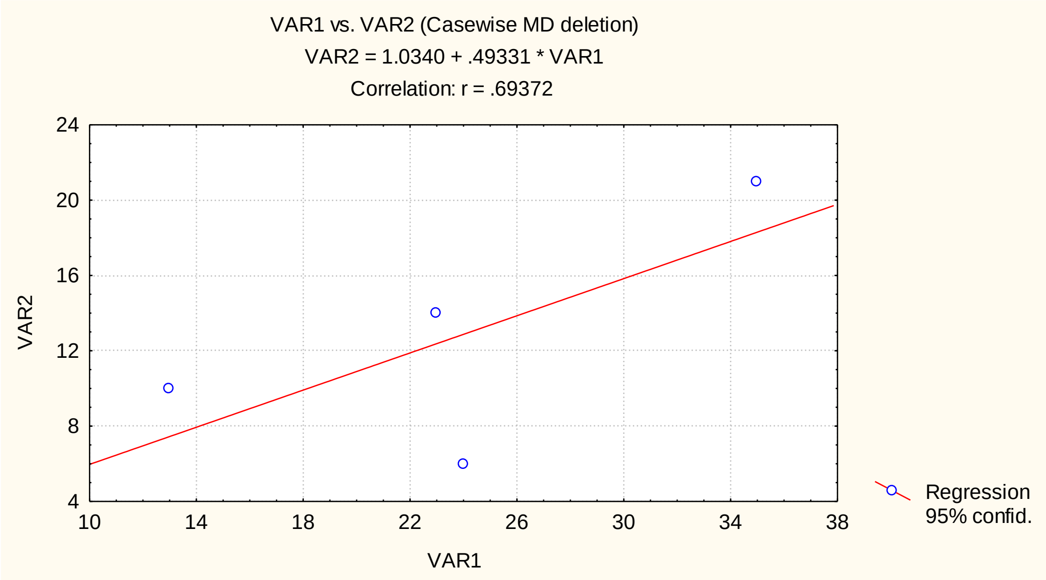

Figure 6. Relationship between the blooming weeds (VAR 1) and the beneficial entomofauna (VAR 2) in conventionally grown pea

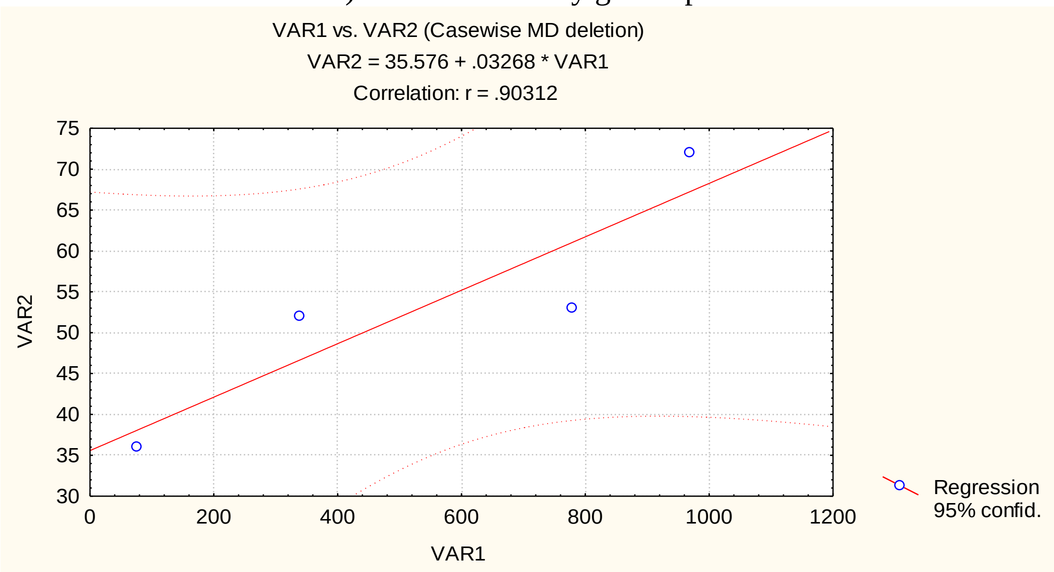

Figure 7. Relationship between the beneficial (VAR 2) and harmful (VAR 1) entomofauna in organically grown pea

Table 5. Total number of reported insects and blooming weeds in organic (OF) and conventional (CF) types of pea farming

