PHEROMONE TRAP CATCH OF THE MICROLEPIDOPTERA SPECIES IN CONNECTION WITH THE ENVIRONMENTAL EFFECTS

Editors

LÁSZLÓ NOWINSZKY & JÁNOS PUSKÁS

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Authors of the book

Prof. Dr. habil. László Nowinszky PhD (ed.)
University professor
University of West Hungary, Savaria University Centre,
H-9700 Szombathely Károlyi G. Square 4., Hungary
E-mail: lnowinszky@gmail.com

Dr. habil. János Puskás PhD (ed.)
College professor
Head of Institute
University of West Hungary, Savaria University Centre,
H-9700 Szombathely Károlyi G. Square 4., Hungary
E-mail: pjanos@gmail.com

Gábor Barczikay
Plant protection consulting engineer
County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection
and Soil Conservation Directorate, 3917 Bodrogkisfalud, Vasút Street 22., Hungary

Dr. habil. Márta Ladányi PhD
Senior lecturer
Head of Department
Corvinus University of Budapest, Dept. of Mathematics and
Informatics
H-1118 Budapest Villányi Street 29., Hungary
E-mail: marta.ladanyi@uni-corvinus.hu

Dr. Csaba Károssy PhD
College professor
University of West Hungary, Savaria University Centre,
H-9700 Szombathely Károlyi G. Square 4., Hungary
E-mail: c.karossy@gmail.com

Dr. habil. Ottó Kiss PhD
College professor
Eszterházy Károly College, Dept. of Zoology, H-3300 Eger Eszterházy Square 1., Hungary
E-mail: otto_kiss@freemail.hu

Dr. Zsuzsanna Kúti PhD
Lecturer
University of West Hungary, Savaria University Centre,
H-9700 Szombathely Károlyi G. Square 4., Hungary
E-mail: kutizsuzsi@gmail.com

Dr. Ferenc Szentkirályi
Scientific member
Plant Protection Institute of the Hungarian Academy of Sciences, Centre for Agricultural
Research, Dept. of Zoology, H-1022 Budapest Herman Ottó Street 15., Hungary
E-mail: szentkiralyi@julia-nki.hu

Zoltán Tóth
Scientific member
Hungarian Meteorological Service
Atmospheric Physics and Measurement Technics Division
1181 Budapest, Gilice Square 39.
E-mail: toth.z@met.hu

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Chapter 1.

Influence of the Construction and Use of Pheromone Traps by the Catching Results of Harmful Moths

G. Barczikay[1], L. Nowinszky[2] & J. Puskás[2]

[1]County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, H-3917 Bodrogkisfalud, Vasút Street 22.
[2]University of West Hungary Savaria University Centre
H-9700 Szombathely, Károlyi Gáspár Square 4.
E-mail: lnowinszky@gmail.com and pjanos@gmail.com

Abstract: The pheromone trap catch of five harmful Microlepidoptera species in conjunction with the capsule and base exchange. The Csalomon type gluey traps were in operation in Borsod-Abaúj-Zemplén County (Hungary) between 1993 and 2007. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius), Peach Twig Borer (*Anarsia lineatella* Zeller), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller), Oriental Fruit Moth (*Grapholita molesta* Busck) and Plum Fruit Moth (*Grapholita funebrana* Treitschke). Our examinations proved that the highest numbers of caught moth are on the fourth or fifth day following the exchange of capsules and then will decrease. The increase in catches cannot therefore be sustained. Replacing the gluey sheets did not modify the effectiveness of the collection.

Keywords: Microlepidoptera species, pheromone traps, replacement of capsule

1. Introduction

The pheromone traps, similar to light-traps, play an important role in the forecasting system of insect pests. However, the efficiency of the traps can be modified by several biotic and abiotic factors in both the collection method. Understanding these would be exceptionally important. However, the application of the light-traps looks back at longer time (onto more decades); researchers studied the effects of modifying factors mainly in respect of these. Research work is complicated by the fact that the catch result is not daily counted in most cases, but according to the proposal of Tóth (2003) 2-3 days together, aggregated. Ghobari et al. (2007) also checked in every second day the number of captured (*Tortrix viridana* L.) individuals in Iran. Giri et al. (2014) the number of Potato Tuber Moth (*Phthorimaea operculella* Zeller), caught by pheromone trap, was counted in every morning between 6 and 8 a.m. in Nepal.

According to Pénzes et al. (2010) the sex pheromone traps can be used effectively for forecasting if the collected insects are daily counted.

The water with detergent was changed in pheromone traps of Nasseh and Moharam (2011) and the African Armyworm (*Spodoptera exempta* Walker) moths are

counted daily. The pheromone capsules were changed in every three weeks.
As the daily catch results were not recorded, it becomes impossible to recognize the effect of a number of factors, which can change day by day, so their influence changes also day by day (eg. temperature, precipitation, wind etc.).

However, our own daily catch data made it possible to show the influence of the Moon phases (Nowinszky et al. 2010), the Péczely's macrosynoptic weather situations (Károssy et al. 2009) and the Puskás type weather fronts (Puskás et al. 2009; Barczikay et al., 2009) on pheromone trap catch.

There is another problem that other influencing effects prevail, than the light-traps. This problem comes from the due to the method of trapping and baits the way of the deviation, like this eg. type of trap, pheromone dose, the place of trap. Ghobari et al. (2009) have been studied these factors in the context of Green Oak Tortrix viridana (*Tortrix viridana* L.) effectiveness of trapping in Iran.

Braham (2014) experienced, that 2-13 times more Tomato Leaf Miner (*Tuta absoluata* Meyrick) individuals were caught by the fresh baits filled traps, as with weathered ones.

According to results of Kovanci et al. (2006) there were continuously high catch results with the Oriental Fruit Moth (*Grapholita molesta* Busck) traps if the traps were placed in the upper canopy level. This statement supports the earlier reports by Rothschild and Minks (1997) in each orchard with this explanation of this that the mating activity happens in the upper canopy. According to experiments of Herman et al. (2005) the water traps caught the most moths per day. The delta-shaped sticky traps caught more moths than cylinder-shaped sticky traps and funnel traps. Trap height had no significant effect on moth catch.

Field experiments were conducted by Taha et al. (2012) to determine the attractive action of different colours of sex pheromone traps (red, yellow, green and blue) on Tomato Leaf Miner (*Tuta absoluta* Meyrick). The results show the red sticky traps (39.7 % reflection at 612.1 nm dominant wavelengths took most of the moths, 46.89 %) of the total caught moths, while the yellow gluey traps caught the fewest insects, only 13.99 %.

The pheromone traps were checked by the Ágoston and Fazekas (2014) twice a week initially and then after harvesting the tomatoes the frequency was once in every week till the end of November.

González-Caberra et al. (2011) recorded the number of *Tuta absoluta* (Meyrick) males captured twice a week. The sticky plate was changed twice a week, and the pheromone capsule once a month.

Abbes and Chermiti (2011) renewed the sex pheromone capsules every four weeks and the number of captured males of *Tuta absoluta* was recorded every week before the change of the sticky cardboards.

Hári (2014) counted of fruit moths twice a week and replaced every 4-6 weeks the pheromone capsules. The sticky sheets were exchanged on the basis of saturation and degree of contamination.

Sípos (2012) pheromone trapped the Raspberry Cane Midge (*Resseliella theobaldi* Barnes) males. She changed the sticky sheets once a week and pheromone capsules once a months.

The efficiency of the catch is significantly changed by the effectiveness of capsules and sticky sheets with the passage of time, because of the weather and number of caught individuals.

It is a general experience; there is an increase in the number of caught specimens after the exchange of capsules and sticky sheets. The time of these exchanges are after different period. According to Tóth (2003) the efficiency of the sticky sheets can slowly decrease after 4-6 weeks, because of the weather. It is necessary to change at this time. The sticky sheets' exchange, depending on the catch, is proposed after 7-10 days. Voigt et al. (2010) made this change in their used Codling Moth (*Cydia pomonella* L.) traps, in every six week. Kovács et al. (2008) caught successfully Agriotes species, without any capsule exchange in the full time of swarming. If the number of the individuals can permanently increase following the capsule exchange, we receive regularly a false result about the real procession of swarming (Voigt et al., 2010).

However, there is another problem in case of species with multi-generation, when the duration of a swarming for each generation is relatively short. The long-term impact of the capsule exchange cannot be investigated, the results would be false, because the examined days are in overlap with different periods of swarming.

Gebresilassie et al. (2015) collected *Phlebotomus orientalis* Parrot (Diptera: Psychodidae) individuals significantly higher on horizontally placed sticky traps than vertically deployed ones.

It was the aim of our work to determine, with the help of our daily catch data from several years, how many days, following the capsule exchange, can be show the increased catch.

Field trapping experiments were carried out by Guofa Chen et al. (2010) to evaluate effective trap characteristics for maximising *Ips duplicatus* (Sahlberg) catches in pheromone-baited traps in China.

Window-slot and cross-barrier traps had significantly higher catches than multiple-funnel traps. The colour of window-slot traps showed a significant effect on catches, with dark colours (black and red) being more effective than light colours, especially white and yellow. Window-slot traps at a 1.5-2.0 m level caught more beetles than those at either ground level (0-0.5 m) or at 3.5-4.0 m. *Ips duplicatus* can be attracted to pheromone-baited traps over a distance of > 100 m from the forest edge in an open grassy field. There was a strong diurnal pattern of flight activity, with catches on window-slot traps occurring during the daytime with one broad peak at mid- to late afternoon.

According to Tóth et al. (2010) there is a disadvantage with pheromone traps, that they only collect male individuals. Therefore researchers worldwide engaged for developing new attractants suitable for females.

The daily pheromone emission depends on the compound and the species and ranges from a few femtogram to some nanogram (Tóth, 2009 personal communication).

The femtogram is the thousandth part of a picogram. A picogram is the thousandth part of a nanogram, while nanogram itself is only a billionth part of a gram.

2. Material

Six harmful Microlepidoptera species were caught by the Csalomon type sticky traps at Bodrogkisfalud in Borsod-Abaúj-Zemplén County (Hungary) between 1993 and 2007. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). The catch data are shown in Table 1 2. 1.

There were not traps placed for all the five species during some years, but in other years, however, the majority of species were collected by 2-2 traps. The distance was about 50 metres between the traps. In these cases there was available 2-2 monitoring data during a night. The traps in all years were put on leafy branches of the same tree or leafy vines. The height of traps was generally between 1.5 and 2 metres. The distance of pheromone trap from fruit tree determines the number of moths caught. According to our observations, a trap located 25 metres from the plum-tree collected a large number of Plum Fruit Moth *(Grapholita funebrana* Tr.) specimens. The other trap, located 150 metres from the same tree started to catch moths only days after the first one and collected only a few specimens. After replacing this trap, closer to the tree, the catch of the two traps became nearly equal (Nowinszky et al., 2010).

The traps worked from early April to late September. Changing the capsules was 6-8 weeks according to Tóth (2003) proposal. The number of trapped moths was daily recorded.

3. Methods

We calculated the value of relative catch (RC) for all species and generation using the number of caught specimens. The value of relative catch (RC) is a quotient counted of a given sample time unit (1 day) of specimens taken and the average number of individuals on 1 day in the swarming of generation. If the number of caught specimens is the same as the average, the value of RC is 1.

The relative catch values were assigned to days between five days before and ten ones after exchange of capsules. We made daily sum and then averaged them. The results were illustrated. We determined the regression equation, which was shown in the Figures. We calculated the level of significance as well.

4. Results and Discussion

The success of catch on days between the previous 5 and following 10 are show in Figures 1. 4. 1.–1. 4. 6.

There was no any significant difference between the changes of sticky sheets and the pheromone trap catch of these species. Therefore we conclude the changes of sticky sheets always happened professionally in right time during the trapping periods.

We conclude after our results that after changing the pheromone capsules actually increases the number of trapped moths - in the same way as the general opinion - this maximum of 30% growth is not sustained. Because of this the number of yearly caught individuals of species with multi-generation cannot be influenced significantly by the capsule change. Of course, it would be better the catch result of more days, before and after the change, to take into consideration to the examination. However, in this case some distorting effects can be influence the results, such as the lower number of individuals in the period of generation change.

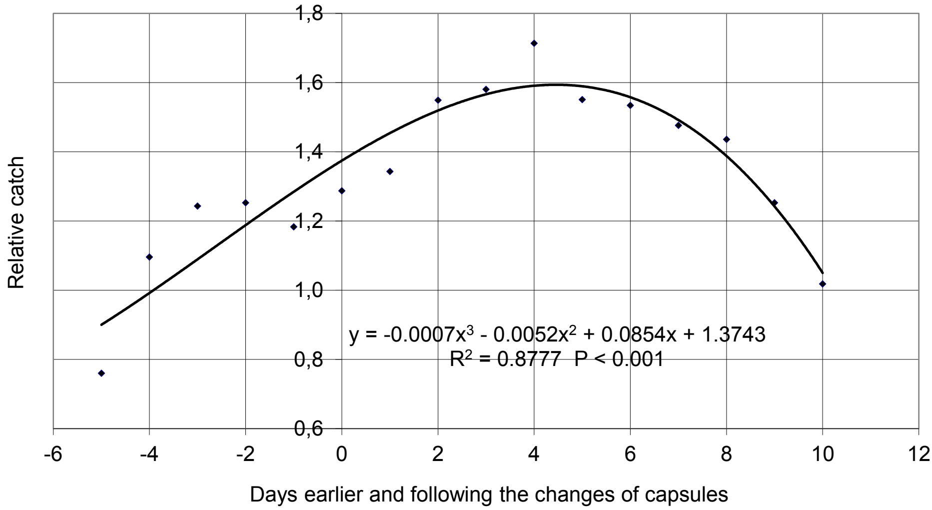

Figure 1. 4. 1.

Figure 1. Pheromon trap catch of Twig Borer Moth (*Phyllonorycter blancardella* Fabricius) in connection with the changes pheromone capsules (Bodrogkisfalud, 1996-2007)

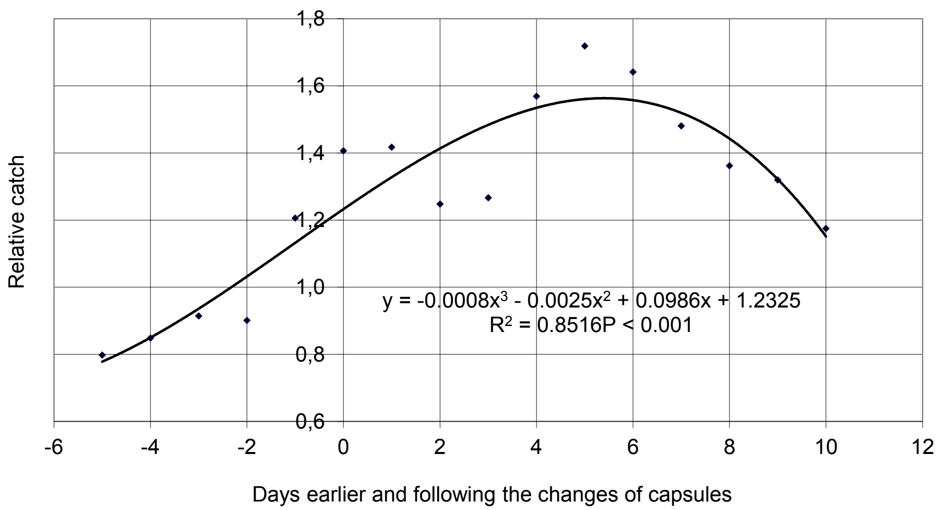

Figure 1. 4. 2.

Figure 2. Pheromone trap catch of the Codling Moth (*Cydia pomonella* Linnaeus) in connection with the changes of pheromone capsules (Bodrogkisfalud, 1996-2007)

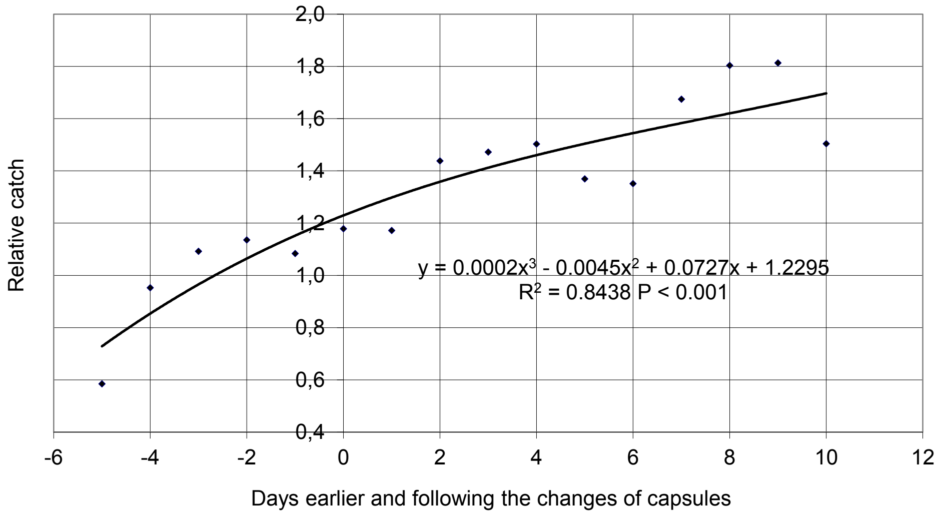

Figure 1. 4. 3.

Figure 3. Pheromone trap catch of the European Vine Moth (*Lobesia botrana* Denis et Schiff-ermüller) in connection with the changes of capsules (Bodrogkisfalud, 1996-2007)

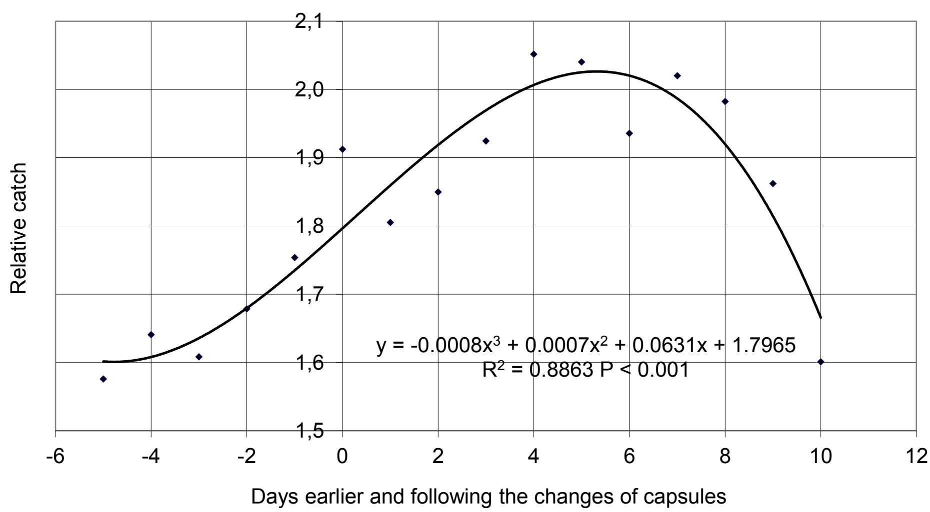

Figure 1. 4. 4.

Figure 4. Pheromone trap catch of Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with the changes of capsules (Bodrogkisfalud, 1996-2007)

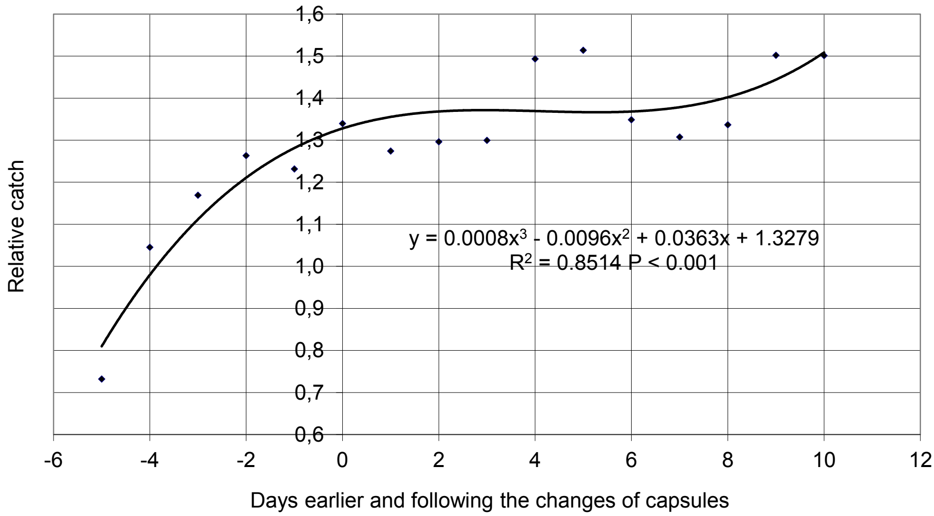

Figure 1. 4. 5.

Figure 5. Pheromone trap catch of Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with the changes of capsules (Bodrogkisfalud, 1996-2007)

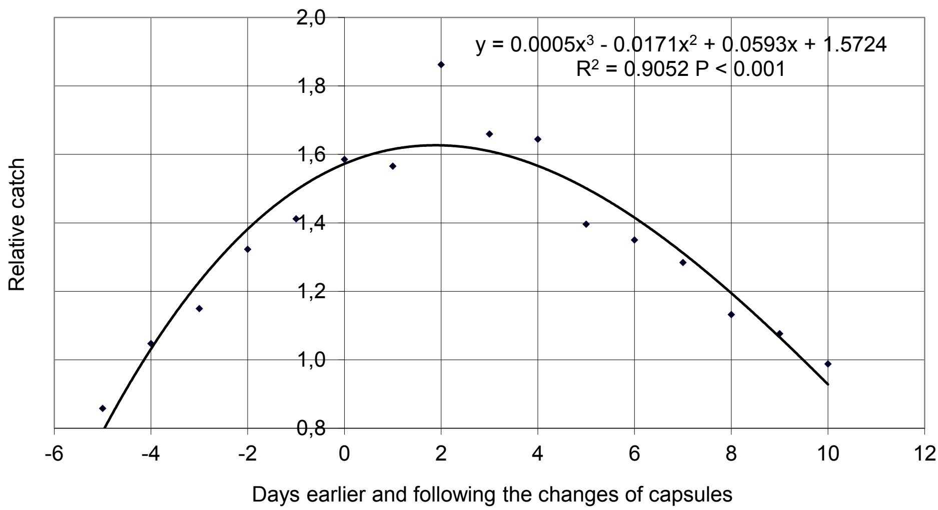

Figure 1. 4. 6.

Figure 6. Pheromone trap catch of Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with the changes of capsules (Bodrogkisfalud, 1996-2007)

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Chapter 2.

Pheromone Trap Catch of Harmful Microlepidoptera Moth Species Depending on the Solar Activity Featured by Q-index

J. Puskás[1], L. Nowinszky[1], G. Barczikay[2], Zs. Kúti[1]
[1]University of West Hungary, Savaria University Centre,
9700 Szombathely Károlyi G. Square 4.
E-mail: lnowinszky@gmail.com *, pjanos@gmail.com, kutizsuzsi@gmail.com
[2]County Borsod-Abaúj-Zemplén
Agricultural Office of Plant Protection and Soil Conservatian Directorate,
H-3917 Bodrogkisfalud, Vasút Street 22.

Abstract: The Q-index is a measure of the solar activity. The study deals with the solar flare activity featured by Q-index in connection with pheromone trap catch of six Microlepidoptera species from Hungary. The increase of the catch can be experienced in five cases and the decrease can be seen, when the value of the Q-index is high. There was once an increase parallel with increase of Q-index values. The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the Q-index, expressing the different lengths and intensities of the solar flares. The different form of behaviour, however, is not linked to the taxonomic position. Further testing will be required to fuller explanation of the results.