	Harmful entomofauna - OF	Beneficial entomofauna - OF	Blooming weeds - OF	Harmful entomofauna - CF	Beneficial entomofauna - CF	Blooming weeds - CF
2019	779	53	18	918	24	6
2020	969	72	43	2076	35	21
2021	339	52	24	957	23	14
2022	76	36	18	354	13	10

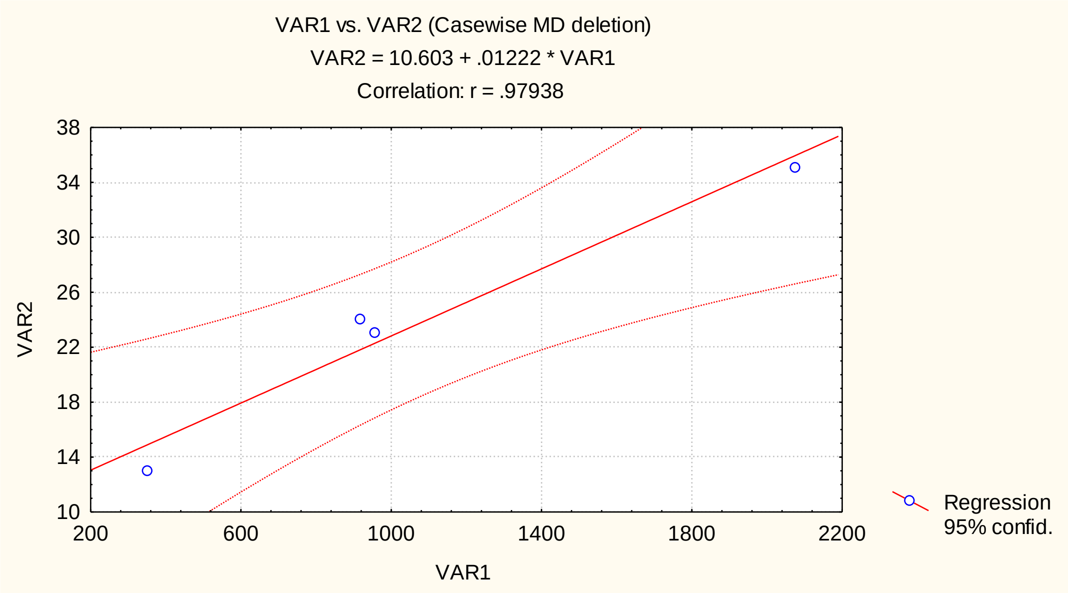

Figure 8. Relationship between the beneficial (VAR 2) and harmful (VAR 1) entomofauna in conventionally grown pea

CONCLUSION

Six and seven species of insects from seven families and three orders were found to harm pea in organic and conventional farming, respectively as their density is higher in conventional farming. The most economically important and the most widespread pest in both types of cropping is the aphid –*Acyrthosiphon pisum* (Harris, 1776).

Of the beneficial insects, thirteen species were found in pea in organic and eleven in conventional farming, from eight families and five orders. A greater species diversity and higher numbers were observed in organically grown pea during all four years of the study.

A greater species diversity of weeds was found in organic farming (from eight to twelve species depending on the conditions over the years) compared to conventional farming (from five to ten species depending on the conditions over the years).

The non-treatment with herbicides in organic farming and the presence of more blooming vegetation stimulates the multiplication of beneficial entomofauna, regulating the number of aphids in peas.

The correlation between the blooming vegetation and the beneficial entomofauna and the correlation between beneficial and harmful entomofauna has been demonstrated in the paper.

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REFERENCES

Alignier, A., Raymond, L., Deconchat, M., Menozzi, P., Monteil, C., Sarthou, J. P., Vialatte, A., & Ouin, A. (2014). The effect of semi-natural habitats on aphids and their natural enemies across spatial and temporal scales. *Biol. Control*, 77, 76–82.

Arlauskienė, A., Šarūnaitė, L., & Kadžiulienė, Ž. (2021). Agronomic practice and performance of organic farms in different environmental conditions in

Lithuania. *Biological Agriculture & Horticulture*, 37(2), 91-106. http://doi.org/10.1080/01448765.2020.1850351

Bailey-Elkin, W., M. Carkner, & Entz, M. H. (2022). Intercropping organic field peas with barley, oats, and mustard improves weed control but has variable effects on grain yield and net returns. *Canadian Journal of Plant Science*, 102(3), 515-528. https://doi.org/10.1139/cjps-2021-0182

Baldi, I., Cordier, S., Coumoul, X., Elbaz, A., Gamet-Payrastre, L., Le Bailly, P., Multigner, L., Rahmani, R., Spinosi, J., & Van Maele-Fabry, G. (2013). Pesticides: Effets Sur la Santé; INSERM, Institut national de la santé et de la Recherche Médicale: Paris, France, ISBN 978-2-85598-905-1.

Balzan, M. V., Bocci, G. & Moonen, A. C. (2016). Landscape complexity and field margin vegetation diversity enhance natural enemies and reduce herbivory by *Lepidoptera* pests on tomato crop. *BioControl*, 61, 141–154.

Bianchi, F. J. J .A., Goedhart, P.W., & Baveco, J. M. (2008). Enhanced pest control in cabbage crops near forest in The Netherlands. *Landsc. Ecol*., 23, 595–602.

Delipavlov, D., Cheshmedzhiev, I., Popova, M., & Kovachev, I. (2003). Identifier of plants in Bulgaria. AU Academic Publishing House - Plovdiv.

Devine, G. J., & Furlong, M. J. (2007). Insecticide use: Contexts and ecological consequences. *Agric. Hum. Values*, 24, 281–306.

Gollner, G., Starz, W., & Friedel, J. K. (2019). Crop performance, biological N fixation and pre-crop effect of pea ideotypes in an organic farming system. *Nutr Cycl Agroecosyst*, 115, 391–405 https://doi.org/10.1007/s10705-019-10021-4

Gronle, A., Heß, J. & Böhm, H. (2015). Weed suppressive ability in sole and intercrops of pea and oat and its interaction with ploughing depth and crop interference in organicfarming. *Org. Agr*., 5, 39–51 https://doi.org/10.1007/s13165-014-0095-x

Hatt, S., Artru, S., Brédart, D., Lassois, L., Francis, F., Haubruge, E., Garré, S., Foster, S. P. Devine, G. J., & Devonshire, A. L. (2007). Insecticide resistance. In Van Emden, H. F., & Harrington, R. (Eds.). *Aphids as Crop Pests*. (pp. 261–286). CABI.

Hatt, S., Lopes, T., Boeraeve, F., Chen, J., & Francis, F. (2017). Pest regulation and support of natural enemies in agriculture: Experimental evidence of within field wildflower strips. *Ecol. Eng*. 98, 240–245.

Hatt, S., Mouchon, P., Lopes, T., & Francis, F. (2017a). Effects of Wildflower Strips and an Adjacent Forest on Aphids and Their Natural Enemies in a Pea Field. *Insects*, 8 (3), 99. https://doi.org/10.3390/insects8030099

Katis, N. I., Tsitsipis, J. A., Stevens, M. H. H., & Powell, G. (2007). Transmission of plant viruses. In Van Emden, H.F., & Harrington, R. (Eds.), *Aphids as Crop Pests*. (pp. 353–390). CABI.

Kornijchuk M. S. (2017). Monitoryng fitosanitarnogo stanu polovyx kultur v texnologichnyx doslidax [Monitoring of phytosanitary condition of field crops in technological experiments]. Zemlerobstvo, 1, 93-99. [in Ukrainian].

Kornijchuk, M. S. (2013). Zaxyst roslyn v adaptyvnyx agrotexnologiyax za optymizaciyi zemlekorystuvannya Ukrayiny [Plant protection in adaptive agricultural technologies for land use optimization in Ukraine]. Zemlerobstvo: mizhvid. temat. nauk. zb. Kyiv, 85, 103–107. [in Ukrainian].

Krebs, J. R., Wilson, J. D., Bradbury, R. B., & Siriwardena, G. M. (1999). The second Silent Spring? *Nature*, 400, 611–612.

Martin, E. A., Seo, B., Park, C. R., Reineking, B., & Steffan-Dewenter, I. (2016). Scale-dependent effects of landscape composition and configuration on natural enemy diversity, crop herbivory, and yields. *Ecol. Appl*., 26, 448–462.

Morandin, L. A., Long, R. F., & Kremen, C. (2014). Hedgerows enhance beneficial insects on adjacent tomato fields in an intensive agricultural landscape. *Agric. Ecosyst. Environ*., 189, 164–170.