Keywords: solar flares, Q-index, harmful moths, pheromone trap

2. 1. Introduction

As part of the global solar activity, accompanied by intensive X-ray, gamma and corpuscular radiation, outbreaks (flares) appear in the vicinity of the active regions on the surface of the Sun. Reaching the Earth, and getting into interaction with its upper atmosphere, these flares change the existing electromagnetic relations (Smith and Smith, 1963). The flares, these temporary flashes in the chromosphere of the Sun in the vicinity of sunspots can be observed for a maximum of 10-20 minutes. They can be observed mainly in the 656.3 nm wavelength red light of the H-α line. During the appearance of intensive solar flares, corpuscular emission can be one thousand times stronger than in a quiet state of the Sun. The corpuscles consist mainly of electrons and spread in all directions, including that of the Earth, at a maximum speed of 1 500 km*s^{-1}. These electrically charged particles form are the so-called solar wind, which, unlike electromagnetic radiation that arrives in 8 and half minutes, reaches the Earth in 26-28 hours. Flair particles, on their way to the Earth, must also pass through interplanetary space. In its turn, the magnetic field of the latter generated by general galactic cosmic radiation can significantly modify the effect of flares on the magnetosphere of the Earth' atmosphere. So not every flare will be induce changes in the physical state of the upper atmosphere. If and when, however, such changes occur, they lead to temporary weather modification and the magnetic field of the charged particles will also affect the quiet daily trend of the magnetic field of the Earth. The intensity of the flares is determined by the area they are observed to occupy in relation to the solar disk as a whole. Flares of first importance are less than 250 times the half of the one millionth of the global surface of the Sun. A flare is of second importance if its area is 250-600 times the unit and it is of importance three if it is more than 600 times the unit. Following from the greater intensity of the flux of energy, second and third importance flares have the most significant cosmic impact. The daily activity of the flares is characterized by the so-called Q index that, used by several researchers.

The flares are classified according to the size of their area as compared to the total solar surface. The flares of primary importance: 1; 250-600 times this size, it receives an index number of 2; if greater 600 times than that, it has a significance of 3. Because of their significant energy emissions, the cosmic influence of the flares No. 2 and 3 is the most considerable. Kleczek (1952) was the first researcher, who introduced the concept of Q-index to use the daily flare activity through quantification of the 24 hours of the day.

$$Q = (i \times t)$$

where i = flare intensity, t = the time length of its existence.

He assumed that this relationship gives roughly the total energy emitted by the flares. In this relation, "i" represents the intensity scale of importance and "t" the duration (in minutes) of the flare. Some researchers of flare activity using Kleczek's method are given for each day by Kleczek, 1952, Knoška and Petrásek, 1984, Ataç, 1987, Ataç and Özgüç, 1998, Özgüç and Ataç, 1989. Örményi (1966) calculated and published the flare activity numbers based on similar theoretical principles (“Flare Activity Numbers”) for the period of 1957-1965. The solar activity also exerts influence on life phenomena. In the literature accessible to the authors, however, no publication can be found that would have dealt with the influence of flares on the collection of insects by light-traps. Earlier we have published our studies and demonstrated the influence of hydrogen alpha flares 2 and 3 (Tóth and Nowinszky, 1983) on light-trap catches.

Most daily flare activities are characterised by Turkish astronomers, Özgüç and Ataç (1989) by index Q that expresses the significance of flares also by their duration.

The solar activity also exerts influence on life phenomena. In the literature accessible to the authors, however, no publication can be found that would have dealt with the influence of flares on the collection of insects by light-traps. Earlier we have published our studies and demonstrated the influence of Hα flares No. 2. and 3. and the Q-index on light-trap catches (Tóth and Nowinszky, 1983, Nowinszky and Puskás, 1999, 2001 and 2013, Puskás et al., 2010). Other authors did not publish studies on theme of solar activity and light trapping of insects.

2. 2. Material

Flare Index Data used in this study were calculated by T. Ataç and A. Özgüç from Bogazici University Kandilli Observatory, Istanbul, Turkey.

In Bodrogkisfalud village Borsod-Abaúj-Zemplén County, Hungary-Europe (Geographical coordinates are: 48°10'41″N and 21°21'77″E), pheromone traps were operated between 1993 and 2010. These traps attracted 6 harmful Microlepidoptera species altogether, in some of the years using 2-2 pheromone traps for each species, however, in other years not all six species were monitored. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). Catch data of the collected species is displayed in Table 2. 2. 1. We examined the trapping data of these species depending on the Q-indexes.

2. 3. Methods

From the catching data of the examined species, relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 day) per the average number of individuals of the same generation falling to the same time unit. In case of the expected average individual number, the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps (Nowinszky, 2003).

At the values of Q-index showed considerable differences in course of the respective years, they were preferably expressed as percentages of the averages of swarming periods (this was named relative Q-index). We studied the influence of flare activities on the daily catches. To disclose the latter, the Q/Q average values were co-ordinated with the relative catch data of different observation posts for each day of the catch period. The Q/Q means (relative Q-index) values have been contracted into groups (classes), and then averaged within the classes the relative catches data pertaining to them.

Data on the relative Q-index were arranged into classes according to Sturges' method (Odor and Iglói (1987). The relative catch values were assigned into the classes of the Q-index belonging to the given day and then they were summarized and averaged. We determined the regression equations, the significance levels which were shown in the figures.

2. 4. Results and Discussion

The connections between relative Q-index (Q/Q) averages and daily catches of examined species are presented in Figures 2. 4. 1.–2. 4. 6. The characteristic curves associated parameters are indicated in the figures and significance levels are also given.

From the results several important consequences could be drawn. Based on our results, we proved that the light-trap catch of examined species is affected by the solar activity featured by Q-index. However, some species may not react the same way.

One species, the Codling Moth (*Cydia pomonella* Linnaeus) was collected in connection with the increasing the high values of the Q-index. The increase of the catch can be experienced in five cases and the decrease can be seen, when the value of the Q-index is high.

The number of Spotted Tentiform Leafminer *(Phyllonorycter blancardella* Fabr.), Peach Twig Borer (*Anarsia lineatella* Zeller), and European Vine Moth (*Lobesia botrana* Den. et Schiff.), begins to decrease when Q values are higher than averages for swarming periods. As opposed to this the number caught of the Oriental Fruit Moth *(Grapholita molesta* Busck) and Plum Fruit Moth (*Grapholita funebrana* Tr.) starts decreasing already when the Q value attains the half of average value of the swarming period.

The results can be written down with second- or third-degree polynomials. Our results proved that the daily catches were significantly modified by the Q-index, expressing the different lengths and intensities of the solar flares. The different form of behaviour, however, is not linked to the taxonomic position. This fact is notable for the plant protection prognostic. Further testing will be required to fuller explanation of the results.

Acknowledgements: Flare Index Data used in this study were calculated by T. Ataç and A. Özgüç from Bogazici University Kandilli Observatory, Istanbul, Turkey. The Q-index daily data for the period 1980 and 2000 were provided by Dr. T. Ataç. His help is here gratefully acknowledged.

Table 2. 2. 1 The number and observing data of the examined species (Bodrogkisfalud, 1993-2010)

Species	Number of	
	moths	data
Gracillariidae » Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	51,805	1,766
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	6,873	1,913
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	20,240	2,320
Tortricidae » Tortricinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	27,679	3,250
Tortricidae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	14,112	2,629
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	4,813	1,288

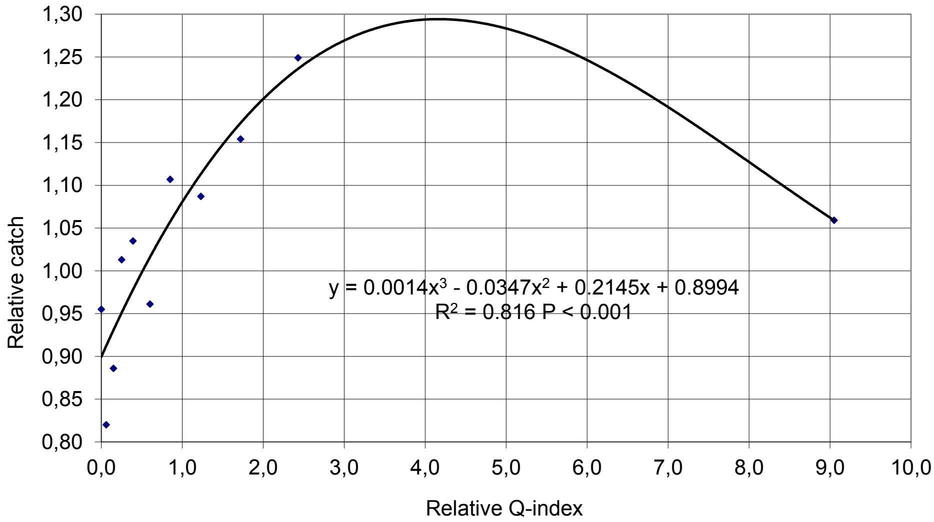

Figure 2. 4. 1.

Figure 2. 4. 1. Pheromone trap catch of Spotted Tentiform Leafminer *(Phyllonorycter blancardella* Fabricius) in connection with relative Q-index Bodrogkisfalud, 1993-2007)

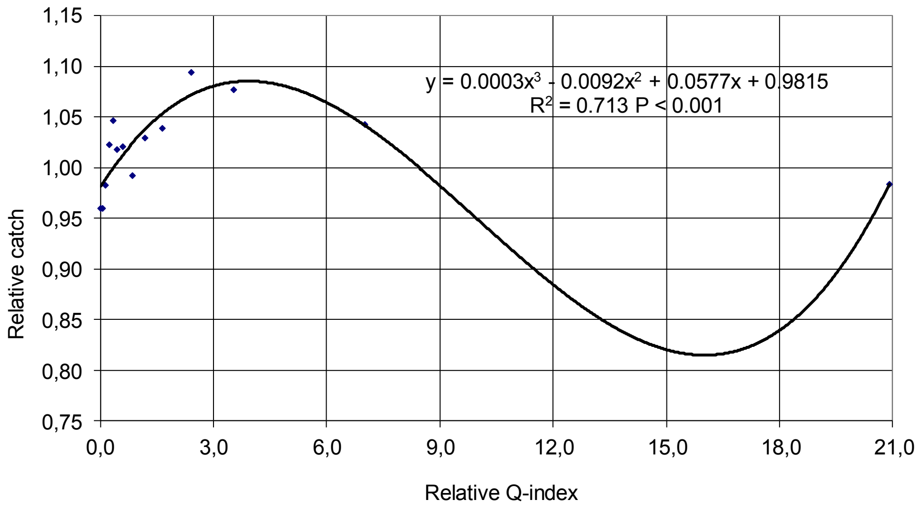

Figure 2. 4. 2.

Figure 2. 4. 2. Pheromone trap catch of Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with relative Q-index (Bodrogkisfalud, 1993-2007)

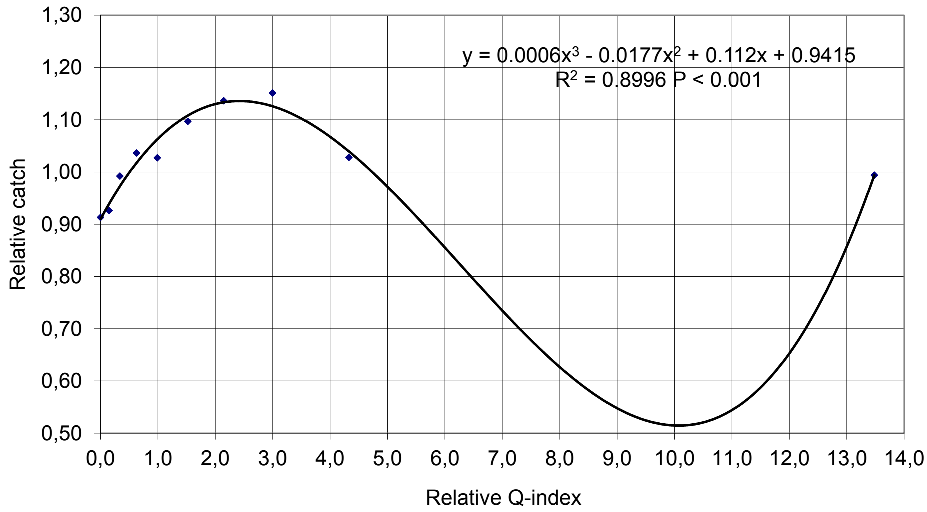

Figure 2. 4. 3.

Figure 2. 4. 3. Pheromone trap catch of European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) in connection with relative Q-index (Bodrogkisfalud, 1993-2007)

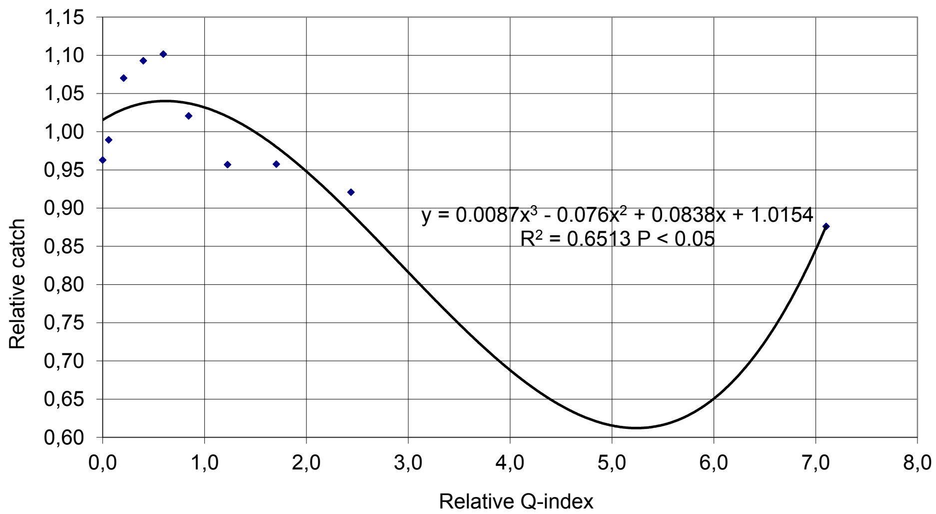

Figure 2. 4. 4.

Figure 2. 4. 4. Pheromone trap catch of Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with relative Q-index (Bodrogkisfalud, 1993-2007)

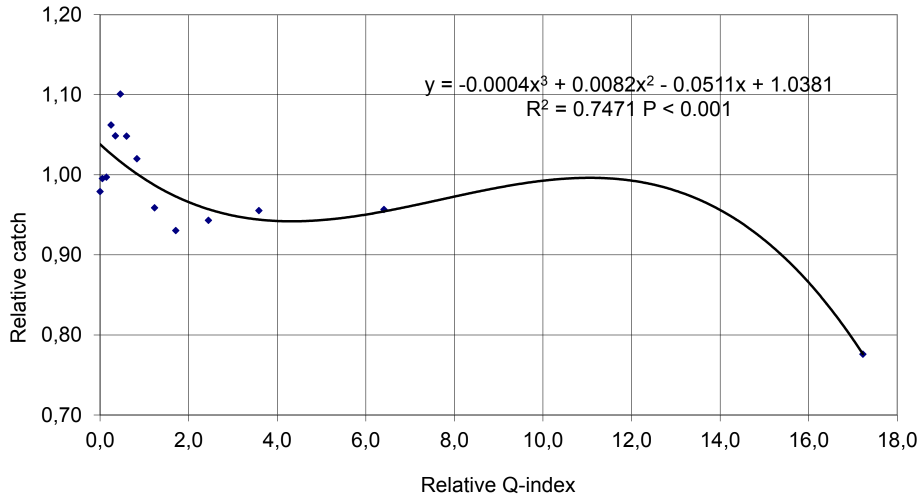

Figure 2. 4. 5.

Figure 2. 4. 5. Pheromone trap catch of Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with relative Q-index (Bodrogkisfalud, 1993-2007)

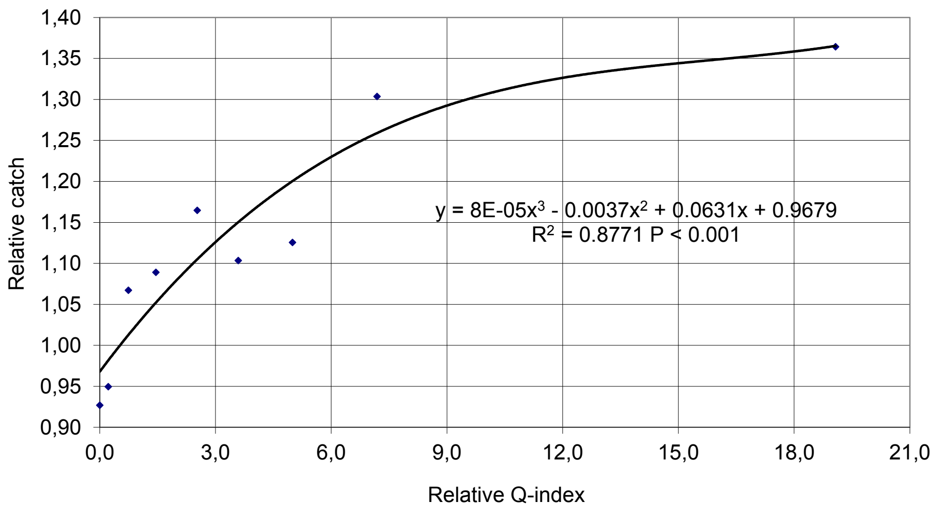

Figure 2. 4. 6.

Figure 2. 4. 6. Pheromone trap catch of Codling Moth (*Cydia pomonella* Linnaeus) in connection with relative Q-index (Bodrogkisfalud, 1996-2010)

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Chapter 3.

Relationship between UV-B Radiation of the Sun and the Pheromone Trap Catch of Microlepidoptera Species

L. Nowinszky[1], J. Puskás[1], G. Barczikay[2], Z. Tóth[3]

[1]University of West Hungary, Savaria University Centre,
H-9700 Szombathely Károlyi G. Square 4., Hungary Europe
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2]County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, H-3917 Bodrogkisfalud Vasút Street 22., Hungary Europe
[3]Hungarian Meteorological Service Atmospheric Physics and Measurement Technics Division, 1181 Budapest, Gilice Square 39. E-mail: toth.z.@met.hu

Abstract: The study deals with the influence of the solar UV-B radiation on pheromone trapping of Microlepidoptera species. The catch data pertaining to Microlepidoptera species have been provided by between 1994 and 1998 Csalomon type pheromone traps were operating in Bodrogkisfalud (48° 10'N; 21°21E; Borsod-Abaúj-Zemplén County, Hungary, Europe). These own traps worked every day and caught 6 Microlepidoptera species. UV-B data used for examination come from measurements in the Keszthely observatory of the Hungarian Meteorological Service by Robertson-Berger UV-Biometers in the years between 1994 and 1998.

Keywords: UV-B radiation, moths, pheromone trapping

3. 1. Introduction

The most important knowledge on the Sun's UV radiation can be summarised in the following (Örményi, 1991). Increase in the number of sunspots increases the solar ultraviolet radiation, which mainly extracts it in the high atmosphere his effect, primarily through ionization (Saikó 1979).

Atmospheric ozone absorbs considerable part of the UV radiation coming from the Sun and harmful for biosphere so only a very small part of it can reach the Earth's surface thus organisms adapted to that intensity. The amount of UV irradiance at the earth's surface is relatively small; the photons at these wavelengths are biologically active and commonly detrimental to plant and animal health (Grant and Heisler 1997). Podstawczyńska-Bienias and Fortuniak (1998) present the analysis of measurements of UV (290-400 nm) and total solar radiation (303-2800 nm) values in Lodz in the period 1997-1999. The daily values of UV and total radiation are highly correlated with a general linear relation. The UV daily values are constituted on average 4.2 % of total daily radiation. The high values of ratio (>7%) occurred in cloudy days while the total irradiance decreased with increasing cloudiness. This shows that the clouds absorb more in near infrared than UV region of the solar spectrum.

Cloud cover influences UV-B intensity measured at the surface, aerosol content of the atmosphere and, of course the solar elevation (Németh et al. 1996). The latter causes a change in UV-B irradiance, which is regular and can be accurately given: UV-B irradiance increases with the increasing solar elevation. Cloudiness and aerosol content are very variable quantities; both can considerably change during a day.

Especially the UV-B range is detrimental in large quantities to living organisms. We could not find our studies outside their own works of other authors, which deal with the effect of the Sun's ultraviolet radiation and pheromone trapping of insects. We studied therefore that on the nights following days with catching of pheromone trap catch of moth (Microlepidoptera) species.

However, it is striking that it cannot be found such publication that deals with the UV-B radiation of the Sun and pheromone trapping of insects. We have demonstrated in our previous works that UV-B affect the light-trap effectiveness (Nowinszky et al. 1997 and 2000, Puskás et al. 2004).

3. 2. Material

One of the most important ranges of sunshine is the band of ultraviolet radiation. According to the international classification of Schulze (1970) radiation on the Earth's surface can be detected in two domains, i. e. UV-A (315-390 nm) and UV-B (290-315 nm). Radiation can be measured both by physical, chemical and biological methods. Örményi (1991) has used physical ones in his above-mentioned study.

The world-wide known instruments applying the physical methods are the following:

- Eppley UV radiation counter (Marchgraber and Drummonand, 1960) and
- the Robertson (1972) and Berger (1976) UV radiation counter (sunburn-meter) working mainly in UV-B range.

UV-B data used for the study come from measurements in the Keszthely observatory of the Hungarian Meteorological Service. Measurements in Keszthely are carried out continuously by Robertson-Berger UV-Biometers which are connected to VAISALA/MILOS automatic weather station and 10 minute averages are produced by the data acquisition system from the samplings. The UV-Biometers measures biological effective ultraviolet radiation in special unit. The biological effectiveness of the UV radiation is measured in MED/h (Minimum Erythema Dose per hour). One MED/h would cause minimal redness of the average number 2 skin after an one-hour irradiation. The integral of the cross-multiplication of irradiating flux [W/cm nm] and the Erythema Action Spectrum (McKinlay and Diffey 1987), which means the wavelength distribution of sensitivity of the skin so it is a weighting function actually, gives the Effective Power. It was established that 1 MED/h -5.83*10'6 [Won2] of Effective Power for a MED of 21 mJ per cm² effective dose. Daily totals given in MED/day are calculated by totalizing hourly values.

Six harmful Microlepidoptera species were caught by the Csalomon type sticky traps at Bodrogkisfalud in Borsod-Abaúj-Zemplén County (Hungary) between 1994 and 1998. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). The catching data of examined moths (Lepidoptera) species and pheromone trapping stations are shown in Table 3. 2. 1.

3. 3. Methods

Than the number of individuals of a given species in different places and different observation years is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago (Nowinszky 2003). The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals. If the number of specimens taken from the average of the same, the relative value of catch: 1 (Nowinszky 2003).

From the collection data pertaining to examined species we calculated relative catch values (RC) by pheromone trap stations and by swarming. Following we arranged the data on the UV-B in classes. Relative catch values were placed according to the features of the given day, and then RC were summed up and averaged. The data are plotted for each species and regression equations were calculated for relative catch of examined species and UV-B data pairs.

3. 4. Results and Discussion

The results are shown in the Figures 3. 4. 1—3. 4. 6.

In the majority of examined species the solar UV-B radiation increases the catch initially; at higher values of UV-B radiation the catch is lower. Four of all species: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, Codling Moth *Cydia pomonella* Linnaeus, European Vine Moth *Lobesia botrana* Denis et Schiffermüller, and Plum Fruit Moth *Grapholita funebrana* Treitschke) was obtained in this result, regardless of the trapping method and location of the taxonomic classification of species. One species, the Peach Twig Borer *Anarsia lineatella* Zeller we experienced continuous elevation in increasing the UV-B radiation and one species (Oriental Fruit Moth (*Grapholita molesta* Busck) though decrease if the value of UV-B radiation will be higher. The increase or decrease of the catch is explainable by our previous hypotheses.

Low relative catch values always refer to environmental factors in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism. The imago is short-lived; therefore unfavourable environmental endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to environmental factors of an unfavourable situation. By the present state of our knowledge we might say that unfavourable environmental factors might be accompanied by both high and low catch (Nowinszky 2003).

It can be explained on the basis of our hypothesis of the first rising and then falling catch results. But however their answer is already the passivity for the additional increase of the radiation. However, it is striking that the taxonomic place of the single species is not attached to by this response, so may be widespread in the world of the insects widely presumably.

It is a remarkable fact, that the swarming peaks of different species can be experienced at totally different UV-B values.

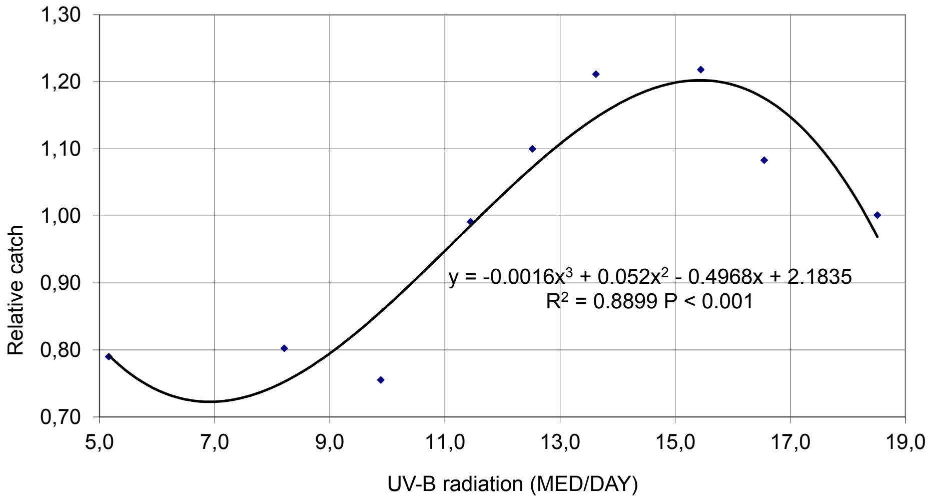

Figure 3. 4. 1.

Figure 3. 4. 1. Pheromone trap catch of the Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius) in connection with the UV-B radiation of the Sun (Bodrogkisfalud, 1994—1998)

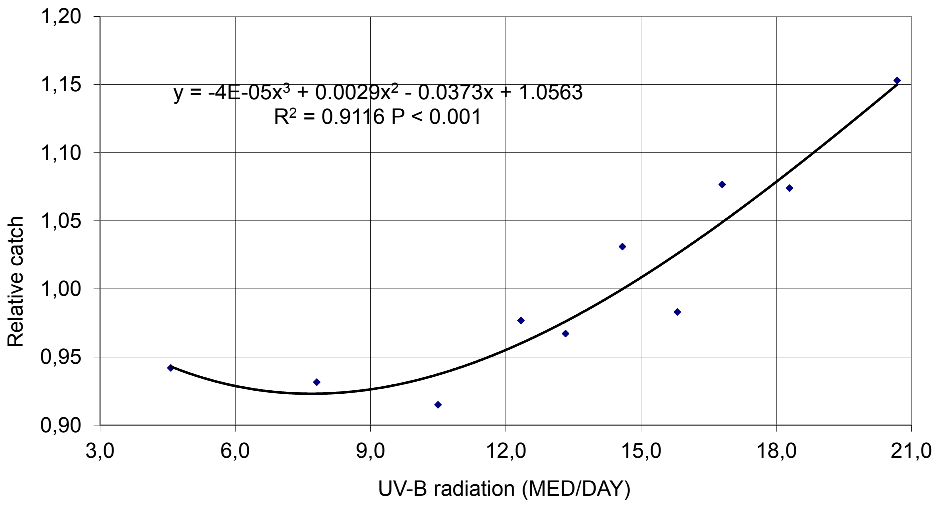

Figure 3. 4. 2.

Figure 3. 4. 2. Pheromone trap catch of the Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with the UV-B radiation of the Sun (Bodrogkisfalud, 1994—1998)

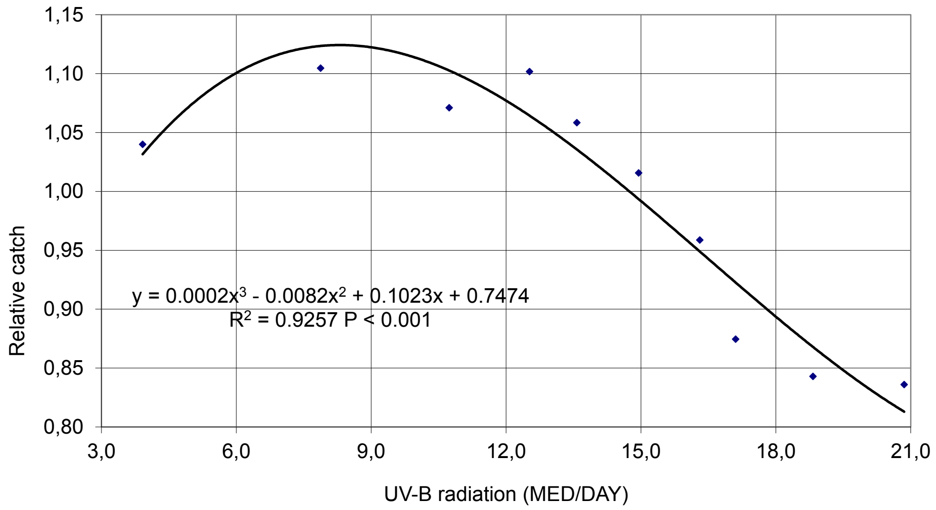

Figure 3. 4. 3.

Figure 3. 4. 3. Pheromone trap catch of the European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) in connection with the UV-B radiation of the Sun (Bodrogkisfalud, 1994—1998)

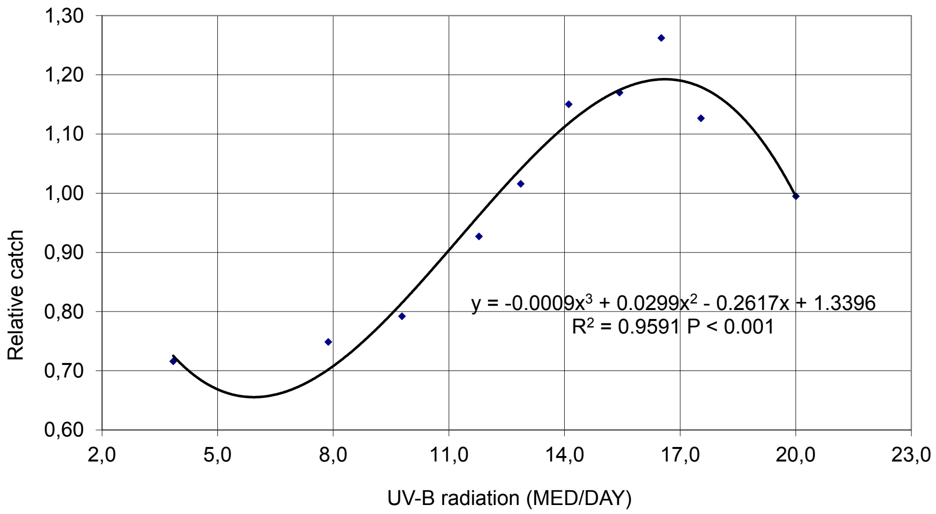

Figure 3. 4. 4.

Figure 3. 4. 4. Pheromone trap catch of the Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with the UV-B radiation of the Sun (Bodrogkisfalud, 1994—1998)

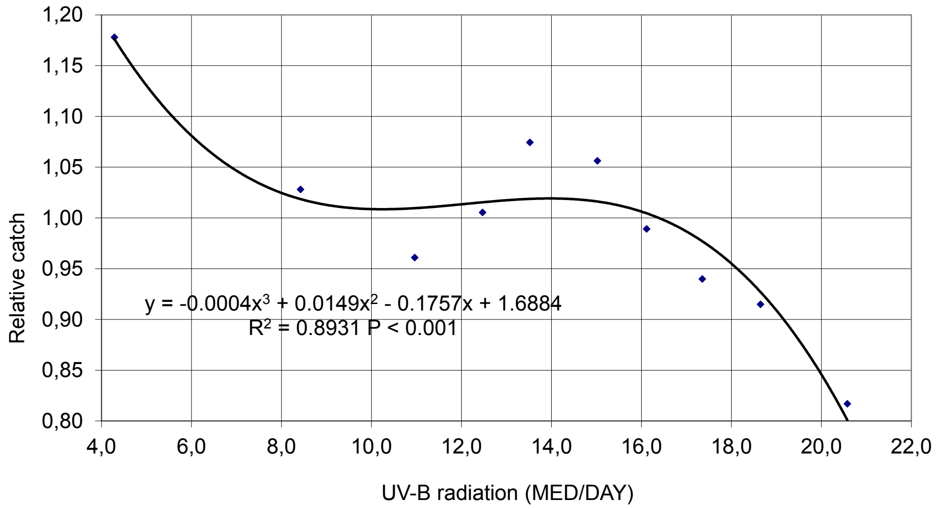

Figure 3. 4. 5.

Figure 3. 4. 5. Pheromone trap catch of the Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with the UV-B radiation of the Sun (Bodrogkisfalud, 1994—1998)

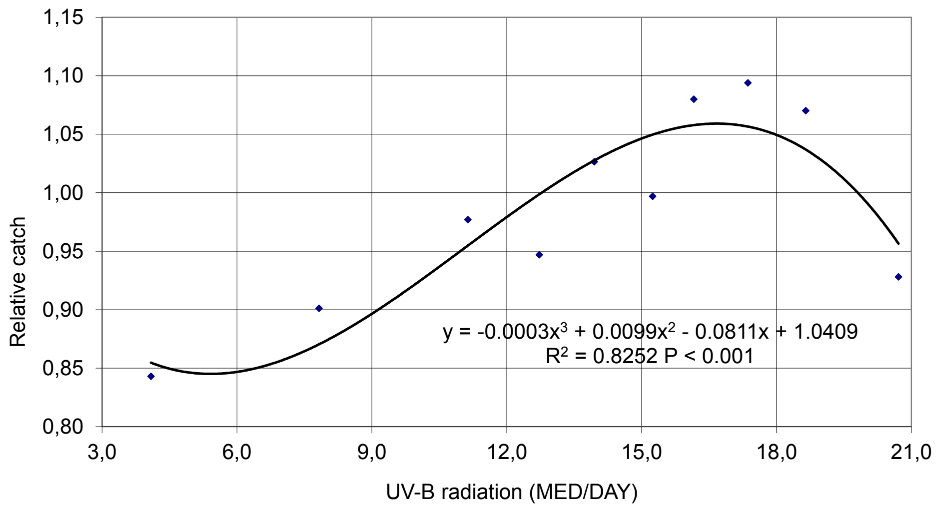

Figure 3. 4. 6.

Figure 3. 4. 6. Pheromone trap catch of the Codling Moth (*Cydia pomonella* Linnaeus) in connection with the UV-B radiation of the Sun (Bodrogkisfalud, 1994—1998)

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Chapter 4.

Pheromone Trap Catch of Harmful Microlepidoptera species of the Csalomon Type Pheromone Traps in Connection with the Height of the Tropopause

Puskás J.[1], Nowinszky L.[1] , Barczikay G.[2]

[1]University of West Hungary Savaria University Centre
H-9700 Szombathely, Károlyi Gáspár Square 4.
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2]County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, H-3917 Bodrogkisfalud, Vasút Street 22.

Abstract: In present study we examined the connection between height of tropopause and the pheromone trap catch of moth species. The data of 6 Microlepidoptera species were caught from the material of the Csalomon-type pheromone traps between 1993 and 2000. Groups were made from data of the height of tropopause. The relative catch values of the examined species were categorised according to the characteristics of tropopause on each day, after it these values were summarised, averaged and depicted. We defined the parameters of the regression equations. Five species were collected in a rising quantity initially and then after further increasing of height of the tropopause there was a decrease. In connection with the increasing the height of the tropopause, decrease was observed only in case of three species. The different form of behaviour, however, is not linked to the taxonomic position.

Keywords: Microlepidoptera, tropopause, pheromone trap, moths.

4. 1. Introduction

The changes in midlatitude air mass circulation are caused by a rise in the height of the tropopause, and other factors as increased moisture content in the atmosphere (Lorenz and DeWeaver 2007). If there are changes in the air mass circulation it must be changes in the elements of the weather such as temperature, air humidity, air pressure, wind speed and direction.

The tropopause is a surface separating the lower layers of the atmosphere (troposphere) from the upper layers (stratosphere). It is of varying height. The changes in tropopause height more weather elements contains a complex way: air temperature, humidity, strength of wind, air pressure, precipitation. In the presence of very cold air masses from the Arctic it may be a mere 5 kilometres, while in the presence of subtropical air it may grow to 16 kilometres. Sometimes there are two or three tropopauses one above the other.

A low tropopause is related the presence of cold and high tropopause the presence of warm types of air, while insect activity is increased by warm and reduced by cold air. An over 13 km height of the tropopause often indicates a subtropical air stream at a great height. This has a strong biological influence. These results may lead us to assume that the electric factors in the atmosphere also have an important role to play, mainly when a stream of subtropical air arrives at great height. On such occasions the 3Hz aspheric impulse number shows a decrease, while cosmic radiation of the Sun will be on the increase (Örményi, 1984). The preponderance of negative ions in polar air reduces activity, while the preponderance of positive ions in subtropical maritime air may spur flight activity (Örményi, 1967). The warm air increases the activity of the insects; the cold reduces it on the other hand. As the changes in tropopause height causes also changes in the weather in the lower layers of air in large areas, we examined the efficiency of the catch of the light traps in connection with changes in the tropopause height. We did not find communications dealing with this topic in the literature apart from our own works.

In earlier, a few studies have been published, which deal with the efficiency of the light trap and the altitude of the tropopause of the Heart and Dart (*Agrotis exclamationis* L.), the Common Cockchafer (*Melolontha melolontha* L.), the Turnip Moth (Agrotis segetum Den. et Schiff.) and Fall Webworm Moth (*Hyphantria cunea* Drury) (Puskás and Nowinszky, 2000), (Örményi et al., 1997) and Puskás and Nowinszky (2011). It has been stated that the subtropical air masses, observed in the high altitudes, differently affect the efficiency of light-trap collection according to whether they come from that route over Hungary. The light-trap catch of Turnip Moth (Agrotis segetum Den. et Schiff.) and Heart & Dart (Agrotis exclamationis L.) is high during subtropical residence time of air masses, but during the Saharan air mass residence time it is low. It is just opposed the results to the Fall Webworm Moth (*Hyphantria cunea* Drury) light trapping catch.

In our earlier works we have examined the light-trap catch of European Cornborer (*Ostrinia nubilalis* Hübner) and Setaceous Hebrew Character (*Xestia c-nigrum* L.) and the caddisfly (Trichoptera) species as a function of the height of the tropopause, too (Nowinszky and Puskás, 2013 and Nowinszky et al., 2015).

We found in our former studies that the light trapping efficiency of parallel increases if the tropopause height is about 13 kilometres. However, the catch of the different species is not growing already longer on the higher values of the tropopause, but decreasing.

Therefore, we refer to our earlier studies where the effects of air masses influencing the collection were investigated (Nowinszky et al, 1997; Örményi et al, 2003). In these studies the subtropical air masses were divided on the basis of their origin and the path as follows:

Subtropical air; Azores air moving from W and WSW; Continental subtropical air arriving from the Middle East from SE; Saharan air from the Middle East from SE (observing in the upper layers only); Saharan air from across the Mediterranean Sea; Saharan air from across the Black Sea and Warm air from the Black Sea.

4. 2. Material

Data for Budapest on the height of the tropopause have been collected from the Annals of the Central Meteorological Institute of the Hungarian Meteorological Service. Because area of Hungary is 93 036 km² only, so this data is valid for the entire territory of the country (Örményi et., 1997).

Between 1993 and 2000 Csalomon type pheromone traps were operating in Bodrogkisfalud (48°10' N, 21°21' E; Borsod-Abaúj-Zemplén County, Hungary, Europe). These traps attracted 6 Microlepidoptera species. Every year 2-2 traps per species were collected; one night after a 2-2 catching, data were available.

Six harmful Microlepidoptera species were caught by the Csalomon type sticky traps at Bodrogkisfalud in Borsod-Abaúj-Zemplén County (Hungary) between 1993 and 2000. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). The catch data of the collected species is displayed in Table 4. 2. 1.

4. 3. Methods

The traps near each other worked all year. They were placed on leafy trees of the same branches and vines at a distance of 50 meters between the traps. The height of each species was different, from 1.5 to 2 meters. The traps operated from the beginning of April to the end of September. According to Tóth (2003) the proposed capsules exchange was in a 6-8 week period. The number of moths captured per day was recorded, which is different from the general practice of counting the catch two or three days together.

The pheromone traps operated in the same orchards and vineyards in every year. There were no performed chemical pest control treatments.

Than the number of individuals of a given species in different places and different observation years is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago (Nowinszky, 2003).

The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals If the number of specimens taken from the average of the same, the relative value of catch: 1. The relative catch allows the processing of collecting aggregate data from different years and observation locations (Nowinszky, 2003).

From the collection data pertaining to examined species we calculated relative catch values (RC) by light-trap stations and by swarming. Following we arranged the data on the height of the tropopause in classes.

Relative catch values were placed according to the features of the given day, and then RC were summed up and averaged. The data are plotted for each species and regression equations were calculated for relative catch of examined species and tropopause data pairs. We determined the regression equations, the significance levels which were shown in the figures.

4. 4. Results and Discussion

Our results are shown in Figures 4. 4. 1.-6. The characteristic curves and associated parameters are indicated in the figures and significance levels are also given.

Our results show that the pheromone trap catch of Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius), Codling Moth (*Cydia pomonella* Linnaeus), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller), Oriental Fruit Moth (*Grapholita molesta* Busck) and Plum Fruit Moth (*Grapholita funebrana* Treitschke) rising to near 11 km tropopause height increases, but higher values have been greatly reduced.

The tropopause height in the lower air layers is associated with different weather situations. Insects, such as moths also change the flight activity of responding to changing weather conditions. Low tropopause is linked to the presence of cold, but high tropopause with hot air masses. The hot air can decrease the insect activity and very cold air causes the same effect. If there is a link to tropopause height other factors may have an influence.

Only one species (Peach Twig Borer (*Anarsia lineatella* Zeller) was caught the highest during the moderately cool temperatures (tropopause height is 9 km).

The optimum air temperature of this species for flight can be lower than the other examined species.

The reason can be explained, that in subtropical air masses residence at the time of very hot nights have reduced flight activity.

The tropopause height above 13 km often indicates the type of subtropical air inflow at high altitude and it has a strong biological effectiveness. Atmospheric electrical factors may also have a role, especially during the high-altitude subtropical air inflow. In this case, for example, 3 Hz spherics pulses are reduced, while the solar cosmic rays increase (Örményi 1984). The atmospheric ions may also have a significant role (Örményi 1967). The arctic air may decrease flight activity factor due to the dominance of negative ions, but the dominance of positive ions

in the subtropical air could be a factor in increasing flight activity.
We do not know yet every detail of how effects the height of the tropopause the catch results.

The connection between weather and tropopause is not completely known; therefore we hope later investigations will provide a fuller explanation about the causes of the results we obtained. Further researches will hopefully lead to a clear answer.

Our results show that the pheromone trap catch of five Microlepidoptera species rising to near 11 km tropopause height increases, but higher values have been greatly reduced. Only one species was caught the highest during the moderately cool temperatures (tropopause height is 9 km).

Table 4. 2. 1. The number and observing data of the examined species

Species	Number of	
	moths	data
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	16,630	533
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	2,100	564
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	3,738	264
Tortricidae » Olethreutinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	7,594	929
Tortricidae » Olethreutinae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	2,597	615
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	1,915	632

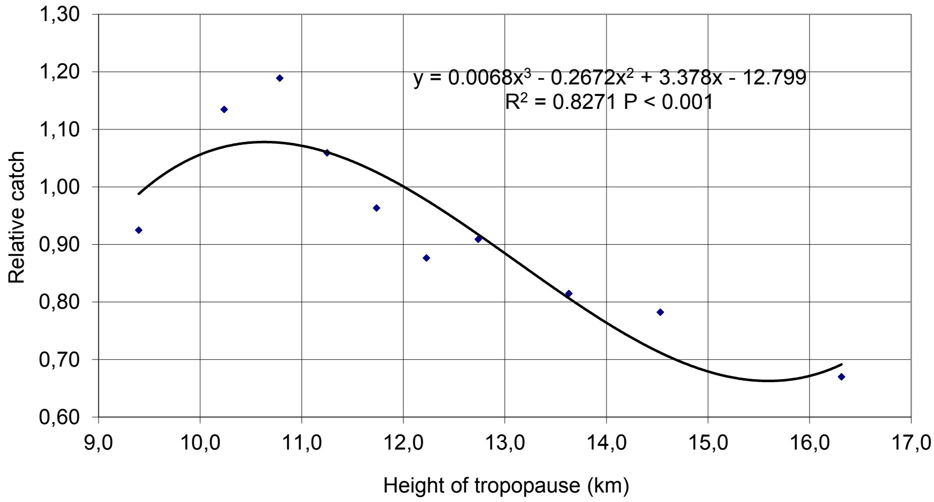

Figure 4. 4. 1.

Figure 4. 4. 1. Pheromone trap catch of Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius) in connection with the height of tropopause (Bodrogkisfalud, 1993-2000)

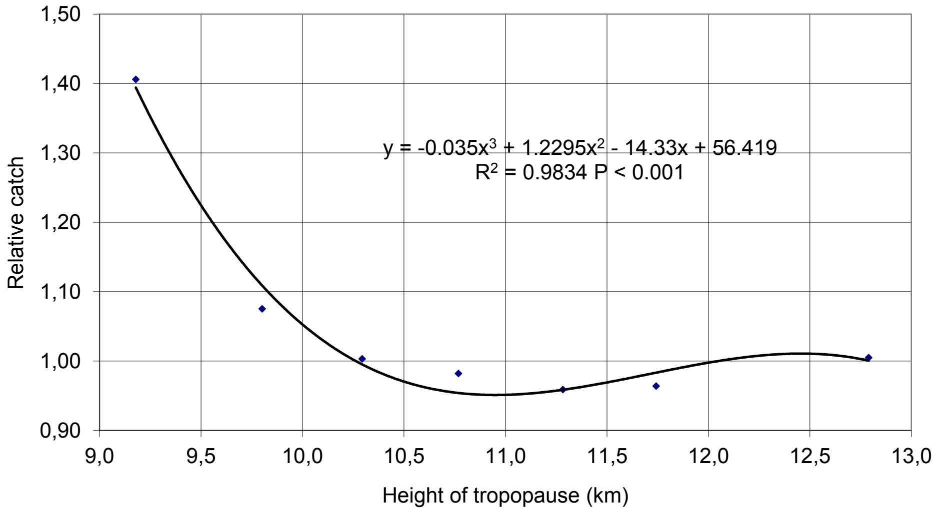

Figure 4. 4. 2.

Figure 4. 4. 2. Pheromone trap catch of Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with the height of tropopause (Bodrogkisfalud, 1993-2000)

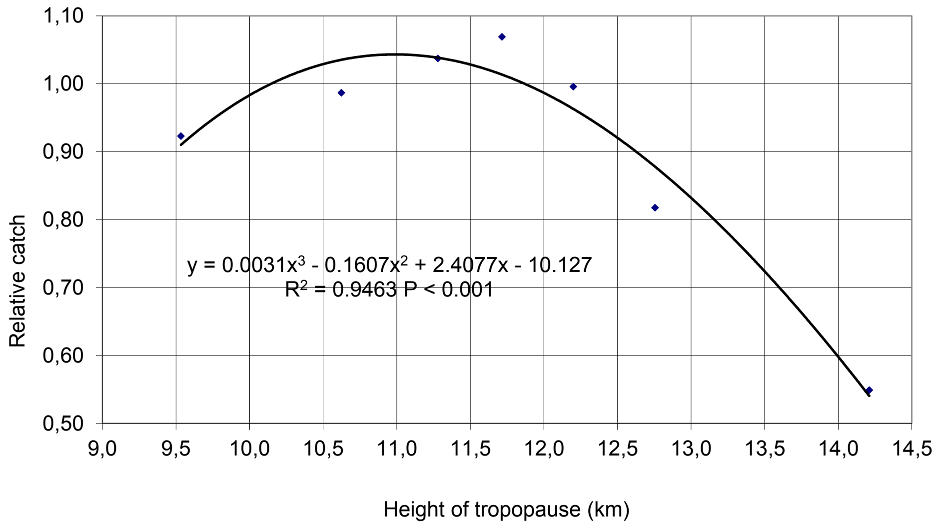

Figure 4. 4. 3.

Figure 4. 4. 3. Pheromone trap catch of European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) in connection with the height of tropopause (Bodrogkisfalud, 1993-2000)

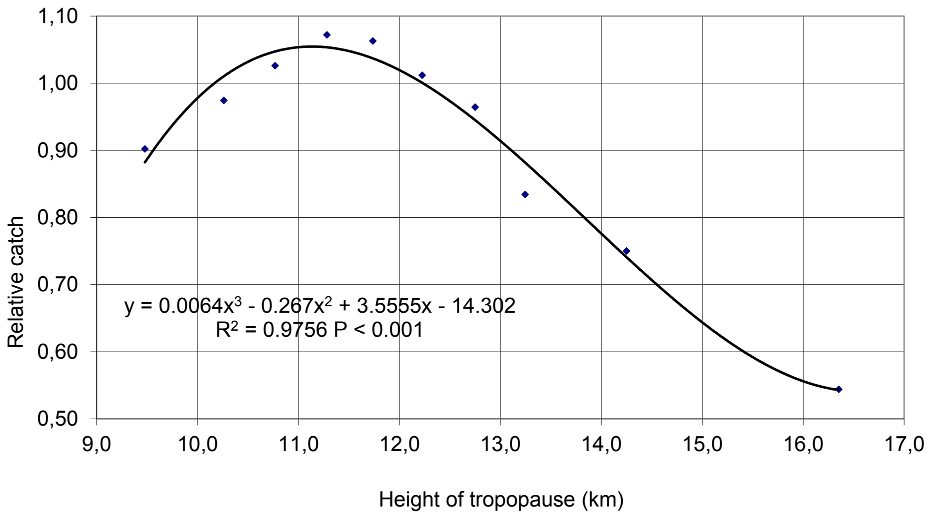

Figure 4. 4. 4.