Ntatsi, G., Karkanis, A., Yfantopoulos, D., Pappa, V., Konosonoka, I. H., Travlos, I., Bilalis, D., Bebeli, P., & Savvas, D. (2019). Evaluation of the field performance, nitrogen fixation efficiency and competitive ability of pea landraces grown under organic and conventional farming systems. *Archives of Agronomy and Soil Science*, 65(3), 294-307. http://doi.org/10.1080/03650340.2018.1501155

Pysarenko, V. M., & Pysarenko, P. V. (2002). Zaxyst roslyn: Ekonomichno obgruntovani systemy. [Plant protection: Economically sound systems]. Poltava: Inter Grafika [in Ukrainian].

Robinson, R. A., & Sutherland, W. J. (2002). Post-war changes in arable farming and biodiversity in Great Britain. *J. Appl. Ecol*, 39, 157–176.

Rusch, A., Chaplin-Kramer, R., Gardiner, M. M., Hawro, V., Holland, J. M., Landis, D. A., Thies, C., Tscharntke, T., Weisser, W. W., Winqvist, C., Waltz, M., & Bommarco, R. (2016). Agricultural landscape simplification reduces natural pest control: A quantitative synthesis. *Agric. Ecosyst. Environ*. 221, 198–204. https://doi.org/10.1016/j.agee.2016.01.039

Sabluk, V. T., & Hryshchenko, O. M. & Smirnykh, V. M. (2018). Optimization of insecticide use is the basis of insect population self-regulation in sugar beet agrocenoses. Zashchita i karantin [Protection and quarantine], 4, 14–17. [in Russian].

Sabluk, W. T., Sinchenko, V. M., Grishchenko, O. M., Gumentik, M. Y., Fedorenko, A. V. (2021). Ecological Aspects of Formation of Entomofauna Complexes in Agrocenoses under Different Systems of Agriculture. *Ukrainian Journal of Ecology*, 11 (2), 8-12.

Salonen, J., Hyvönen, T., & Jalli, H. (2005). Weed flora and weed management of field peas in Finland. http://urn.fi/URN:NBN:fi-fe2015090311327

Schellhorn, N., Bianchi, F. J. J. A., & Hsu, C. L. (2014). Movement of entomophagous arthropods in agricultural landscapes: Links to pest suppression. *Annu. Rev. Entomol*., 59, 559–581.

Skevas, T., Lansink, A. O., & Stefanou, S. E. (2013). Designing the emerging EU pesticide policy: A literature review. Wagening. *J. Life Sci*., 64–65, 95–103. https://doi.org/10.1016/j.njas.2012.09.001

Snyder, W., & Ives, A. (2003). Interactions between specialist and generalist natural enemies: parasitoids,predators and pea aphid biocontrol. Ecology, 84(1), 91-107. https://doi.org/10.1890/0012-9658(2003)084[0091:IBSAGN]2.0.CO;2

Stacey, D., & Fellowes, M. (2002). Influence of temperature on pea aphid *Acyrthosiphon pisum* (*Hemiptera*: *Aphididae*) resistance to natural enemy attack. *Bulletin of Entomological Research*, 92(4), 351-357. https://doi.org/10.1079/BER2002173

Stankevych, S. V., & Zabrodina, I. V. (2016). Monitorynh shkidnykiv silskohospodarskykh kultur [Monitoring of blast of crops]. Kharkiv. [in Ukrainian].

Tscharntke, T., Karp, D. S., Chaplin-Kramer, R., Batáry, P., DeClerck, F., Gratton, C., Hunt, L., Ives, A. R., Jonsson, M., Larsen, A., Martin, E. M., Martínez-Salinas, A., Meehan T. D., O'Rourke, M., Poveda, K., Rosenheim, J. A., Rusch, A., Schellhorn, N., Wanger, T. C., Wratten, S., & Zhang, W. (2016). When natural habitat fails to enhance biological pest control—Five hypotheses. *Biol. Conserv*. 204, 449–458. https://doi.org/10.1016/j.biocon.2016.10.001

Tschumi, M., Albrecht, M., Collatz, J., Dubsky, V., Entling, M. H., Najar-Rodriguez, A. J., & Jacot, K. (2016). Tailored flower strips promote natural enemy biodiversity and pest control in potato crops. *J. Appl. Ecol*. 53, 1169–1176.

Vorozhko, S. P., & Hryshchenko O. M. (2017). Harmful entomofauna of sugar beet agrocenosis. Naukovì pracì Ìnstitutu bìoenergeti čnih kultur ta cukrovih burâkìv: zb. nauk. pracz. Kyiv: FOP Korzun D. Yu. [in Ukrainian].