Figure 4. 4. 4. Pheromone trap catch of Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with the height of tropopause (Bodrogkisfalud, 1993-2000)

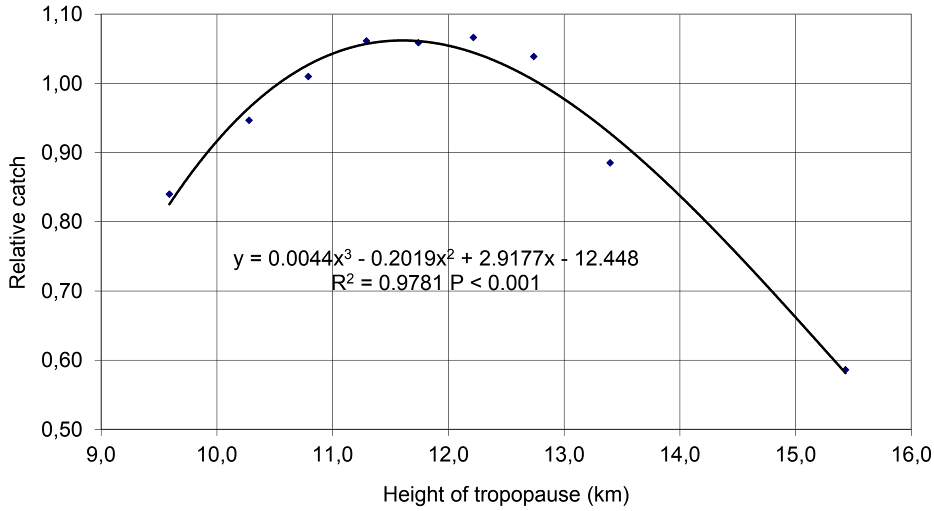

Figure 4. 4. 5.

Figure 4. 4. 5. Pheromone trap catch of Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with the height of tropopause (Bodrogkisfalud, 1993-2000)

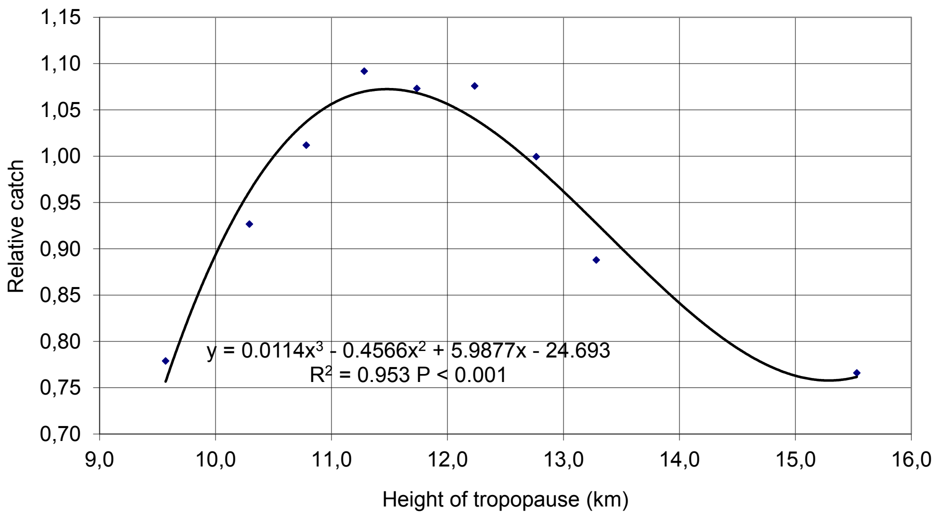

Figure 4. 4. 6.

Figure 4. 4. 6. Pheromone trap catch of Codling Moth (*Cydia pomonella* Linnaeus) in connection with the height of tropopause (Bodrogkisfalud, 1993-2000)

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Chapter 5.

Pheromone Trap Catch of the Harmful Microlepidoptera Species in Connection with the Ozone Content of the Air

L. Nowinszky[1], J. Puskás[1], G. Barczikay[2], M. Ladányi[3], O. Kiss[4], F. Szentkirályi[5]

[1]University of West Hungary, Savaria University Centre,
H-9700 Szombathely, Károlyi G. Square 4., Hungary
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2] County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, H-3917 Bodrogkisfalud, Vasút Street 22., Hungary
[3]Corvinus University of Budapest, Dept. of Mathematics and Informatics,
H-1118 Budapest Villányi Street 29., Hungary
[4]Eszterházy Károly College, Dept. of Zoology, H-3300 Eger Eszterházy Square 1., Hungary
[5]Plant Protection Institute of the Hungarian Academy of Sciences, Centre for Agricultural Research, Dept. of Zoology, H-1022 Budapest Herman Ottó Street 15., Hungary

Abstract: The study deals the efficiency of pheromone trapping of the seven harmful Microlepidoptera species depending on the ozone content of air. Between 2004 and 2011 Csalomon type pheromone traps were operating in Bodrogkisfalud (48°10' N, 21°21' E; Borsod-Abaúj-Zemplén County, Hungary, Europe). We calculated relative catch values from the number of caught insects. We assigned these to the ozone values, we averaged them, and we depicted the results together with the regression equation though. We established that the pheromone trapping of this species is most fruitful when the ozone content of the air is high. By contrast, low ozone values reduce the successfulness of the catching to a moderate level. Our results will be exploitable in plant protecting and environment conservation research.

Keywords: Microlepidoptera, pheromone trapping, ozone content of air

5. 1. Introduction

Summer daytime ozone concentration correlates strongly with temperature. Tropospheric ozone is expected to increase at 40-60 % up to the end of the 21st century which is linked to air quality and climate change (Meleux et al., 2007).

Ozone is a harmful agent causing oxidative stress on plants which may vary in their tolerances. Changes in agricultural productivity can be, in one hand, the result of direct effects of ozone at the plant level, or, in the other hand the consequence of indirect effects at the system level, for instance, through shifts in nutrient cycling, crop-weed interactions, insect pest occurrence, and plant diseases (Fuhrer, 2003).

The instruments used for measurements and description of the methods were described in the previous studies (Nowinszky et al., 2012; Puskás and Nowinszky, 2010; Nowinszky and Puskás, 2011; Puskás and Nowinszky, 2011a and 2011b; Puskás et al., 2013); we refer here only to our former work.

Kalabokas and Bartzis (1998), Kalabokas et al. (2000), Kalabokas (2002), Papanastasiou et al. (2002 and 2003), Papanastasiou and Melas (2006) in Greece have been studying both the monthly changes and those in the different periods of each day of the ozone content. Ozone content in the summer months - from May until August - is higher than in other months of the year. There are typical daily changes. The ozone content is high from noon to evening and goes down from evening to dawn. It hits its lowest point in the dawn hours and begins to rise again in the early morning. Ozone concentrations in the atmosphere depended on several meteorological factors, too (Tiwari et al., 2008). According to Juhász et al. (2006) the ozone content of the atmosphere is still significantly high during the night.

The high concentration of ozone is maleficent to insects. The study of Kells et al. (2001) evaluated the efficacy of ozone as a fumigant to disinfect stored maize. Treatment of 8.9 tonnes of maize with 50 ppm ozone for 3 days resulted in 92-100 % mortality of adult Red Flour Beetle, *Tribolium castaneum* (Herbst), adult Maize Weevil, *Sitophilus zeamais* (Motsch.), and larval Indian Meal Moth, *Plodia interpunctella* (Hbn.). Biological effects of ozone have been investigated by Qassem (2006) as an alternative method for grain disinfestations. Ozone at a concentration of 0.07g/m^3 killed adults of the Grain Weevil *(Sitophilus granarius* L.), Rice Weevil *(Sitophilus oryzae* L.) and Lesser Grain Borer *(Rhyzopertha dominica* Fabr.) after 5-15 hours of exposure. Adult death of the Rice Flour Beetle *(Tribolium confusum* Duv.) and Saw-toothed Grain Beetle *(Oryzaephilus surinamensis* L.) was about 50% after 15 -20 hours of exposure. The total adult death of all insect species occurred with 1.45 g/m^3 ozone concentration after one hour of exposure. Valli and Callahan (1968) examinations made with light traps indicated an inverse relationship between O_3 and insect activity.

The our recent study (Ladányi et al. 2012) investigates the effect of the tropospheric ozone content on the relative catch of European Vine Moth (*Lobesia botrana* Den. et Schiff.), Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabr.), Setaceous Hebrew Character *(Xestia c-nigrum* L.), Latticed Heath *(Chiasmia clathrata* L.), April Beetle (*Rhizotrogus aequinoctialis* Herbst) and *Ecnomus tenellus* Rambur trapped between 2004 and 2011 in Hungary. In order to describe the empirical connection between the ozone content of the air and the relative number of trapped insects, we introduce some nonlinear regression models of the same general model as origin. We show that elevated ozone content of air stimulates basically two different kinds of response in flying activity of insects.

5. 2. Material

Between 2004 and 2011 Csalomon type pheromone traps were operating in Bodrogkisfalud (48°10' N, 21°21' E; Borsod-Abaúj-Zemplén County, Hungary, Europe). These traps attracted 7 Microlepidoptera species. Every year 2-2 traps per species were collected; one night after a 2-2 catching, data were available.

The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth *(Phyllonorycter corylifoliella* Hübner.), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). Data on the Hawthorn Red Midget Moth *(Phyllonorycter corylifoliella* Hübner.) were collected between 2008 and 2011 only. The catch data of the collected species is displayed in Table 5. 2. 1.

5. 3. Methods

The traps near each other worked all year. They were placed on leafy trees of the same branches and vines at a distance of 50 meters between the traps. The height of each species was different, from 1.5 to 2 meters. The traps operated from the beginning of April to the end of September. According to Tóth (2003) the proposed capsules exchange was in a 6-8 week period. The number of moths captured per day was recorded, which is different from the general practice of counting the catch two or three days together.

The pheromone traps operated in the same orchards and vineyards in every year. There were no performed chemical pest control treatments.

In Hungary, ozone monitoring is carried out at four stations of the Hungarian National Meteorological Service. Monitoring at K-puszta (46° 58' N, 19° 33' E) has been done since 1973 and in 37 other cities and villages since 2004. Today 10 minute average concentration values are detected at every station with the help of the ozone monitors. Since 1998, MILOS has forwarded data and QLC that were collected earlier by local data collecting software (SCANAIR) and stored in PCs. SCANAIR reduced 15-minute data into half-hour averages which were then entered in the data base. At the stations the job is performed by an Environment type monitor. A Thermo Electron type monitor executes parallel monitoring at stations. The ozone monitors are UV photometric ozone analysers which, with a UV lamp, establish ozone concentration by illuminating an air sample drawn into an absorption cell, then measure the decline of illumination at a wavelength of 254 nm. The extent of this is proportional to the ozone content of the air. The instrument establishes the ozone concentration in a ppb unit, by taking samples in every 10 minutes. The data are in a 0-150 ppbs range. Sometimes negative values are received after calibration: this is to be handled as 0. High ozone values (> 100 ppb) occur mainly in the summer season, sometimes in early spring. Values over 120 ppb were measured vary rarely (so far in 1-2 cases). A Thermo Electron type ozone calibrator is being used. Every measuring instrument must be calibrated at least once a year. In fact, the ozone calibrator must be regularly adjusted to the international standard (in Prague), too. Calibration and data control cannot be fully automated, as the daily curves must be checked separately and outliers must not be automatically discarded. Each item of data is marked with an error code, which characterizes the quality of the data. Every external circumstance, including the various meteorological features (wind direction, wind speed, temperature, etc.), must be examined in order to explain extreme and clearly incorrect ozone values. A final file of data stores the raw measurement data, the calibrated and controlled data and the mistake code referring to data quality. The database is copied to CDs annually (Puskás et al. 2001). From the catching data of the examined species, relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 day) per the average number of individuals of the same generation falling to the same time unit. In the case of the expected averaged individual number, the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps.

The ozone content values and the moths caught were calculated with consideration to the method of Sturges (Odor and Iglói, 1987). The RC values of a species from all sites and years were arranged into the proper classes. The results obtained are plotted. We determined the regression equations, the significance levels which were shown in the figures.

5. 4. Results and Discussion

Our results, including regression equations and significance levels, are displayed in Figures 1-7. Our results have shown that high ozone content of the air is accompanied by a higher pheromone trap catch. Our previous work has demonstrated that when the atmospheric ozone content is high, the flying activity of the several insect species increases and their light-trap catch will be more effective.

The relationship of pheromone trap relative catch to ozone concentration can be described using different types of functions. For the following species: *Phyllonorycter blancardella* Fabr., *Cydia pomonella* L., *Lobesia botrana* Den. et Schiff. and *Grapholita funebrana* Treitschke, such ratio can be described by logarithmic function. On the other side, for species such: *Phyllonorycter corylifoliella* Haw., *Anarsia lineatella* Zeller and *Grapholita molesta* Busck, named relation can be described using second or third degree polynomial functions.

Our current work can be done based on a similar statement of pheromone trap catch in the harmful moth species also. Nowinszky and Puskás (2011), Puskás and Nowinszky (2011a) and for the *Ecnomus tenellus* Rambur (Trichoptera: Ecnomidae) by Puskás et al. (2011).

We found that the pheromone trap catch of five harmful moth species increases in strength when the atmospheric ozone content is more than 40 $\mu g/m^3$ and in the case of two species when it is more than 50 $\mu g/m^3$. In contrast, the low ozone content of air significantly reduces the pheromone trap catch success of these examined species.

Higher concentrations of ozone are generally typical on those days when a stronger UV radiation can be measured. Probably the daily average temperature and temperature of swarming hours are higher on these days because of the more intensive sunshine. This can cause intensive flight activity and also high value in catch. Some literature, however, suggests that direct ozone effect on behaviour cannot be ruled out.

The pheromone trap catch of the death-borer beetles seems to support the theory that the flight activity of some insects is increased as a direct consequence of increased ozone concentration (Grodzki et al*.,* 2004). However, due to expected increased tropospheric ozone concentration in future, to clarify the direct or indirect influence of ozone concentration on the flight activity of the insects, further investigation will be required.

We suggest similar examinations of other harmful insect species be done with other relevant sampling methods (for example light-, suction-, Malaise-, bait traps). If it were proved that the high ozone content of air increases the flying activity of other insect species, it will be necessary to take this fact into consideration when developing the plant protection prognoses. Moreover, more accurate plant protection prognosis could be prepared. Our result contradicts that of Valli and Callahan (1968), who experienced a decrease in the activity of Corn Earworm (*Heliothis zea* Boddie) with the parallel increase of the ozone content. This contradiction may be due to the fact that low relative catch values always refer to environmental factors in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism. The imago is short- lived; therefore an unfavourable environment endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the hindrances to the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity, or it may take refuge in passivity to environmental factors which create an unfavourable situation. And so, given the present state of our knowledge, we might say that both favourable and unfavoura-

Table 5. 2. 1. The number and observing data of the examined species

Species	Number of	
	moths	data
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	53,515	2,092
Gracillariidae »Lithocolletinae Hawthorn Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	5,834	929
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	5,957	1,606
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	6,993	1,738
Tortricidae » Tortricinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	23,386	2,144
Tortricidae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	11,830	1,996
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	11,830	1,996

Cydia pomonella, imago

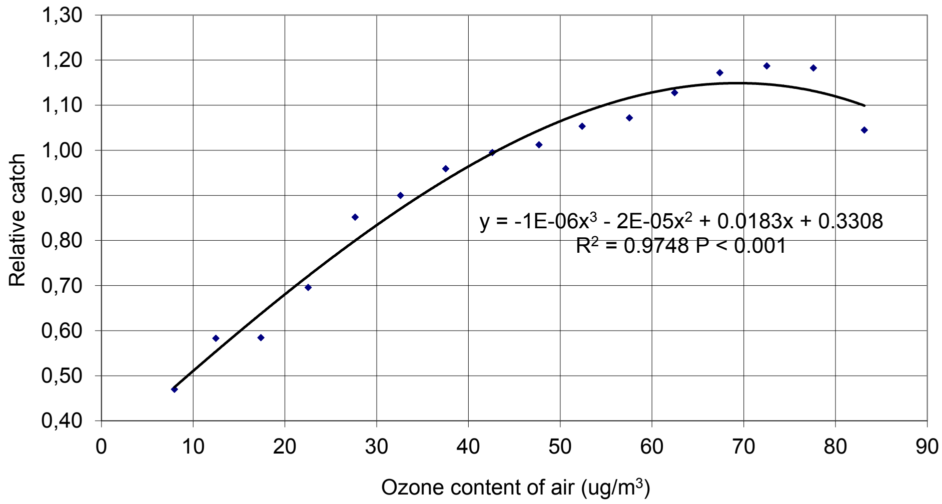

Figure 5. 4. 1.

Figure 5. 4. 1. Pheromone trap catch of Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius) in connection with ozone content of air (Bodrogkisfalud, 2004-2011)

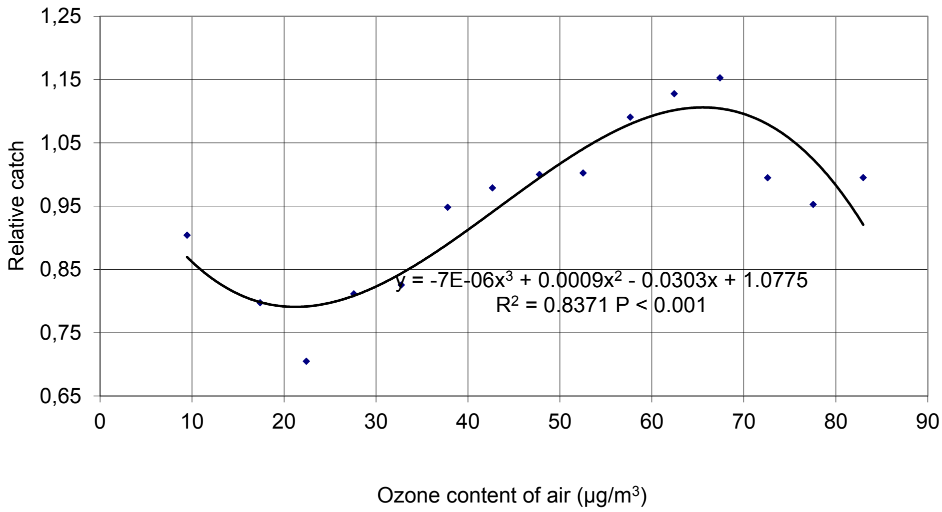

Figure 5. 4. 2.

Figure 5. 4. 2. Pheromone trap catch of Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hübner) in connection with the ozone content of air (Bodrogkisfalud, 2008 -2011)

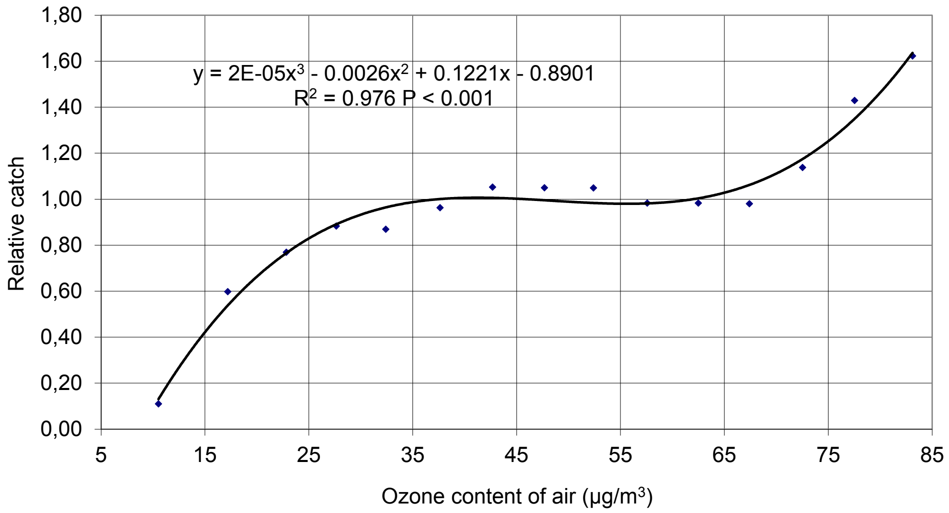

Figure 5 . 4. 3.

Figure 5. 4. 3. Pheromone trap catch of Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with ozone content of air (Bodrogkisfalud, 2004-2011)

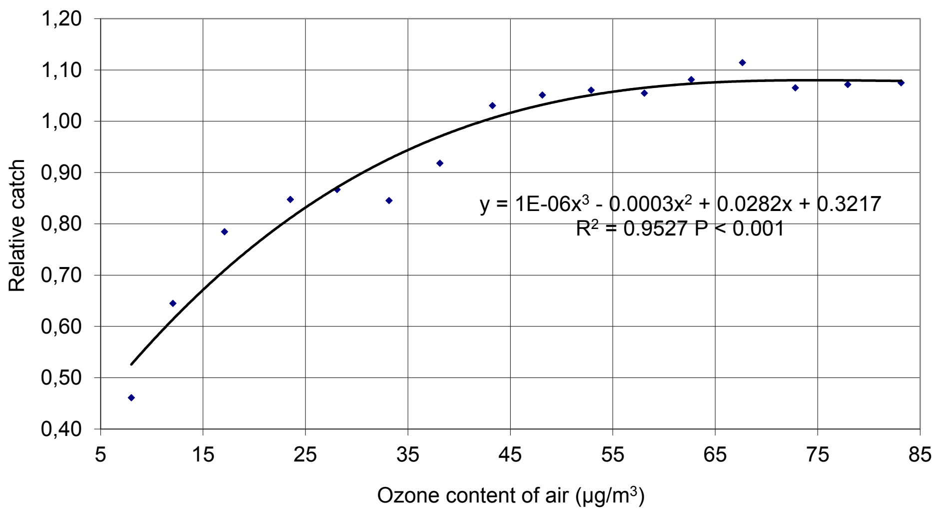

Figure 5. 4. 4

Figure 5. 4. 4. Pheromone trap catch of European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) in connection with the ozone content of air (Bodrogkisfalud, 2004-2011)

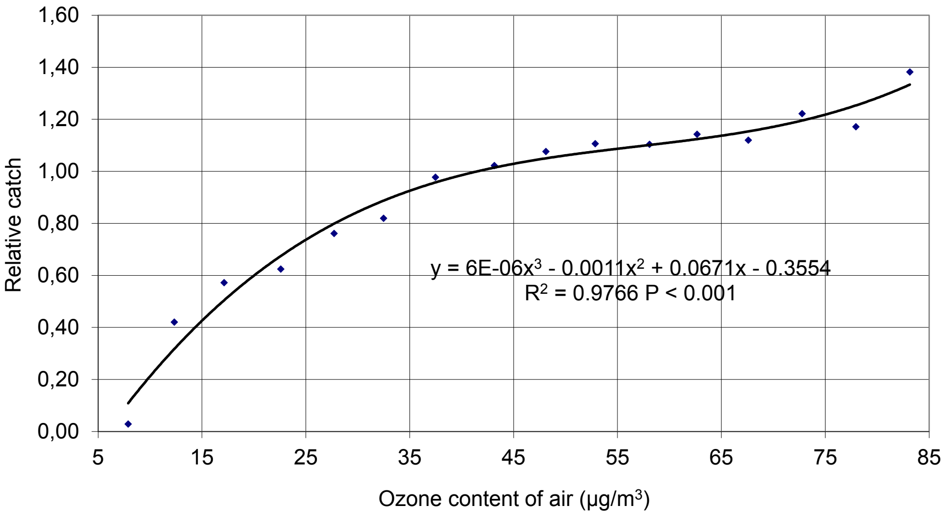

Figure 5. 4. 5.

Figure 5. 4. 5. Pheromone trap catch of Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with ozone content of air (Bodrogkisfalud, 2004-2011)

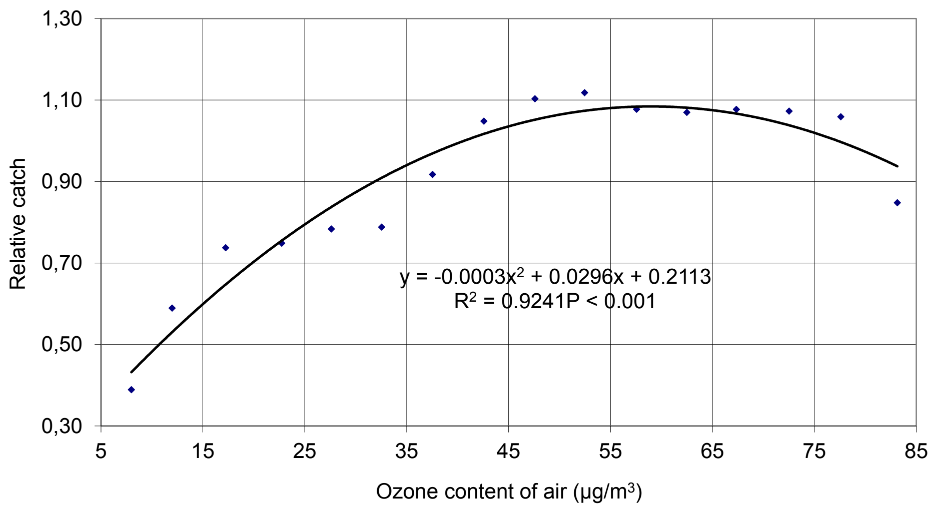

Figure 5. 4. 6.

Figure 5. 4. 6. Pheromone trap catch of Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with ozone content of air (Bodrogkisfalud, 2004-2011)

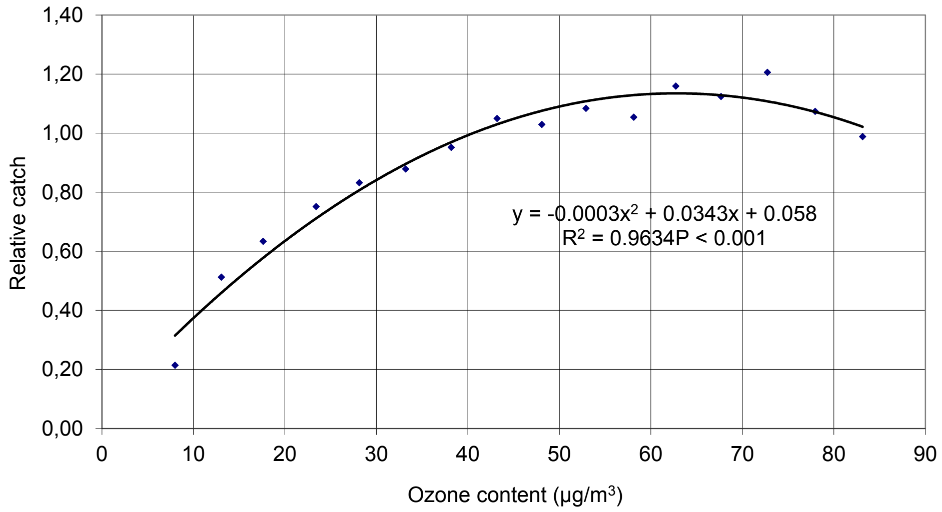

Figure 5. 4. 7.

Figure 5. 4. 7. Pheromone trap catch of Codling Moth (*Cydia pomonella* Linnaeus) in connection with the ozone content of air (Bodrogkisfalud, 2004-2011)

ble environmental factors might be accompanied by an equally high catch (Nowinszky, 2003).

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Chapter 6.

Pheromone Trap Catch of the Harmful Microlepidoptera Species in Connection with the Geomagnetic C9 Index

L. Nowinszky[1] J. Puskás[1], G. Barczikay[2]

[1] University of West Hungary, Savaria University Centre,
H-9701 Szombathely Károlyi G. Square 4.
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2] County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate,
H-3917 Bodrogkisfalud Vasút Street 22.

Abstract: The study deals with the change of pheromone trap catch of six harmful Microlepidoptera species in connection with the geomagnetic C9 index. The numbers of specimens caught by generation of all species were calculated relative catch values. These daily relative catch data were assigned to the daily values of geomagnetic C9 index. We correlated the daily catch results pertaining to the daily values of geometric C9 values. The pheromone trap catch of four examined species increased in the higher values of the C9 index. These species are as follows: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius), Peach Twig Borer (*Anarsia lineatella* Zeller), Plum Fruit Moth (*Grapholita funebrana* Treitschke) and Oriental Fruit Moth (*Grapholita molesta* Busck). The catch decreased of two species European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) and Codling Moth (*Cydia pomonella* Linnaeus) when the value of C9 index increased.

6. 1. Introduction

It has been known for decades that the insects detect the geomagnetic field, and even can use it as a three-dimensional orientation. A number of laboratory experiments and comprehensive studies are devoted to the physiological bases of perception and the ways of orientation (Wehner and Lobhart, 1970; Kirschvink, l983; Wehner, 1984 and 1992; Jahn, 1986).

Studying some species of termites (Isoptera), beetles (Coleoptera), flies (Diptera), orthopteroids (Orthoptera), and hymenopterans (Hymenoptera), Becker (1964) found that they orient according the natural magnetic field. Way of their mobility is North-South, rarely East-West. Their original way of movement could be modified by artificial magnetic field.

Mletzko (1969) carried out his experiments with specimens of ground beetles *(Broscus cephalotes* L., *Carabus nemoralis* Mull. and *Pterostichus vulgaris* L.) on a 100 square meter asphalt coated area in the Moscow botanical garden. He placed the insects in the middle of the area and followed their movement with a compass. After some uncertainty, the insects flew in a given direction with an accuracy of +5° at daylight and + 60° at night. The author assumes that orientation is guided by geomagnetism. Iso-Ivari and Koponen (1976) studied the impact of geomagnetism on light trapping in the northernmost part of Finland. In their experiments they used the K index values measured in every three hours, as well as the ΣK and the δH values. A weak but significant correlation was found between the geomagnetic parameters and the number of specimens of the various orders of insects caught. Studying the few Willow Ermine *(Yponomeuta rorella* Hbn.), Pristavko and Karasov (1970) revealed a correlation between the C and ΣK values and the number of individuals caught. In a later study (Pristavko and Karasov, 1981) they also established that at the time of magnetic storms ΣK has a greater influence on the flying activity of the above species. The influence is also significant in years when ΣK is not higher than 16-26. Equally interesting is the observation that if ΣK < 26, flying activity intensifies the same day, if ΣK = 27-30, this happens the following day and if ΣK = 33-41, intensification follows only on the second or third day. Studying the termite species *Heterotermes indicola* Wasmann, Becker and Gerisch (1977) found a stronger correlation between this activity and the vertical component of geomagnetism (z) than with the values of the K index. Tshernyshev and his colleagues have discussed in a series of studies the results of their laboratory and light trapping experiments with species of different orders of insects to reveal a connection between geomagnetism and certain life phenomena. Tshernyshev (1966) found that the number of light-trapped beetles and bugs rose many times over at the time of geomagnetic storms in Turkmenia. He found a high positive correlation between the horizontal component and the number of trapped insects. In laboratory conditions, Tshernyshev and Danilevsky (1966) could not reveal the influence of an alternating magnetic field on the activity of flies at low temperature (22 °C), but observed a significant rise at (29 °C). Tshernyshev (1968) studied the changes in the biological rhythm of the *Trogoderma glabrum* Herbst as a function of the perturbations of the magnetic field. His assessment was based upon the K-index values over 4, i.e. over 40y measures at 6 and 9 p.m. as well as at 3 a.m. It was proved that the biological rhythm of the species observed was influenced by factors that coincided with perturbations of the magnetic field. It was also observed by Tshernyshev (1965) that the number of light-trapped insects significantly raised at the time of magnetic perturbations. Later, however, he reported that while light-trap catches of some Coloptera and Lepidopera species increased, that of other Lepidoptera and Diptera species fell back during magnetic perturbations (Tshernyshev, 1971 and 1972). Tshernyshev and Afonina (1971) also observed that the activity of certain moths and beetles increased, but in some cases fell back under the influence of a weak and changing magnetic field induced in laboratory conditions. Based on international literature and his own results, Tshernyshev (1989) published a comprehensive study to give a summary of the latest state of knowledge on the relation between geomagnetism and the activity of insects. Tshernyshev and Danthanarayana (1998) used an infrared actograph to study in laboratory conditions the activity of Scarcere Bordered Straw *(Helicoverpa* *armigera* Hübner), Native Budworm *(Helicoverpa punctigera* Wallengren) and Ruby Quaker Moth *(Orthosia rubescens* Walker). Examining the influence of the geomagnetic K index also in the context of the four typical lunar quarters (First Quarter, Full Moon, Last Quarter and New Moon), a significant negative correlation was found in the Last Quarter and a positive correlation in the other three. Moths are also disturbed by geomagnetic perturbations. 30 hours after perturbations the influence was still felt.

Examinations over the last decade**s** have also confirmed that some Lepidoptera species, such as Large Yellow Underwing *(Noctua pronuba* L.) (Baker and Mather, 1982) and Heart & Dart (*Agrotis exclamationis* L) (Baker, 1987) are guided by both the Moon and geomagnetism in their orientation, and they are even capable of integrating these two sources of information. On cloudy nights, the imagos of *Noctua pronuba* L. orientated with the help of geomagnetism. In this case, too, their preference lay with the direction they had chosen when getting their orientation by the Moon and the stars. Using hourly data from the material of the Kecskemét fractionating light-trap, we have examined the light trapping of Turnip Moth *(Agrotis segetum* Den. et Schiff.), Heart & Dart *(Agrotis exclamationis* L.) and Fall Webworm Moth *(Hypantria cunea* Drury) in relationship with the horizontal component of the geomagnetic field strength (Kiss et al., 1981).

According to the authors of recent publications (Srygley and Oliveira, 2001; Samia et al., 2010) the orientation/navigation of moths at night may becomes not by the Moon or other celestial light sources, but many other phenomena such as geomagnetism.

The results of our calculations have shown that in the period of the New Moon when there is no measurable moonlight, the higher values of the horizontal component are accompanied by a falling relative catch. In the other moon phases, i.e. in the First Quarter, Full Moon and the Last Quarter, growing values of the horizontal component are accompanied by an increasing catch in both the moonlit and moonless hours (Nowinszky and Puskás, 2011).

In a recent study (Nowinszky and Puskás, 2012) our research have shown that in the period of the New Moon when there is no measurable moonlight, the higher values of the vertical component are accompanied by a falling relative catch. In the other moon phases, i.e. in the First Quarter, Full Moon and the Last Quarter, growing values of the vertical component are accompanied by an increasing catch in both the moonlit and moonless hours.

However, we did not found any studies that investigate the relationship between geomagnetism and the pheromone trap catch.

6. 2. Material

Six harmful Microlepidoptera species were caught by the Csalomon type sticky traps at Bodrogkisfalud in Borsod-Abaúj-Zemplén County (Hungary) between 1993 and 2000. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Peach Twig Borer (*Anarsia* *lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). The catching data of examined moths (Lepidoptera) species and pheromone trapping stations are shown in Table 6. 2. 1.

The average field strength of the Earth as a magnetic dipole is 33,000γ. [1γ =10^{-5} Gauss = 10^{-9} Tesla = 1 nanotesla (nT)]. Geophysical literature uses γ as a unit.

The three-hour index ap and the daily indices Ap, *Cp* and C9 are directly related to the Kp *index*. In order to obtain a linear scale from Kp, Bartels (1957) gave the following table to derive a three-hour equivalent range, named ap index.

This ap index is made in such a way that at a station at about dipole latitude 50 degrees, ap may be regarded as the range of the most disturbed of the two horizontal field components, expressed in the unit of 2nT.

The daily index Ap is obtained by averaging the eight values of ap for each day. In order to replace the somewhat subjective index Ci, the Cp index - the planetary daily character figure - was developed. Cp is a qualitative estimate of overall level of magnetic activity for the day determined from the daily sum of eight ap amplitudes. Cp ranges, in steps of one-tenth, from 0 (quiet) to 2.5 (disturbed). Another index devised to express geomagnetic activity on the basis of the Cp index is the C9 index. It converts the 0 to 2.5 range of Cp to one digit between 0 and 9.

The simplest local characteristic of magnetic activity is the character number: C_i. The C_p planetary number of characters can be calculated for the total Earth from these numbers based on a few selected observing places, distributed evenly on the Earth.

The three-hour K index shows the activity of the variations created by the solar wind, which is measured in every 3 hours at all observatories. The K index may be a whole number from 0 up to 9 (Völgyesi, 2002).

We investigated, therefore, that the effectiveness of pheromone trap catch of insects changes to the geomagnetic ΣKp or C9 index?

The Kp index were used because other researchers have also successfully applied earlier. We also worked with C9 index which were easily used.

Geomagnetic data, required for our work, were downloaded from the British Geological Survey Natural Environment Research Council website: http://www.bgs.ac.uk/home.html

6. 3. Methods

Than the number of individuals of a given species in different places and different observation years is not the same. The collection efficiency of the modifying factors (temperature, wind, moonlight, etc.) are not the same at all locations and at the time of trapping, it is easy to see that the same number of items capture two different observers place or time of the test species mass is entirely different proportion. To solve this problem, the introduction of the concept of relative catch was used decades ago (Nowinszky 2003).

The relative catch (RC) for a given sampling time unit (in our case, one night) and the average number individuals per unit time of sampling, the number of generations divided by the influence of individuals. If the number of specimens taken from the average of the same, the relative value of catch: 1 (Nowinszky 2003).

From the collection data pertaining to examined species we calculated relative catch values (RC) by pheromone trap stations and by swarming. Following we arranged the data on the ΣKp and C9 index in classes. Relative catch values were placed according to the features of the given day, and then RC were summed up and averaged. The data are plotted for each species and regression equations were calculated for relative catch of examined species and ΣKp and C9 index data pairs.

6. 4. Results and Discussion

Unfortunately we got satisfactory results only with a few species in the context of the ΣKp index. However, the examinations of C9 index showed significant relationship with all the six species. Our results are shown in the Figures 6. 4. 1.—6. 4. 6.

The pheromone trap catch of four examined species increased in the higher values of the C9 index. These species are as follows: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius), Peach Twig Borer (*Anarsia lineatella* Zeller), Plum Fruit Moth (*Grapholita funebrana* Treitschke) and Oriental Fruit Moth (*Grapholita molesta* Busck). The catch decreased of two species European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) and Codling Moth (*Cydia pomonella* Linnaeus) when the value of C9 index increased.

The increase or decrease of the catch is explainable by our previous hypotheses.

Low relative catch values always refer to environmental factors in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism. The imago is short-lived; therefore unfavourable environmental endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by increasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to environmental factors of an unfavourable situation. By the present state of our knowledge we might say that unfavourable environmental factors might be accompanied by both high and low catch (Nowinszky 2003).

It can be explained on the basis of our hypothesis of the first rising and then falling catch results. But however their answer is already the passivity for the additional increase of the radiation. However, it is striking that the taxonomic place of the single species is not attached to by this response, so may be widespread in the world of the insects widely presumably.

It is a remarkable fact, that the swarming peaks of different species can be experienced at totally different C9 index values.

Table 6. 2. 1 The locality of pheromone traps, catching data of the examined species

Species	Number of	
	Individuals	Data
Gracillariidae » Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	22,076	720
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	3,088	720
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	6,862	744
Tortricidae » Olethreutinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1835	9,816	1,435
Tortricidae » Olethreutinae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	4,068	906
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	2,135	728

Lobesia botrana

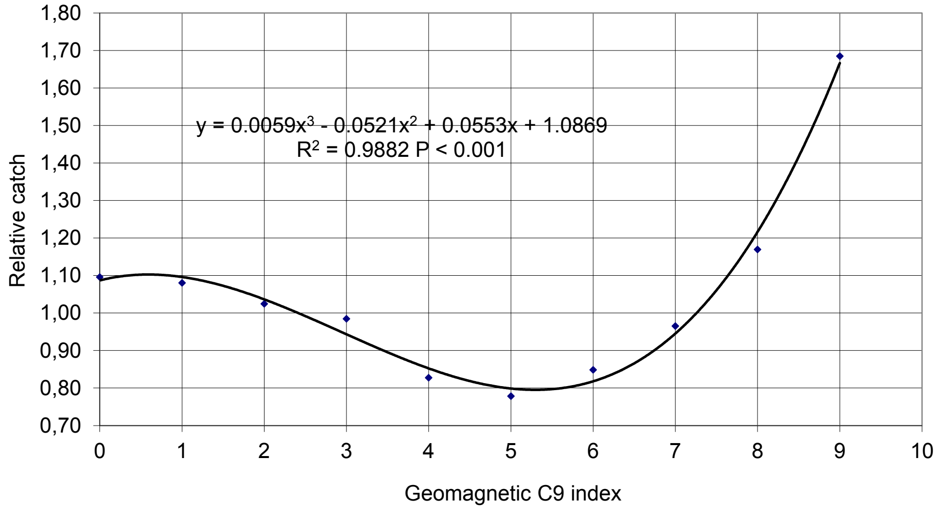

Figure 6. 4. 1.

Figure 6. 4. 1. Pheromone trap catch of Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius) in connection with the geomagnetic C9 index (Bodrogkisfalud, 1993–2000)

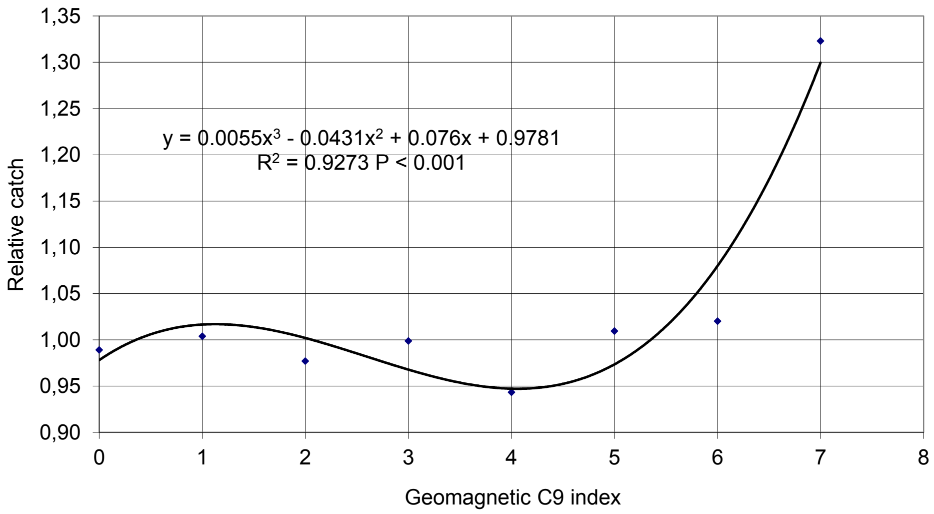

Figure 6. 4. 2.

Figure 6. 4. 2. Pheromone trap catch of the Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with the geomagnetic C9 index (Bodrogkisfalud, 1993–2000)

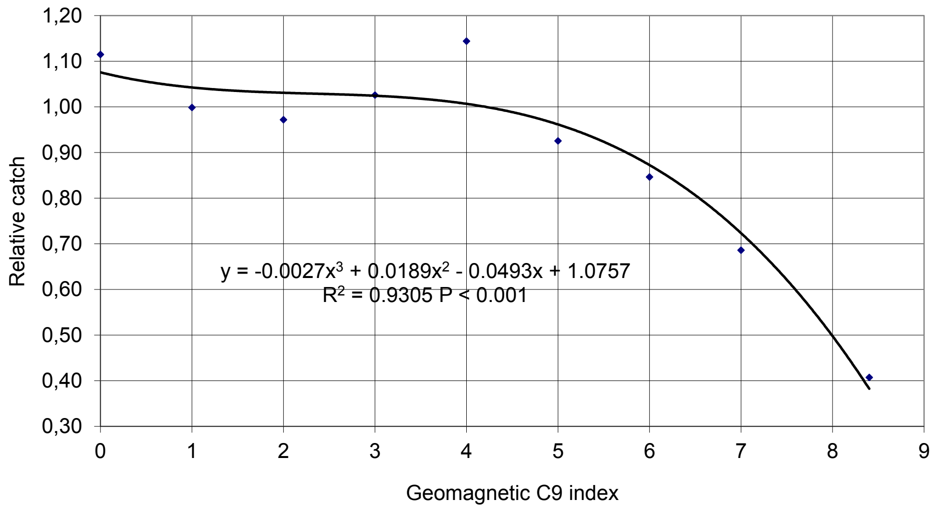

Figure 6. 4. 3.

Figure 6. 4. 3. Pheromone trap catch of European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) in connection with the geomagnetic C9 index (Bodrogkisfalud, 1993–2000)

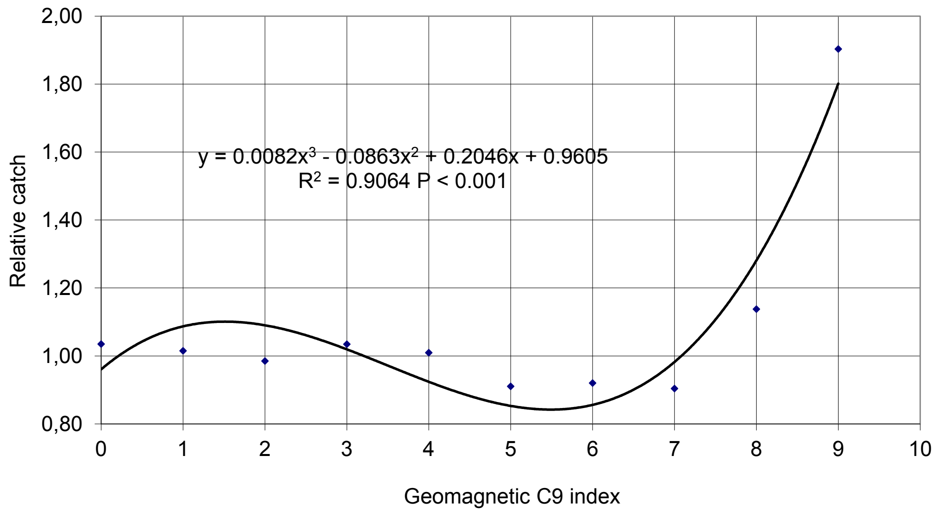

Figure 6. 4. 4.

Figure 6. 4. 4. Pheromone trap catch of the Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with the geomagnetic C9 index (Bodrogkisfalud, 1993–2000)

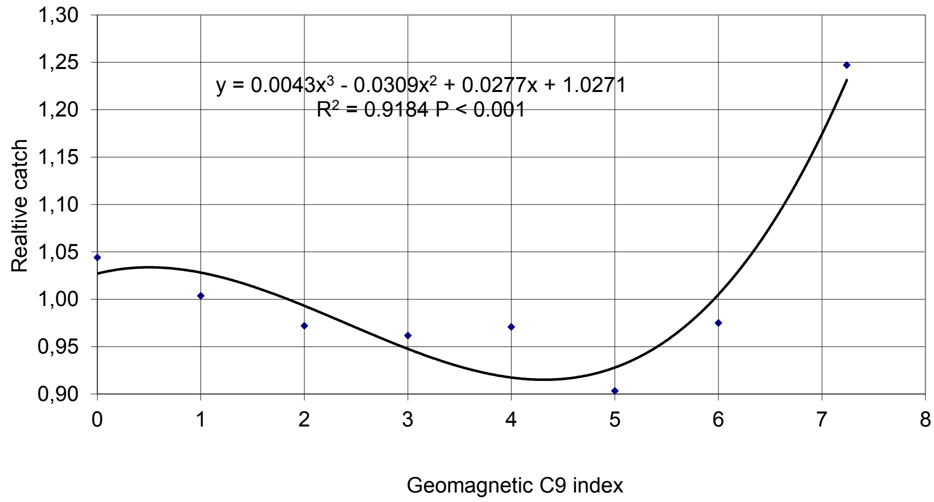

Figure 6. 4. 5.

Figure 6. 4. 5. Pheromone trap catch of Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with the geomagnetic C9 index (Bodrogkisfalud, 1993–2000)

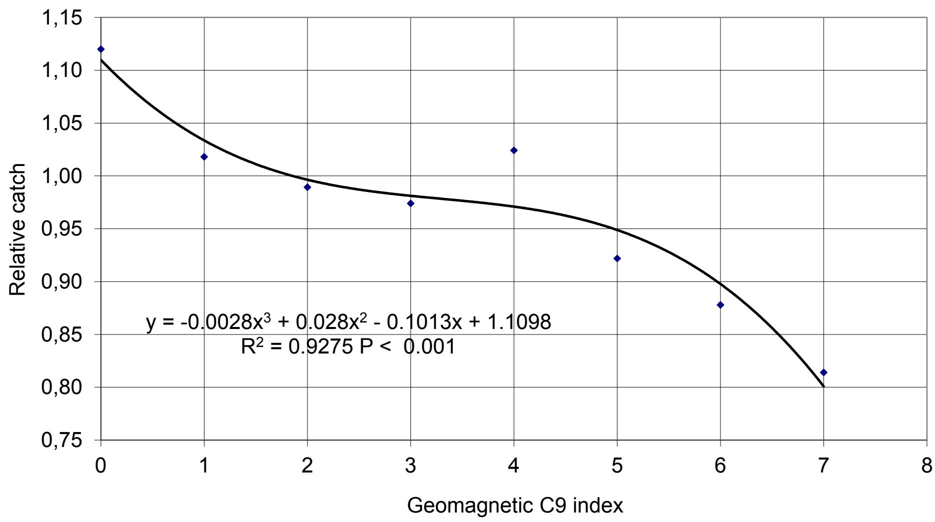

Figure 6. 4. 6.

Figure 6. 4. 6. Pheromone trap catch of the Codling Moth (*Cydia pomonella* Linnaeus) in connection with the geomagnetic C9 index (Bodrogkisfalud, 1993–2000)

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Chapter 7.

Pheromone Trap Catch of Harmful Microlepidoptera Species in Connection with the Polarized Moonlight

L. Nowinszky[1], J. Puskás[1], G. Barczikay[2]

[1] University of West Hungary, Savaria University Centre,
H-9701 Szombathely, Károlyi G. Square 4.
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2] County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate,
H-3917 Bodrogkisfalud, Vasút Street 22.

Abstract: Pheromone traps were operating in Borsod-Abaúj-Zemplén County (Hungary) between 1982 and 1988, in 1990 and also between 1993 and 2013. These traps attracted 8 Microlepidoptera species as the follows: *Phyllonorycter blancardella* Fabr., *Phyllonorycter corylifoliella* Hbn., *Anarsia lineatella Z., Eupoecilia ambiguella* Hbn., *Lobesia botrana* Den. et Schiff., *Grapholita funebrana* Tr., *Grapholita molesta* Busck and *Cydia pomonella L.* We examined the trapping data of these species depending on the moon phases and polarized moonlight. The catch of the European Vine Moth (*Lobesia botrana* Den. et Schiff.) and the Codling Moth (*Cydia pomonella L.*) is higher in the First Quarter. The catch is higher in the Last Quarter of Peach Twig Borer (*Anarsia lineatella Z.),* Vine Moth *(Eupoecilia ambiguella* Hbn.), Plum Fruit Moth (*Grapholita funebrana* Tr.) and Oriental Fruit Moth *Grapholita molesta* Busck. In case of the other two species, The Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabr.), *and* Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hbn.) the catch is higher both in the First- and Last Quarter. In the case of using pheromone traps, insects do not fly to a light source. The moonlight no modifies neither the catching distance, neither the flying activity of the pheromone trap catch of these species. However, in case of high proportion of the polarized moonlight, the pheromone trap catches will increase, similar to the light-trap catches. The results are understandable when consider that the examined species can fly daytime and also during the night.

Keywords: Microlepidoptera, polarized moonlight, lunar phases, pheromone traps.

7. 1. Introduction

Pheromone traps and light traps play an equally important role in pestiferous insect forecast. However, the efficiency of traps may be influenced by several biotic and abiotic factors. As the application of light traps has a past of several decades, thus scientists studied the modifying effect of different factors primarily with the help of light traps. The efficiency of collecting by a light trap is significantly influenced by the Moon. Despite numerous investigations and several interesting results achieved in different parts of the world, opinions on this influence in scientific literature are still quite controversial. Although there are several studies in international scientific literature on the efficiency of pheromone traps and the influence of the Moon, the details of this relationship continue to be less explored. Comprehensive research in this field would be of extreme importance, as the exploration of lunar influence on the efficiency of pheromone traps would also contribute to a better understanding of the relationship between the Moon and light traps. This is because the attracting force of pheromone capsules is not weakened by moonlight. Consequently, any lunar influence detected shall not be explained by the change of collecting distance or the suspected effect of moonlight in decreasing flight activity. Kehat et al. (1975) used traps containing live intact females and synthetic pheromone to collect the Cotton Leaf-worm (*Spodoptera littoralis* Boisduval) on cotton fields in Israel. No correlation between the catch and the lunar phases could be found.

Collecting with synthetic pheromone traps in Malawi, Marks (1976) found that the moonlight had no hindering influence on the collecting of the Pink Bollworm (*Pectinophora gossypiella* Saud). On maize and sorghum fields in western Kenya, in 1981 and 1982 Ho and Reddy (1983) caught the following moth species using light traps and pheromone traps baited with intact females: the African White Stem Borer *(Maliarpha separatella* Rag.), the Spotted Stalk Borer *(Chilo partellus* Swinh.), the African Sugarcane Borer *(Eldana saccharina* Wlk.), the African Pink Stem Borer (*Sesamia calamistis* Hmps.) and the Maize Stalk Borer *(Busseola fusca* Fuller). They found moonlight to have a stronger influence on the catch by light traps than on the catch by pheromone traps. Hoffmann et al. (1991) operated a pheromone trap in California to catch Corn Earworm *(Heliothis zea* Boddie) and Darker-spotted Straw Moth (*Heliothis phloxiphaga* Grote & Robinson). Lunation did not have an influence on the timing of catch peaks. Suckling and Brown (1992) operated pheromone traps in an orchard in New Zealand between 1989 and 1991, to monitor populations of the Black-lyre Leafroller *(Ctenopseustis herana* Walker), the Green Headed Leafroller *(Planotortrix octo* Dugdale), the Codling Moth (*Cydia pomonella* L.) and the Light Brown Apple Moth (*Epiphyas postvittana* Walker). Lunation did not have a significant influence. In their pheromone trap experiments focusing on the Scarce Bordered Straw *(Helicoverpa armigera* Hübner), Sekhar et al. (1995) did not observe any difference between the catch at a Full Moon and at a New Moon. The following studies confirm the theory of decreased trapping efficiency of moths in the vicinity of a Full Moon. To record the weekly number of male specimens of the Potato Tuberworm (*Phthorimaea operculella* Zeller), Roux and Baumgartner (1995) operated pheromone traps on potato fields in Tunisia between 1986 and 1991. They detected a four-week cycle presumably influenced by the Moon. Operating sex pheromone traps, Parajulee et al. (1998) were monitoring the flight activity of the Corn Earworm *(Helicoverpa zea* Boddie) and the Tobacco Budworm *(Heliothis virescens* F.) in Texas for 15 years, between 1982 and 1996. The daily catch of the trap was influenced by lunar phases. They revealed a significant positive correlation between the catch and the percentile value of lunar illumination. The maximal daily catch of the trap occurred at a Full

Moon (71 %), followed by the values of the First Quarter (11 %), the Last Quarter (9 %) and that of the New Moon (9 %). Using pheromone traps, Rajaram et al. (1999) collected cotton pests in 1994 in India. They observed a characteristic difference between the nocturnal activity of the week of the Full Moon and the New Moon. The ratio of the week of Full Moon and New Moon was 1:1.40 for the Pink Bollworm *(Pectinophora gossypiella* Saunders) and 1:1.17 for the Oriental Leafworm Moth *(Spodoptera litura* Fabr.). However, Das and Katyar (2001) studied the pheromone trap catch of the Oriental Leafworm Moth *(Spodoptera litura* Fabr.) in India. The lowest catch results were recorded in the vicinity of Full Moon. According to their investigations, collecting is more efficient in the period between Full and New Moon than in the period between New and Full Moon. Between 1973 and 1990 Sheng et al. (2003) operated "Gossyplure" pheromone traps for the Pink Bollworm Moth *(Pectinophora gossypiella* Saunders) at 10 entomological forecast stations of China. The highest activity was recorded in the First Quarter, resulting in a significant catch peak. Kamarudin and Wahid (2004) used a pheromone trap to collect the Coconut Rhinoceros Beetle *(Oryctes rhinoceros* L.). Male beetles were more active during Full Moon. However Gebresilassie et al. (2015) found that the number of *Phlebotomus orientalis* Parrot and the other *Phlebotomus* spp. from sticky traps did not differ in their density among the four lunar phases (P = 0.122).

We have already studied the pheromone trap catch results depending on the phases of the Moon (Nowinszky et al., 2010). In the work we publish the results of the pheromone trap catch of examined species distributions for each moon phase. We also investigated, using new data, what is the cause of experienced differences at different moon phases in our present study.

Examining the light-trap catches of the selected insect species, we found consequent alterations of the catching curves, which seemed to show high correlation to the polarization rate of the moonlight.

The moonlight is linearly polarized. The maximum polarization rate 7.5 % is reached during ± 2 days of the First- and the Last Quarter. It is impossible to measure the polarization rate at New Moon ± 3 days. At Full Moon, the moonlight is not polarized, but in an interval of ± 2.5 days, the polarization plane turns over (Nowinszky et al., 1979).

7. 2. Material

Between 1982 and 1990 pheromone traps were operating in Borsod-Abaúj-Zemplén County (Hungary-Europe) at 9 villages (Table 7. 2. 1). An additional one trap operated between 1993 and 2013 at Bodrogkisfalud. These traps attracted 8 Microlepidoptera species altogether, in some of the years using 2-2 pheromone traps for each species, however, in other years not all 8 species were monitored.

The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth

(*Phyllonorycter corylifoliella* Hübner, 1796), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). Catch data of the collected species is displayed in Table 7. 2. 2. We examined the trapping data of these species depending on the moon phases.

The traps were operated through every day during the season from April until October.

7. 3. Methods

We calculated for each midnight of Full Moon the phase angle values. Henceforward, all the midnights after the full moon were calculated the phase angle values. The mean revolution time of the moon in its orbit around the Earth is 29.53 days. This time period is not divisible by entire days, therefore we rather used phase angle data. Daily phase angle values change with phase angle value of 12.19. For every midnight of the flight periods (UT = 0 h) we have calculated phase angle data of the moon. The 360° phase angle of the complete lunation was divided into 30 phase angle groups.

For every midnight of the flight periods (UT = 0 h), we have calculated phase angle data of the Moon. Of the 360 phase angle degrees of the full lunation we established 30 phase angle divisions. The phase angle division including Full Moon (0º or 360º) and values 0 ± 6º was named 0. Beginning from this group through the First Quarter until New Moon, divisions were marked as -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The next division is ±15, including the New Moon. From the Full Moon through the Last Quarter in the direction of the New Moon divisions, were marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each division consists of 12 degrees (Nowinszky, 2003 and 2008). These phase angle divisions can be related to the four quarters of lunation as follows: Full Moon (-2 – +2), Last Quarter (3 – 9), New Moon (10 – -10) and First Quarter (-9 – -3). The nights and hours of the periods under examination were all classed into these phase angle divisions.

We have calculated the relative catch values of the number of specimens trapped by species and broods. Relative catch (RC) is the ratio of the number of specimen caught in a given sample unit of time (1 hour or 1 night) and the average number of specimen caught in the same time unit calculated for the whole brood. If the number of the specimen trapped equals the average, the value of relative catch is: 1. Only nights with some catch were included in the calculations, as our earlier works (Nowinszky, 2003 and 2008), had convinced us that although the Moon has an influence on the efficiency of trapping, it never makes collecting impossible.

The relative catch values were classified by species belonging to the daily phase angle group. The results are plotted. We determined in which Moon Quarter is significantly higher or lower relative catch value that the expected value (1). We found higher catch values in the First and Last Quarter of Moon environment, when polarized light of the Moon is highest. We were looking for the highest correlation between the percentage ratio of the polarized moonlight and the relative catch values. We determined the parameters of the curves and the level of significance of the results as well.

7. 4. Results and Discussion

Results are shown in Figures 7. 4. 1. – 7. 4. 10. Specimens of all the 8 species examined can be collected in various numbers on the different days of the lunar phase. Consequently, the Moon has an influence on the efficiency of the trapping of these species. However, this influence may hardly be attributed to moonlight. In case of light trap studies, the majority of scientists share the view of Williams (1936), attributing deviations of the catch during the lunation to smaller collecting distances caused by moonlight or reduced flight activity, perhaps to the behaviour of the moths flying in higher layers of air (El-Ziady, 1957). Nevertheless, in the case of pheromone traps insects do not fly to a light source, so moonlight may not have a similar influence on this method of trapping. Based on our results, we presume the life cycles of the Microlepidoptera species examined to be somewhat related to lunation. The life of moths is usually short, so there should be some kind of timing factor ensuring that mature specimens find each other. The regularly changing lunar phases seem to be appropriate for this purpose (Nowinszky and Puskás, 2013).

Further, research would be necessary to gain a more comprehensive knowledge on lunar influence also in the case of pheromone traps. The recognition that lunar influence is not identical with the influence of moonlight is an important new result of our work. Similar investigations based on data of traps baited with intact females could be interesting. Through these studies we could get an answer the question of whether the pheromone emission of females is independent of the lunar phases.

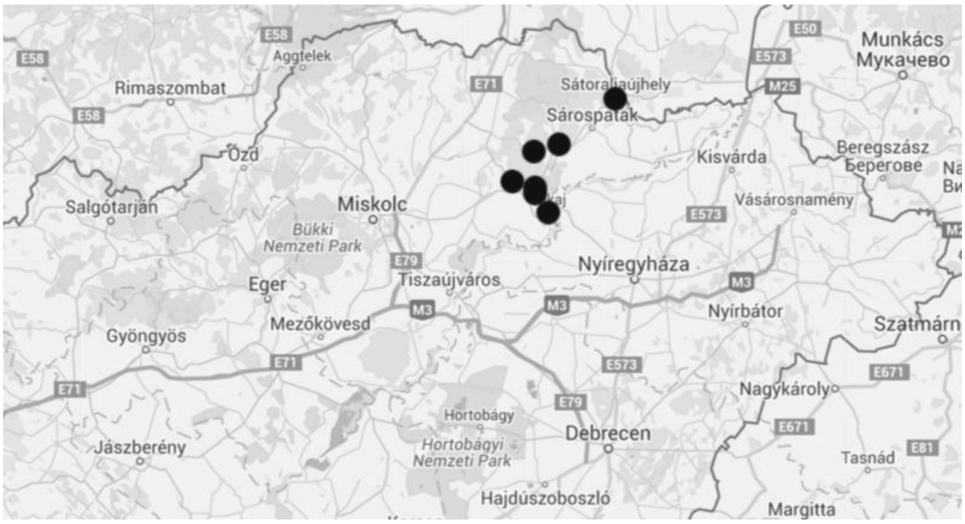
The catch of the European Vine Moth (*Lobesia botrana* Den. et Schiff.) and the Codling Moth (*Cydia pomonella L.)* is higher in the First Quarter. The catch is higher in the Last Quarter of Peach Twig Borer (*Anarsia lineatella* Z.), *Eupoecilia ambiguella* Hbn., *Grapholita funebrana* Tr. and *Grapholita molesta* Busck. In case of the other two species, The Spotted Tentiform Leafminer *(Phyllonorycter blancardella* Fabr.), and Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella Hbn.)* the catch is higher both in the First- and Last Quarter. In the case of pheromone traps insects do not fly to a light source. The moonlight so may modify it neither the catching distance, neither the flying activity.

In case of pheromone trapping the bait is not done with light, so the collecting area, modified by the moonlight, has no influence for the quantity of catch. We did not find relationship with the strength of the moonlight. However, we found a very impressive and highly significant relationship with the polarized moonlight.

This explanation may be that the test species can fly day and night, though not with the same intensity throughout the day.

We could not find any moon influence on species during the full lunar month. It is not surprising the fact that the difference between the lowest and the highest catch in lunar month is much lower than we have experienced for the light trap catch. Probably the explanation may be of this, the examined species fly daytime and also at night, although the intensity is not the same during the whole day.

Most of moths fly to pheromone capsule at dusk and dawn, but also there is catch at night, however very few at days.



Map of the pheromone traps were operated in Borsod-Abaúj-Zemplén County, N-Hungary, see in Table 7. 2. 1. (draw: By I. Fazekas)

Table 7. 2. 1. The pheromone traps were operated in Borsod-Abaúj-Zemplén County

Villages	Years	Longitude	Latitude
Bodrogkisfalud	1982–1983, 1993–2013	48°10'41″	21°21'77″
Bodrogkeresztúr	1988	48°09'54″	21°21'64″
Bodrogszegi	1982–1983	48°26'82″	21°35'61″
Erdőbénye	1987–1988	48°15'91″	21°21'18″
Erdőbénye-Meszesmajor	1988	48°11'43″	21°22'46″
Mád	1987–1988	48°11'55″	21°16'70″
Sátoraljaújhely	1988	48°23'80″	21°39'34″
Tolcsva	1988	48°17'05″	21°27'02″
Tokaj	1990	48°06'75″	21°24'75″

Table 7. 2. 2. The number and observing data of the examined species`

Species	Years	Number of	
		Moths	Data
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	1993-2013	95,610	4,023
Gracillariidae »Lithocolletinae Hawthorn Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	2008-2013	10,202	1,712
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	1993-2013	14,648	3,552
Tortricidae » Tortricinae Vine Moth *Eupoecilia ambiguella* Hübner, 1796	1982-83, 1990, 1987-1988 2000, 2002	2,266	507
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	1982–83, 1987–88, 1990, 1993–2013	30,270	3,964
Tortricidae » Olethreutinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	1982-83 1985 1993-2013	53,386	5,324
Tortricidae » Olethreutinae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	1988, 1993-2013	26,867	4,375
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	1982-1983, 1985, 1988 1993-2013	16,077	3,841

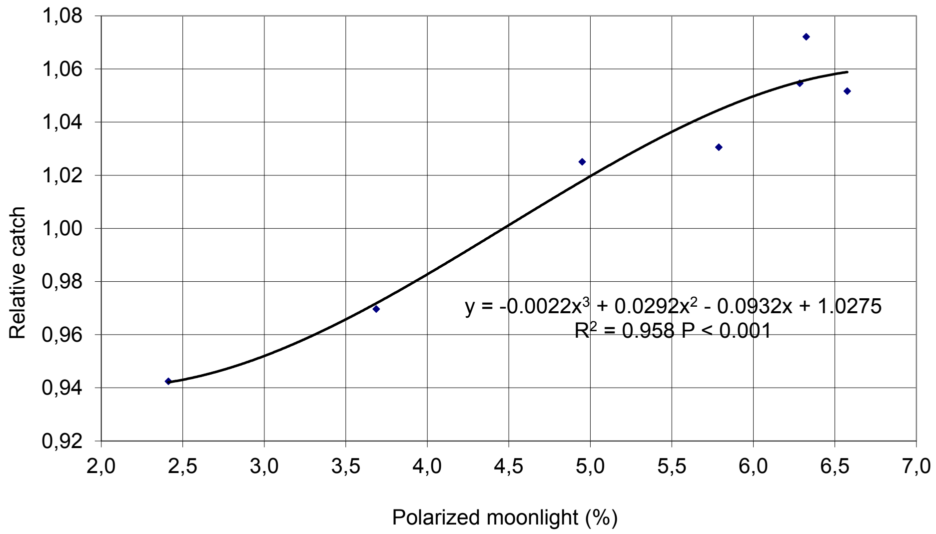


Figure 7. 4. 1.

Figure 1. Pheromone trap catch of the Spotted Tentiform Leafminer *(Phyllonorycter blancardella* Fabricius) in connection with the polarized moonlight (First Quarter)

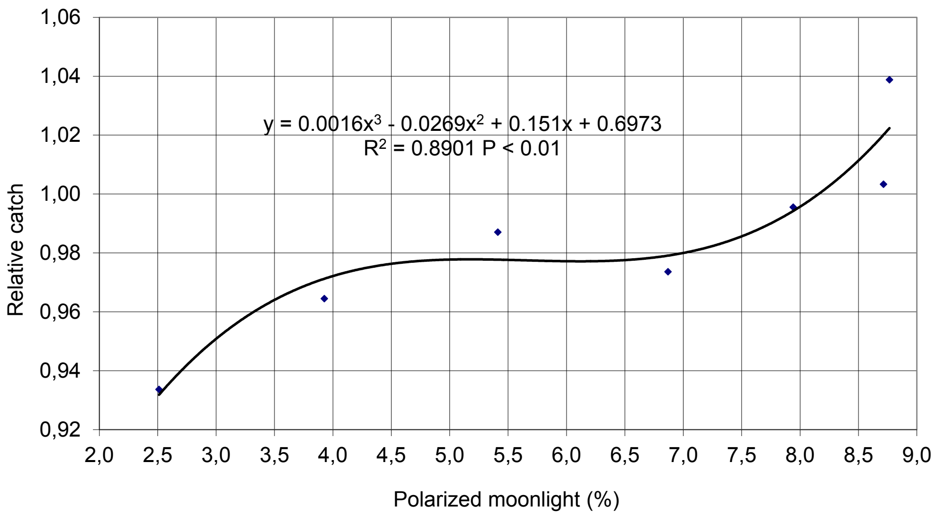


Figure 7. 4. 2.

Figure 2. Pheromone trap catch of the Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius) in connection with the polarized moonlight (Last Quarter)

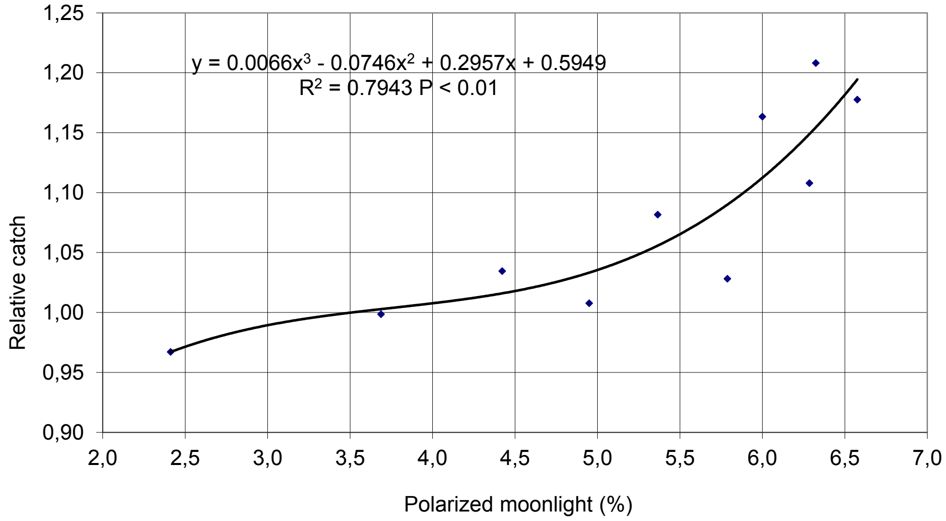


Figure 7. 4. 3.

Figure 3. Pheromone trap catch of Red Midget Moth (*Phyllonorycter corylifoliella* Hübner) in connection with polarized moonlight (First Quarter)

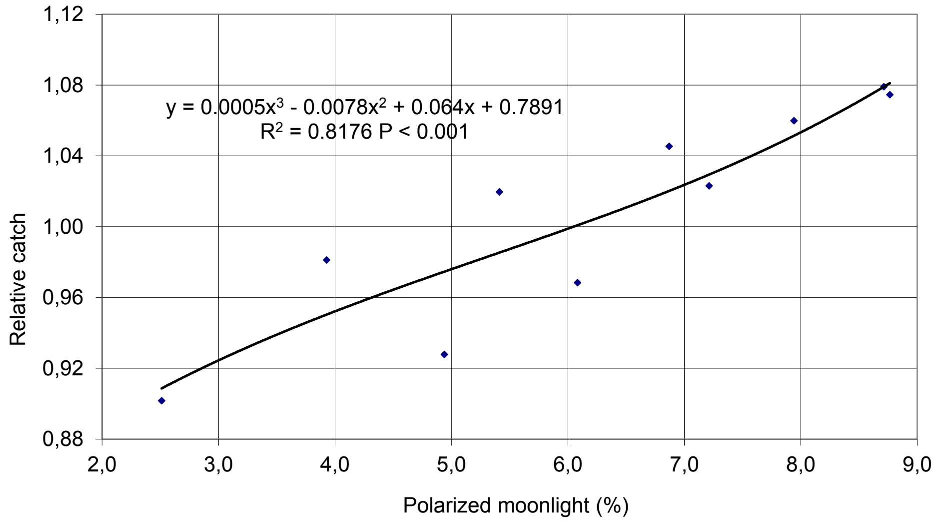


Figure 7. 4. 4.

Figure 4. Pheromone trap catch of Red Midget Moth (*Phyllonorycter corylifoliella* Hübner) in connection with polarized moonlight (Last Quarter)

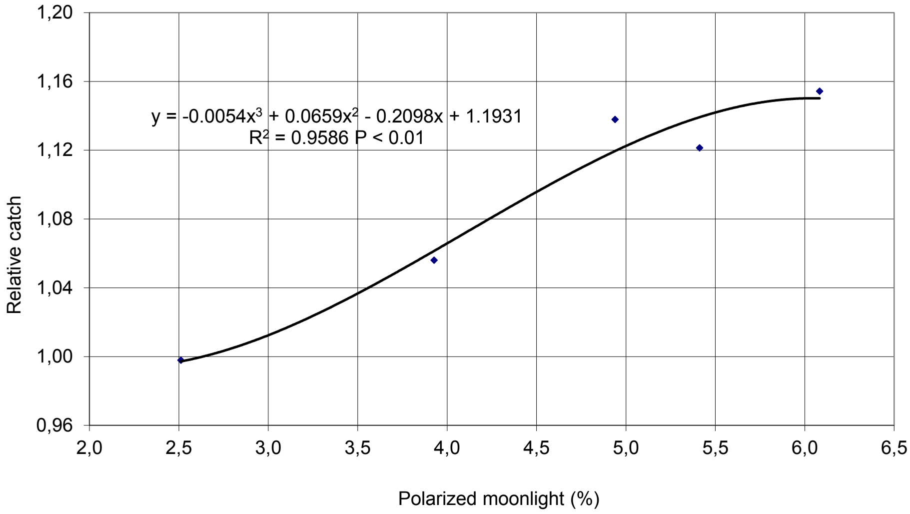


Figure 7. 4. 5.

Figure 5. Pheromone trap catch of the Peach Twig Borer (*Anarsia lineatella* Zeller) in connection with the polarized moonlight (Last Quarter)

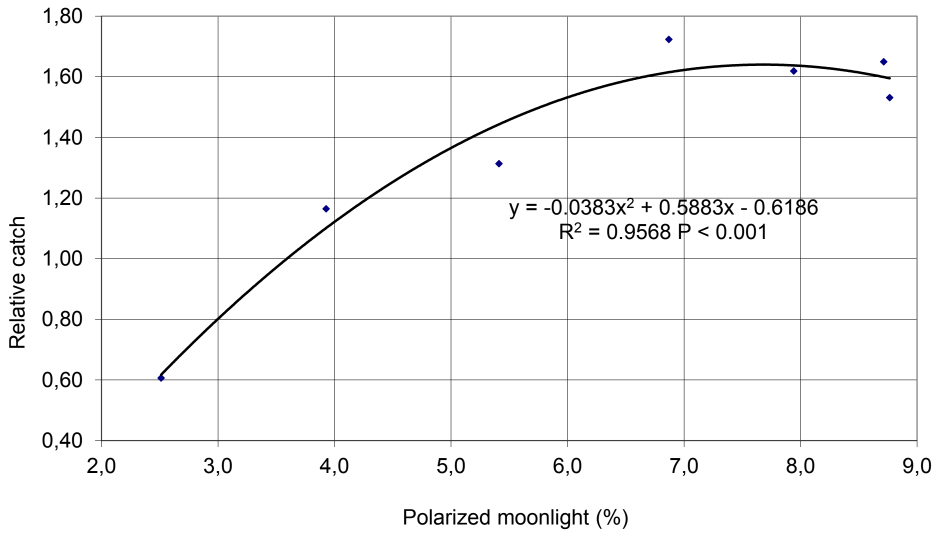


Figure 7. 4. 6.

Figure 6. Pheromone trap catch of the Vine Moth (*Eupoecilia ambiguella* Hübner) in connection with the polarized moonlight (Last Quarter)

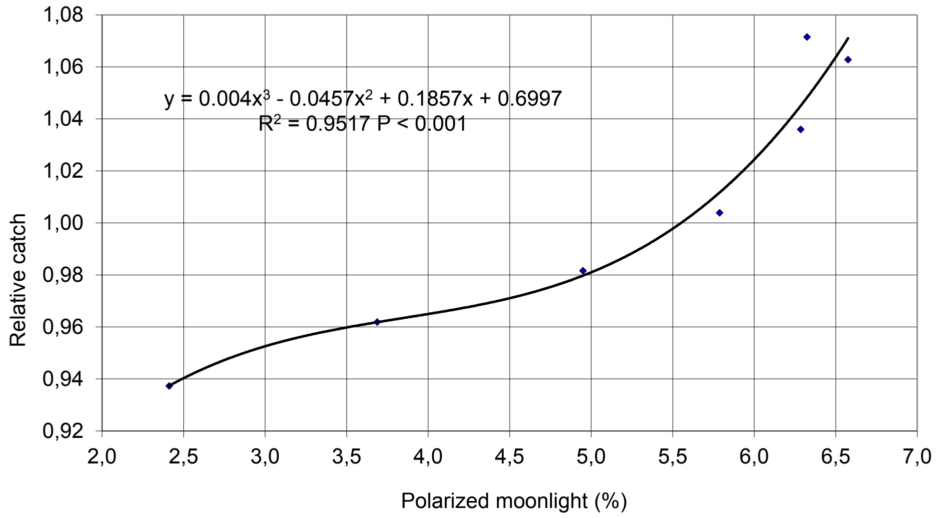


Figure 7. 4. 7.

Figure 7. Pheromone trap catch of European Vine Moth (*Lobesia botrana* Denis et Schiffermüller) in connection with polarized moonlight (First Quarter)

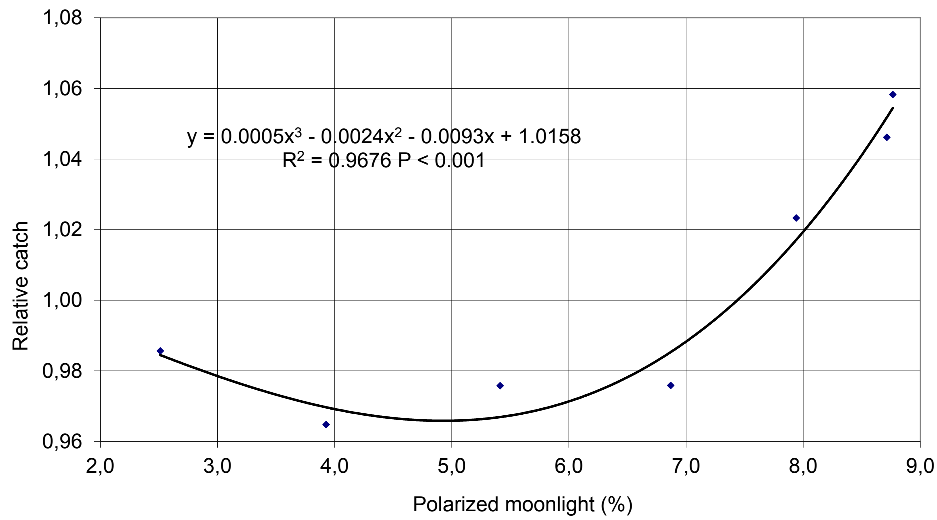


Figure 7. 4. 8.

Figure 8. Pheromone trap catch of the Plum Fruit Moth (*Grapholita funebrana* Treitschke) in connection with the polarized moonlight (Last Quarter)

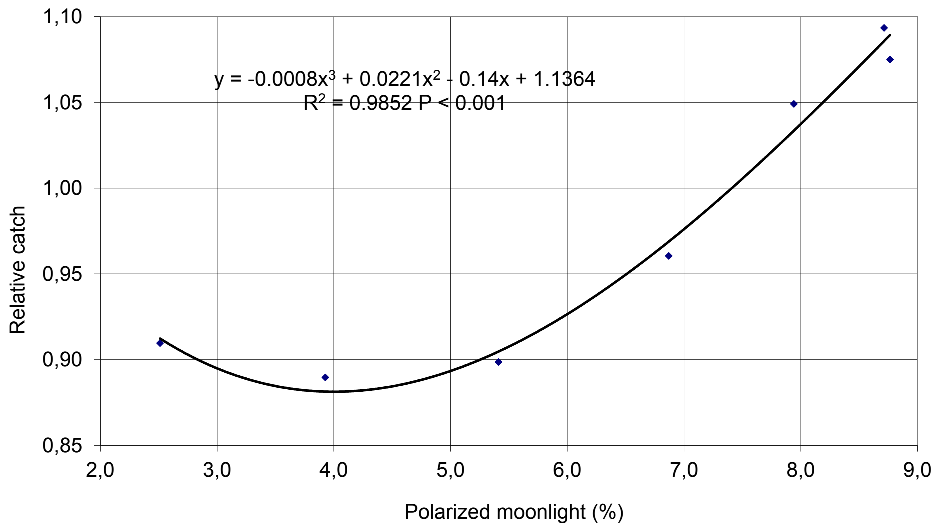


Figure 7. 4. 9.

Figure 9. Pheromone trap catch the Oriental Fruit Moth (*Grapholita molesta* Busck) in connection with the polarized moonlight (Last Quarter)

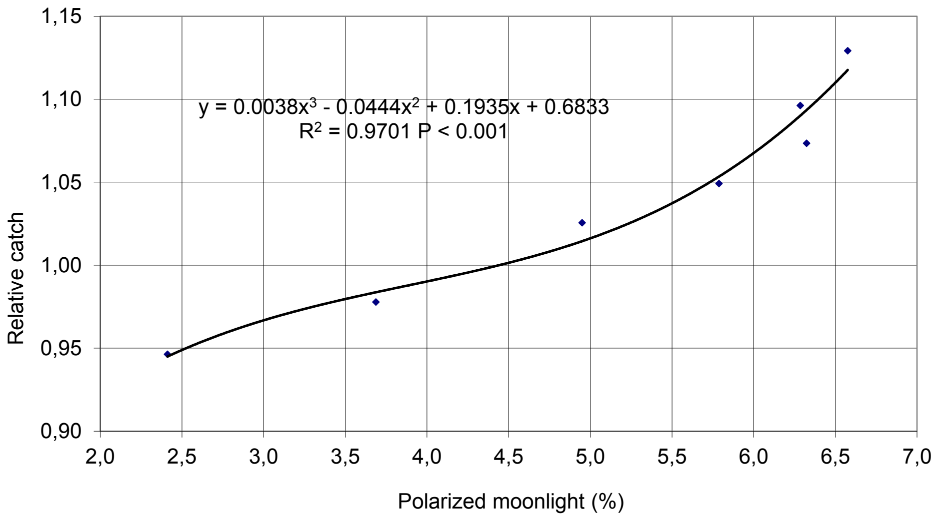


Figure 7. 4. 10.

Figure 10. Pheromone trap catch of the Codling Moth (*Cydia pomonella* Linnaeus) in connection with the polarized moonlight (First Quarter)

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Chapter 8.

Pheromone Trap Catch of Harmful Microlepidoptera Species in Connection with the Péczely–Type Macrosynoptic Weather Situations

J. Puskás[1], G. Barczikay[2], Cs. Károssy[1], L. Nowinszky[1]

[1]University of West Hungary, Savaria University Centre,
9700 Szombathely Károlyi G. Square 4.
E-mail: pjanos@gmail.com, c.karossy@gmail.com, lnowinszky@gmail.com
[2]County Borsod-Abaúj-Zemplén
Agricultural Office of Plant Protection and Soil Conservation Directorate,
H-3917 Bodrogkisfalud, Vasút Street 22.

Abstract: The pheromone trapping success of the examined 8 harmful Microlepidoptera species connected with of Péczely-type macrosynoptic weather situation was examined in our present paper using the collecting data of Csalomon type pheromone traps operating in nine villages in Borsod-Abaúj-Zemplén County Hungary between 1982 and 2013. The value of relative catch (RC) was calculated for each observing stations and generations using the catching data. There was made a comparison between the relative catch values and the Péczely-type macrosynoptic weather situations belonging to the date. After it the relative catch values were averaged in all the 13 macrosynoptic situations. We compared the difference of the averaged relative catch value of each case with the averaged ones of the sum of all other cases. The significance levels were calculated by t-test. We can conclude from our results, the Péczely-type macrosynoptic weather situations influenced the pheromone trap catch of examined individuals of species. This effect causes an increase or decrease in various species. However, most of the Péczely-type situations will not cause any change in the catching of a certain species.

Keywords: Microlepidoptera, pheromone trap, Péczely-type, Hungary.

8. 1. Introduction

Weather is one of the many abiotic factors modifying the flight activity of insects and consequently also the effectiveness of collecting by pheromone trap or pheromone ones. Unfortunately, however, the overwhelming mass of the catch results supplied by the pheromone trap network cannot be examined in its relationship with the various weather constituents. This is because most posts of observation, especially in the first decades, fell far from meteorological stations, and the operators of pheromone traps and pheromone ones did not carry out any meteorological measuring in the vicinity. Unfortunately, we no measurement weather elements between 1993 and 2003 in the garden, where we worked our pheromone traps. We measured only but the minimum and maximum temperatures between 2004 and 2013.

The daily macrosynoptic weather situations which were determined on the basis of the baric field at ground level Therefore we have examined the relationship between the weather and the effectiveness of collecting by pheromone trap in the context of the Péczely-type macrosynoptic weather situations which express complex simultaneously existing weather conditions interpreted for the whole of the Carpathian Basin. The system was worked out by Péczely (1957 and 1983) who identified and characterized 13 types of daily macrosynoptic weather situations for the Carpathian Basin taking into account the surface baric field (Péczely, 1961). Since 1983, typifying has been continued and Károssy (1987, 1994, 1997 and 2001) has published the daily code numbers. The interpretation period for each type is the 24 hours of each calendar day. The only criterion for coding is the definition of the type prevailing for a longer period in the course of a day, so the switch-over from one type to the other may precede or lag behind by as much as ± 12 hours the time of the change of the calendar date. The progression of the changes in time, the tendency of the various types to last and the empirical frequency of successive situations show significant differences. Following Péczely's work of typifying macrosynoptic weather situations (1957 and 1983), his associates elaborated on the individual weather situations with regard to some weather elements by use of a detailed climatic database. Subsequently, with the continuity of typifying ensured, certain combinations of elements were also examined in the context of macrosynoptic situations. In recent years, the examination of the connection between the flight activity of harmful insects and the prevailing macrosynoptic weather situation has become an important, in fact decisive part of the above line of research. In this, we first examined pheromone trap effectiveness in connection with the macrosynoptic weather situations prevailing at the trapping time of harmful insects flying at dusk or in the first half of the night.

Insect flight activity, and similarly, the effectiveness of their pheromone trap collection, is considerably modified by weather, together with a number of abiotic factors. Unfortunately, a decisive majority of the catch results provided by the pheromone trap network cannot be examined in connection with the particular weather elements, as most observation sights are situated far from meteorological stations, and those operating the traps did not take any meteorological measurements. Therefore, we revealed the connection between weather and effectiveness of collecting with a pheromone trap using a different method. For the purposes of our investigations we found those Péczely's macrosynoptic weather situations to be suitable which express complex weather conditions simultaneously existing and pertaining to the whole area of the Carpathian Basin.

In the last few years the examination of the connection between the flight activity of harmful insects and the various macrosynoptic weather situations has become an important and determining trend in the above mentioned research. During this research we examined the effectiveness of trapping in connection with the macrosynoptic weather situations pertaining to the trapping time of harmful insects flying at dawn or in the first part of night.

We precede to our investigation the Winter Moth (*Operophtera brumata* L.) the flies late in the autumn (Nowinszky and Károssy, 1986).

In subsequent years, pheromone trap catch of several other species were examined in connection with Péczely-type weather situations: Károssy (1987), Károssy and Nowinszky (1987a, 1987b), Károssy et al., 1990, 1992, 1996), Nowinszky and Károssy (1988), Nowinszky et al. (1995), Puskás et al. (1996).

8. 2. Material

Between 1982 and 1990 pheromone traps were operating in Borsod-Abaúj-Zemplén County (Hungary-Europe) at 9 villages (Table 8. 2. 1.)

Table 8. 2. 1. The pheromone traps were operated in Borsod-Abaúj-Zemplén County

Villages	Years	Longitude	Latitude
Bodrogkisfalud	1982–1983, 1993–2013	48°10'41″	21°21'77″
Bodrogkeresztúr	1988	48°09'54″	21°21'64″
Bodrogszegi	1982–1983	48°26'82″	21°35'61″
Erdőbénye	1987–1988	48°15'91″	21°21'18″
Erdőbénye-Meszesmajor	1988	48°11'43″	21°22'46″
Mád	1987–1988	48°11'55″	21°16'70″
Sátoraljaújhely	1988	48°23'80″	21°39'34″
Tolcsva	1988	48°17'05″	21°27'02″
Tokaj	1990	48°06'75″	21°24'75″

An additional one trap operated between 1993 and 2012 at Bodrogkisfalud. These traps attracted 8 Microlepidoptera species altogether, in some of the years using 2-2 pheromone traps for each species, however, in other years not all 8 species were monitored. The traps were operated through every day during the season from April until October. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hübner, 1796), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), Vine Moth (*Eupoecilia ambiguella* Hübner, 1796), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758).

Catch data of the collected species is displayed in Table 8. 2. 2. We examined the trapping data of these species depending on the moon phases.

The daily data of the Péczely-type of macrosynoptic weather conditions we used up from the personal catalogues and personal communications of Károssy.

Characterization of the Péczely's macrosynoptic weather situations (Károssy, 2001) can be seen in the Appendix.

Table 8. 2. 2. The number and observing data of the examined species

Species	Years	Number of	
		Moths	Data
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	1993-2013	95,610	4,023
Gracillariidae »Lithocolletinae Hawthorn Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	2008-2013	10,202	1,712
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	1993-2013	14,648	3,552
Tortricidae » Tortricinae Vine Moth *Eupoecilia ambiguella* Hübner, 1796	1982-83, 1990, 1987-1988 2000, 2002	2,266	507
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	1982–83, 1987–88, 1990, 1993–2013	30,270	3,964
Tortricidae » Olethreutinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	1982-83 1985 1993-2013	53,386	5,324
Tortricidae » Olethreutinae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	1988, 1993-2013	26,867	4,375
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	1982-1983, 1985, 1988 1993-2013	16,077	3,841

8. 3. Methods

We have calculated the relative catch values of the number of specimens trapped by species and broods. Relative catch (RC) is the ratio of the number of specimen caught in a given sample unit of time (1 hour or 1 night) and the average number of specimen caught in the same time unit calculated for the whole brood. If the number of the specimen trapped equals the average, the value of relative catch is: 1. (Nowinszky, 2003 and 2008).

We have sorted relative catch values into the proper Péczely-type macrosynoptic weather situation. We have arranged data regarding macrosynoptic situations together with the relating relative catch values into classes.

There was made a comparison between the relative catch values and the Péczely-type code number belonging to the date. After it the relative catch values were averaged in all the 13 macrosynoptic situations. We compared the difference of the relative catch value of each case with the averaged ones of the sum of all other cases. The significance levels were calculated by t-test. The results are plotted.

8. 4. Results and Discussion

The relative catch values of examined species in connected with of Péczely-type macrosynoptic weather situations are shown in Table 8. 4. 1.

Table 8. 4. 1. Pheromone trap catch of the harmful Microlepidoptera species in connection with the Péczely-type macrosynoptic weather situations

	Ph. blancardella Fabr.	*Ph. coryljfoliella* Hbn.	*A. lineatella* Zeller	*E. ambiguella* Hbn.	*L. botrana* Den. et Schiff.	*G. funebrana* Tr.	*G. molesta* Busck	*C. pomonella* L.
1 mCc			1.091**					
2 AB	0.827**	0.773*						
3 CMc					0.679			
4 mCw						0.877	0.779**	1.212
5 Ae		1.119					1.196**	1.119
6 CMw	0.661**	0.673**						
7 zC								
8 Aw	1.092*							
9 As	1.151							
10 An							0.917	
11 AF				1.477				
12 A	1.085*	1.215**	0.904					
13 C			0.806	0.426				0.843

Notes: Significance levels are: normal = P < 0.05, * = P < 0.01, ** = P < 0.001

High and law catching results also belong to changing weather situations. After examining these situations we cannot declare clear regularity.

We think the practical importance is very small, because it is very infrequent. We can conclude from our results, the significant changing of weather increases the flight activity of examined individuals of species. This fact does not mean favourable weather conditions for the flying of insects. The low values of relative catch mean those weather situations in all cases, when the flight activity of insects decreased, but the meaning of high values are not so equivalent. The significant environmental changes cause physiological changes in the organism of insects. The life of imago is short the unfavourable weather endangers not only the continuance of individual but also the continuance of the total species. According to our supposition the individuals can use two kinds of strategies to prevent the hindering influences of normal function in phenomenon of life. First is the increased activity. It means the growing of intensity in flying, copulation and oviposition. The second strategy is to hide and ride out in passivity the unfavourable situation. Seeing the above-mentioned facts, according to our present knowledge high pheromone trapping results can belong to both favourable and unfavourable situations.

Seeing that the Péczely's macrosynoptic situations are valid simultaneously in the whole Carpathian Basin, our results can be utilized not only in Hungary, but also in one part of territory in neighbouring countries for the purpose of making plant protecting prognosis. We can declare is spite of that case we cannot give the correct explanation of high or law catching results in all the changing situations according to our knowledge.

Further agrometeorological researches are necessary to find how can be modified the insect's comfort feeling and flight activity by different type changing situations.

Using the Péczely's macrosynoptic weather situations offers a possibility for investigating the insect's life-phenomena in connection with weather also in those cases where the measuring of certain elements for some reasons comes up against difficulties.

The collecting data of the national pheromone trap network, which is invaluable for science, has also become employable to insect ecological and ethological investigations. On the basis of our work it is also proved that Péczely's macrosynoptic situations are reliable not only from the point of view of climatologically typification, but also with regard to agrometeorological research. We think it essential to elaborate a similar typification for other geographical regions, and other harmful species of insects.

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Appendix

Meridional, northerly oriented situations

mCc (1) Cold front from the meridional situations
A situation is with meridional direction and northern stream. Hungary belongs to the rear cold front current system of the cyclone, which stays east or north-east of it, over the Balticum or the Ukraine. This situation causes changeable, windy and wet weather in the Carpathian Basin. In summer a version without a cold front may also arise, when a termic depression effect from South-West Asia spreads over South-East Europe. In summer, this situation is favourable for forming local showers, thunderstorms, in winter snowstorms are frequent. In summer the temperature is above average, in winter it is below average, in spring the deviation is not significant. Cloudiness surpasses the average level, visibility is good, and in winter the tendency for fog is smaller. Air pollution is usually insignificant. Typically, the northerly and the north-westerly winds are strong while the westerly and south-westerly winds are strong beyond the Tisza River. There is more precipitation in the eastern half of the country. Atmospheric temperature layers are stabile, the lower layers are warmer. The daily temperature fluctuation is small and aperiodic.

AB (2) Anticyclone over the British Isles
This is a meridionally directed situation with northerly current. Partly because of the Azores cyclone moving to the north, partly because of the anticyclones moving from the arctic basins to the south, high-pressure air masses develop over the British Isles or the North Sea. Its appearance in the Carpathian Basin is usually connected to the passing of a cold front, and results in intensive north-, north-westerly air currents in our region. When the above situation stabilises in summer, the baric gradient is a lot lower over Central Europe; on such occasions, dry, prolonged warm weather evolves in the Carpathian Basin. It is a misty situation in autumn, winter and spring as well. During the greater part of the year it is characterised by colder air masses of arctic origin and average cloudiness, with higher degrees of cloudiness in summer. There is a strong tendency for fog in winter. There is a north-westerly, westerly wind; over the Tisza River it is westerly, south-westerly, and relatively strong. The temperature stratification of the air is stabile.

CMc (3) Cold front arising from a Mediterranean cyclone
A situation is with meridional direction and northern current. It is the current-system of the back-side of the cyclone. The situation emerges by way of a Mediterranean cyclone moving towards the Balkan Peninsula or the region of the Black Sea, so the Carpathian Basin falls in the rear, cold front current system of the cyclone. The movement of air is in a northern, north-west direction. Its speed, mainly in the Transdanubia, may even reach storm intensity. Especially in summer, precipitation may increase, in different amounts at various locations. Snow

showers are frequent in winter, storms in spring. Cloudiness is definitely extensive, especially in the summer half of the year. Air pollution is low; the tendency for fog is also low in winter. The temperature is lower in spring and autumn and higher in winter than on the days preceding this weather situation. The daily fluctuation of the temperature is aperiodic.

Meridional situations with a southern direction

mCw (4) Warm front arising from a meridional cyclone
This is a situation of meridional direction, with flow toward the south; it is the frontal current system of the cyclone. The current over the Carpathian Basin is directed by a cyclone with its centre either in the region of North-Western Europe or in Western Europe. Hungary's territory is under the effect of the cyclone's warm front, or falls into its warm sector. In autumn it is cooler, in winter and spring milder than the average temperature of the given season. Cloudiness is more extensive, mainly in spring and autumn. Prolonged, slow rains and snowfalls are equally frequent from autumn to spring. Visibility is bad; the frequency of fog is high in winter. In summer it is characterised by sultriness and high degree of air pollution. The southern air current brings considerable precipitation, especially in the winter half of the year.

Ae (5) Anticyclone located east of the Carpathian Basin
This is a meridional situation with southern current. A dry, southerly, or south-westerly air current dominates in an anticyclone located east of Hungary with its centre over the Ukraine. The weather fronts range west of the Carpathian Basin. This situation is characterised by dry, warm, bright weather in summer, and in winter, after snowy days by bitter cold, frequent rime and fog. In autumn and spring, temperature fluctuation is large with a strong rise in temperature. In the cold season the range of the Eastern Carpathians often modifies the direction of the isobars, and in this way the cold, surface level air masses invade the territory of the country passing round the Southern Carpathians (Kossava effect). It is characterised by a temperature surpassing the average prevalent during the greater part of the year. Cloudiness, mainly in summer, is smaller and dry, droughty weather is frequent at this time. In accordance with the weak, southerly current, the amount of precipitation is small, visibility is bad, and air pollution is considerable. The air shows inverse temperature stratification.

CMw (6) Warm front arising from a Mediterranean cyclone
This situation has a meridional direction and southerly current. The cyclone's frontal system of current asserts itself in Hungary. The system is defined by a cyclone which arises over the central part of the Mediterranean Sea and moves toward the Adriatic region. It’s warm front passes over the Carpathian Basin causing substantial rains in the winter and spring months, as well as snowfalls in winter. In summer its temperature is lower than the national average temperature. Visibility

is low, cloudiness strong, and the fluctuation of the temperature is aperiodic.

Zonal situations with western direction

zC (7) Zonal cyclone
There is a zonal, westerly flow. While it prevails the European stretch of the frontal zone ranges near the 50° latitude. The air flow is westerly. Northern Europe is affected by fast moving cyclones. The weather is windy and changeable. The temperature, characteristically, is cool in autumn, mild in winter, and in summer it is colder than the average for that season. In spring the fluctuation in temperature is low. Cloudiness is strong, especially in the spring and autumn months. The yield of precipitation is larger at the beginning of autumn and in winter. The lower air strata are warmer. Colder, arctic air strata flow in the higher layers.

Aw (8) Anticyclone located west of the Carpathian Basin
It has zonal current with a western direction. When the Azores cyclone travels north (mainly in summer), its protrusion advances as far as the Central-European region. Its formation usually takes place in connection with a cold front which passes through and results in an intense westerly or north-westerly current in the Carpathian Basin. It is characterised by pleasant, warm and bright weather which however, is misty in autumn and spring, and mild, misty and foggy in winter. In winter it is colder than the temperature typical for that season. Its cloudiness is average, yet it is overcast in summer. Visibility is good, air pollution is low. The lower stratum of air is usually warmer than the one over it, in which there is a cold air current.

As (9) Anticyclone located south of the Carpathian Basin
This situation has a zonal, western current. The northern fringe of the anticyclone situated over the basin of the Mediterranean Sea protrudes into the Carpathian Basin. The northern edge of the frontal zone moves upward, so the cyclone moves along a more northern trajectory, and their frontal system does not effect Hungary. During the greater part of the year this situation-type is warmer than the average and is characterised by a lower degree of cloudiness. In winter, autumn and spring the bright, warm days are followed by mild nights. In winter cloudiness is somewhat stronger, and the frequency of fog is higher. In summer it brings about sultry weather. The air flow is weak, and precipitation is low. The lower stratum of air is colder than the upper; however the opposite may also occur.

Zonal situation eastern direction

An (10) Anticyclone located north of the Carpathian Basin
This situation has an eastern, zonal current. The anticyclone stays north of Hungary over the Baltic or Poland, and forms a high-pressure ridge from the British Isles as far as Eastern Europe. In summer it is warmer than the temperature typical for that season. It causes a strong fall in temperature in autumn and in spring,

but after the cold night a rise in temperature follows about midday. It is characterised by clean air and northern winds. In winter it is connected with the invasion of very cold air masses. On such occasions it is easy to observe how the Carpathian ranges modify the movement of ground level cold air masses and their passage through mountain passes. Many times characteristic, embracing isobars develop along the Carpathians, and the cold invasion from either side sometimes may result in and occlusion front inside the Basin. The weather is windy and foggy even in winter with average cloudiness, and a sky which is a bit more overcast in the spring and autumn months. Sometimes air pollution is high. The air-flow is typically of north-eastern direction. The stratification of air characterised by warmer lower and colder higher strata.

AF (11) Anticyclone located over the Scandinavian Peninsula
This situation has a zonal eastern air-flow. The characteristic orientation of the longitudinal axis of the anticyclone which stays in the Fenno-Scandinavian region has a north-easterly direction. This weather situation brings about a northern or north-eastern flow in Hungary. During its existence, the weather, especially in autumn, winter and spring is bright and clear, but the air is very cold. It is characterised by northerly winds, wide fluctuation in temperature, average cloudiness, and little precipitation. The Icemen (the three chilly days in May) are usually connected to this macrosynoptic type.

Central anticyclone

A (12) Anticyclone located over the Carpathian Basin
The whole region of Central Europe is dominated by a centrally situated anticyclone which rises above the Carpathian Basin. It can be of smaller size, even just a few hundred kilometres in diameter, but it can also be a so called intermediate anticyclone, which moves fast separating other cyclone systems. In most cases, however, it remains for a longer period over the Carpathian Basin. Its duration gets prolonged in winter by a cold air-cushion stuck on the bottom of the Basin (inversion). Its prolonged existence ensures undisturbed radiation weather. In winter it is accompanied by a strong fall in the temperature, and considerable inversions of temperature, and in summer by a great rise in temperature, heat waves and thunderstorms. One frequent feature is an air-flow in diverse directions which originates from the centre. During the greater part of the year it can be characterised by a temperature of radiation effect - i. e. warm during the day and in summer, cold during the night and in winter. The weather is warm and pleasant either in spring or in autumn, while it is foggy, frosty and rimes in winter. Temperature fluctuation is great. Cloudiness is slight. It is a bit more overcast in winter and brighter in summer. Precipitation is small, showing large regional variability. Visibility is bad. There is a high frequency of fog, and air pollution may be strong. The air is usually dry. The wind has no uniform or characteristic direction.

Central cyclone

C (13) Cyclone located above the Carpathian Basin
The centre of the cyclone is located over the Carpathian Basin. It is in a great majority of cases, Mediterranean cyclones which pass over Hungary from this type. There may, however, be cases when a cyclone develops having local, orographic causes along a front that has grown stagnant. A sharp contrast in temperature evolves in Hungary. The north-western parts of the country fall in the rear flow system of the cyclone, so the temperature there is much lower than in the eastern part of the country, which fall into the frontal flow system. In the western, north-western and south-western regions of the country, because of what was said above, the frequency of fronts is higher than in the rest of the country. When this type is present, in winter the temperature is higher, in summer it is lower than during the preceding days. In autumn this type is characterised by cold, windy, overcast and rainy weather and in winter by stormy weather. In spring it is characterised by rainy weather. In all three seasons temperature fluctuation is small. Cloudiness is greater in summer, smaller in winter. Visibility is bad, and air pollution is low. A strong field of flow is characteristic, although its direction is not homogeneous. Precipitation is markedly large.

Chapter 9.

Pheromone Trap Catch of the Harmful Microlepidoptera Species in Connection with the Puskás–Type Weather Fronts

J. Puskás[1], L. Nowinszky[1], G. Barczikay[2]

[1]University of West Hungary Savaria University Centre, 9700 Szombathely, Károlyi G. Square 4., Hungary; E-mail: pjanos@gmail.com; lnowinszky@gmail.com
[2]County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, 3917 Bodrogkisfalud, Vasút Street 22., Hungary

Abstract: In this study nine new weather front types were determined from the "Daily Weather Reports" valid for the Carpathian Basin. These nine weather front types were successfully used in examinations of catch data of pheromone trap catch of eight harmful Microlepidoptera species. The Csalomon type pheromone traps were operation in Bodrogkisfalud, (Borsod-Abaúj-Zemplén County, Hungary, between 1993 and 2013.We calculated relative catch values from the total number of caught moths. We assigned the daily relative catch values for every species to the daily front types. Catches could be either successful or not according to the weather front types. Our examinations proved that the weather fronts influence the pattern of pheromone trap catch.

Key words: pheromone trap, Puskás-type weather fronts, Microlepidoptera

9. 1. Introduction

Frontal passages result in a sudden and essential transformation of the physical environment of living creatures. A simultaneous change of all the weather factors triggers off a reaction of front sensitivity symptoms in animals and human beings. As against the width and depth of comprehensive medico-meteorological research, there are remarkably few researchers to have examined the behaviour of insects and their flight activity in connection with the various types of fronts. Of Hungarian researchers, Wéber (1959) dealt with the influence of weather fronts on collecting insects by light-trap. In his view, research on the influence of frontal changes is hampered by numerous factors (fronts may follow one another in alone or two, fronts can pass through without any air mass change, the same type of front does not always have the same intensity, etc.). For this reason, in the course of his investigation, he did not make an attempt to define general regularities, instead, by analysing some concrete, typical cases, he demonstrated with a graphical method the influence of weather fronts on collecting. In consequence of the above difficulties, Járfás (1979) advised research on the influence of the different weather factors instead of the weather fronts. Kádár and Szentkirályi (1991), in their turn, showed that the light trapping efficiency of ground beetles (Coleoptera, Carabidae) diminishes on the days of the arrival of cold fronts but increases when warm fronts arrive. For their examinations they used the front and air mass calendar of the Hungarian Meteorological Service which distinguishes only between the above two fronts. Helson and Penman (1970) appraised the results of their light trapping in New Zealand in connection with cold fronts. Shortly before the arrival of the front, they experienced an ion activity peak. Yet, we have not found any studies of basic importance dealing with the relationship between fronts and light trapping in international scientific literature.

Weather fronts can be categorized according to a number of viewpoints. Berkes (1961) determined 21 types of fronts for the territory of Hungary and characterized them. However, their validity does not apply to the whole country.

In our previous work (Nowinszky et al., 1997), we applied this classification successfully in our assessment of the light trap catch results of the Heart and Dart Moth *(Agrotis exclamationis* L.).

Based on the weather features published in the "Daily Weather Reports", Puskás has developed a new, individual classification to be used in our studies. This classification was published recently (Puskás, 2001) in the form of a catalogue. Several scientists employed this classification in their studies on the activity of insects (Puskás, 1998, 1999, Kúti 2001) and birds (Gyurácz and Puskás, 1996a, 1996b, Puskás and Gyurácz, 1998). In connection with the front types worked out by Puskás (2001), Kúti (2002a, 2002b) has recently studied the light trapping efficiency of Macrolepidoptera, Microlepidoptera, Coleoptera and Heteroptera species. By an approaching cold front, he observed a decline in the case of all 4 orders, also by a staying cold front in the case of Coleoptera and Heteroptera, by an approaching warm front in the case of Macrolepidoptera and Microlepidoptera species. The number of specimens trapped increased in the case of all four orders at the time of simultaneously stay-ing cold and warm fronts.

However, in a previous article we had already investigated the pheromone trap catches of the Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius) in conjunction with Puskás-type weather fronts (Puskás et al. 2011).

Table 9. 2. 1. The pheromone traps were operated in Borsod-Abaúj-Zemplén County

Villages	Years	Longitude	Latitude
Bodrogkisfalud	1982–1983, 1993–2013	48°10'41″	21°21'77″
Bodrogkeresztúr	1988	48°09'54″	21°21'64″
Bodrogszegi	1982–1983	48°26'82″	21°35'61″
Erdőbénye	1987–1988	48°15'91″	21°21'18″
Erdőbénye-Meszesmajor	1988	48°11'43″	21°22'46″
Mád	1987–1988	48°11'55″	21°16'70″
Sátoraljaújhely	1988	48°23'80″	21°39'34″
Tolcsva	1988	48°17'05″	21°27'02″
Tokaj	1990	48°06'75″	21°24'75″

9. 2. Material

Between 1993 and 2013, pheromone traps were running in Bodrogkisfalud (Borsod-Abaúj-Zemplén County, Hungary) (Table 9. 2. 1.). These traps caught 8 Microlepidoptera species.

Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth *(Phyllonorycter corylifoliella* Hübner, 1796), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), Vine Moth (*Eupoecilia ambiguella* Hübner, 1796), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). Number of individuals and observing data can be seen in Table 9. 2. 2.

Observing data means the catching of one trap in one night, regard-less of the number of insects caught. But there were years in which each species were collected in two traps.

We worked out new weather front types (Puskás 2001) from the "Daily Weather Reports". This information was the basis of the analysis of meteorological events in Europe and Hungary. The synoptic maps were also used in the categorization process.

9. 3. Methods

The location of warm-, cold- and occluded fronts were determined for each day of the period 1st January 1982 - 31st December 2013, but we used the data of each year between 1st April and 31st October. We classified the fronts on the basis of their quality and location relating to the territory of Hungary. Arriving front means that the front comes close to the border or just enters the territory of Hun-

Table 9. 2. 2. The number and observing data of the examined species`

Species	*Years*	*Number of*	
		Moths	*Data*
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	1993-2013	95,610	4,023
Gracillariidae »Lithocolletinae Hawthorn Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	2008-2013	10,202	1,712
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	1993-2013	14,648	3,552
Tortricidae » Tortricinae Vine Moth *Eupoecilia ambiguella* Hübner, 1796	1982-83, 1990, 1987-1988 2000, 2002	2,266	507
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	1982–83, 1987– 88, 1990, 1993–2013	30,270	3,964
Tortricidae » Olethreutinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	1982-83 1985 1993-2013	53,386	5,324
Tortricidae » Olethreutinae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	1988, 1993-2013	26,867	4,375
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	1982-1983, 1985, 1988 1993-2013	16,077	3,841

gary. The benefit of using these front types is that a lower level of meteorological knowledge is sufficient to appreciate the determination of different types. These types are: 1 arriving cold front (aC), 2 cold front (C), 3 arriving warm front (aW), 4 warm front (W), 5 arriving occluded front (aO), 6 occluded front (O), 7 arriving warm and cold front (aWC), 8 warm and cold fronts (WC), 9 warm-, cold- and occluded fronts (WCO).

Relative catch values were calculated from the number of caught moths. The relative catch (RC) is the quotient of the number of individual moth trapped in one unit of sampling.

If the number of the specimen trapped equals the average, the value of relative catch is 1. In our study this equated to one night, and the average number of specimen of a generation in a time unit of sampling. We assigned the daily relative catch values for every species to the daily front types. This process was also adopted on those days when no front was detected. The values were summarized and the averages together with the levels of significance were calculated. We calculated the regression equations and the differences in all cases the level of significance.

9. 4. Results and Discussion

Results are shown in Table 9. 4. 1.
We found significant high or low catch in different weather fronts. We found that the majority of fronts due to a decrease in catches. An exception is only the arriving warm front (aW), which resulted in increase in catches of two species. Quite exceptional is the Vine Moth (*Eupoecilia ambiguella* Hbn.) because the warm front (W) caused a strong increase in catch of this species. The warm front is effective only for this species.

A cold front can hardly be a favourable weather situation for a moth whose intensified flight activity at the time of such a front can be explained with a hypothesis we described in detail in an earlier work (Nowinszky et al., 1997). In brief: low relative catch values always refer to weather situations in which the flight activity of insects diminishes. However, high values are not so clear to interpret. Major environmental changes bring about physiological transformation in the insect organism. The imago is short-lived; therefore unfavourable weather endangers the survival of not just the individual, but the species as a whole. In our hypothesis, the individual may adopt two kinds of strategies to evade the impacts hindering the normal functioning of its life phenomena. It may either display more liveliness, by in-creasing the intensity of its flight, copulation and egg-laying activity or take refuge in passivity to weather an unfavourable situation. And so by the present state of our knowledge we might say that favourable and unfavourable weather situations might equally be accompa-nied by a high catch.

Table 9. 4. 1. Pheromone trap catch of harmful Microlepidoptera species in connection with the Puskás-type weather fronts

Species	1 aC	3 aW	4 W	6 O	7 aWC	9 WCO
Ph. blancardella Fabr.			0.804*	0.771*	0.856**	
Ph. corylifoliella Hbn.		0.695	0.749*	0.705		
A. lineatella Zeller				0.735		
E. ambiguella Hbn.			3.621**			
L. botrana Den. et Schiff.						
G. funebrana Tr.	1.148	0.863*	0.747**	0.629**		0.759*
G. molesta Busck	1.126		0.792	0.744*		
C. pomonella L.		0.722*		0.780		

Notes: Significance levels are: normal = P < 0.05, * = P < 0.01, ** = P < 0.001
The table includes only those fronts, which includes significant data on catches.

We have no full knowledge of the favourable and unfavourable effects of weather on insects during the stay and especially consecutive passage of different fronts. However, the frequency of weather fronts justifies the need for further examination to yield results to be used in everyday practice as soon as possible.

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Chapter 10.

Influence of Daily Temperature on the Pheromone Trap Catch of Harmful Microlepidoptera Species

J. Puskás[1], L. Nowinszky[1], G. Barczikay[2]

[1]University of West Hungary Savaria University Centre H-9700 Szombathely, Károlyi Gáspár Square 4. Hungary Europe
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2]County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, H-3917 Bodrogkisfalud, Vasút Street 22. Hungary Europe

Abstract: Seven species of pheromone trap collection of Microlepidoptera pest presents the results of the everyday function of the daily temperature range in the study. Between 2004 and 2012 Csalomon type pheromone traps were operating in Bodrogkisfalud (48°10'N; 21°21'E; Borsod-Abaúj-Zemplén County, Hungary, Europe). The data were processed of following species: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hübner, 1796), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). Our results suggest that pheromone trap catches of the species examined are in positive correlation with the daily maximum-, minimum-, daily averaged temperature ranges. The relation can be characterized with tertiary polynomials functions.

Keywords: Microlepidoptera, pests, pheromone traps, daily temperature parameters.

10. 1. Introduction

Temperature and precipitation may have an important role from the point of view of flying activity. The given temperature requirements of insects can be explained by the fact that their body mass is very small compared to both its surface and the environment. That is why their body temperature, instead of being permanent and self-sufficient, follows the changing temperature of the environment. This is because the ratios of the body mass and surface of insects determine the difference between the inner heat content and the incoming or outgoing heat. The heat content of the body is proportionate to its mass, while, on the other hand, the heat energy intake or loss is proportionate to the size of the surface of the body. Therefore an external effect makes its influence felt as against the inner, small heat content of a relatively small mass. The speed as well as the size of the impact follows from the ratio between the mass and surface of the body of the insect (Bacsó, 1964). And so the temperature value always exerts a substantial influence on the life processes of insects. The chemical processes described as metabolism that determine the life functions of insects always follow the temperature changes in the direct surroundings. Naturally, the activity of the organs of locomotion also depends on the temperature of the environment which explains why we can expect a massive light-trap turnout by what is an optimal temperature for the given species (Manninger 1948). According to Tsuji et al. (1986) the air temperature often has a very strong influence to the activity of insects. Such as small butterfly species under certain temperature are not able to fly. Southwood (1978), on the other hand, is of the view that the flight of insects has a bottom and top temperature threshold typical of each species. The insect flies if the temperature is above the bottom and below the top threshold and becomes inactive when the value is below the bottom or above the top threshold. In his view, other reasons explain the fluctuations in the number of specimens experienced in the interval between the low and high threshold values. However, research in Hungary has proved that in the context of a single species, too, a significant regression can be established between the temperature values and the number of specimens collected by light-trap (Járfás 1979, Nowinszky et al. 2003). Kádár and Erdélyi (1991) established positive correlation's between the temperature measured at 7 p.m. and 1 a.m. on the one hand and the number of ground beetles flying to light, on the other. Polish research has also confirmed that the number of noctuids light-trapped increases with the rise of temperature (Buszko and Nowacki, 1990).

Larsson and Svensson (2011) found that temperature was a dominating factor affecting the temporal flight patterns of the Hermit Beetle (*Osmoderma eremita* Scopoli) and the Red Click Beetle (*Elater ferrugineus* Linnaeus).

The temperature is constantly changing significantly and accordingly during the day and it may cause change relatively quickly in the phenomena of insect life as well. Presumably, therefore, that not only the current temperature exerts influence for their vital functions, but the temperature changes as well. The daily temperature ranges – the 24 hour period noted between the highest and lowest temperature difference – are in the temperate zone more important than in the tropics, this can lead to living in insects daily activity is strongly dependent on the daily temperature range than in the tropics living species. There are only a few studies in home and international literature which are in connection with the temperature oscillation and the phenomena of insect life.

According to Yi Liu et al. (1998) the circadian rhythm can be extremely sensitive to temperature changes; in insects, lizards, and fungi, clocks can be entrained by temperature cycles that oscillate only 1 °C to 2 °C. Ferenczy et al. (2010) found it surprising that the highly important factor is the average daily temperature range. This fact was so unexpected, because it is used as phenology models are generally more similar to the amount of heat temperature, or average kind of parameters are taken good results.

We assume that the temperature range rate is faster, and their effect is great. Therefore, we presented our research to the daily temperature range in pheromone trap collections. Our choice was justified by the fact that the studied species can fly during the whole day and night in pheromone traps, so the whole course of daily activity to sense the temperature changes and they adapt well to these conditions.

10. 2. Material

Between 2004 and 2012 Csalomon–type pheromone traps were operating in Bodrogkisfalud (48°10'N; 21°21'E; Borsod-Abaúj-Zemplén County, Hungary, Europe). These traps attracted 7 Microlepidoptera species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth *(Phyllonorycter corylifoliella* Hübner, 1796), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). Data on the Hawthorn Red Midget Moth *(Phyllonorycter*

Table 10. 2. 1. The number and observing data of the examined species

Species	Number of	
	moths	data
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	64,546	2,709
Gracillariidae »Lithocolletinae Hawthorn Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	8,418	1,308
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	8,138	2,005
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	8,913	1,976
Tortricidae » Tortricinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	28,913	2,746
Tortricidae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	16,226	2,615
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	8,961	2,156

corylifoliella Hbn.) were collected between 2008 and 2011 only.

Every year 2-2 traps per species were collected. So one night after a 2-2 catching data were available. Catch data of the collected species is displayed in Table 10. 2. 1.

10. 3. Methods

The distance between the traps were 50 meters and they were in operation all the year on the same branch of leafy trees or vines. The height of each species was different from 1.5 to 2 meters. The traps operated from start of April to the end of September. The capsules exchange was in every 6-8 weeks as it was proposed by Tóth (2003). The number of caught moths was daily recorded. This is different from the general practice, because generally the catch of the traps is counted two or three days together in most cases.

The weather data in the orchard was measured by meteorological instruments located 2 meters height. We measured the actual temperature daily at 7, 14 and 21 o'clock and we also determined the daily maximum and minimum temperature values. We calculated the daily temperature ranges, which was used in our calculations. The daily relative catch values were assigned to the daily temperature ranges data.

From the catching data of the examined species, relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 day) per the average number of individuals of the same generation falling to the same time unit. In case of the expected averaged individual number the RC value is 1. The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps.

The number of daily temperature ranges and the moths caught was calculated with consideration to the method of Sturges (Odor & Iglói 1987).

The RC values of a species from all sites and years were arranged into the proper classes. The results obtained are plotted. We determined the regression equations, the significance levels which were shown in the figures.

10. 4. Results and Discussion

The results are shown in Figures 10. 4. 1.–10. 4. 7.

Our results are without antecedents in the literature. Partly because the temperature can be found almost daily temperature ranges context for the insect releases. On the other hand the collecting results of the pheromone traps (with counted only in 2-3 days) are not suitable for investigations.

Our results clearly show the effectiveness of increasing the daily temperature range, on the pheromone trap catches of the examined species. The relations can be described with exponential (in one case), linear (in two cases) and logarithmic function (in four cases).

In the first two cases, the rise of daily temperature ranges increases with the number of captured moths. The logarithm function can be described by relationships but suggest that the growth of the catch has an upper limit. The highest values of daily temperature range belong to decreasing catch. It needs to be explained that when the daily temperature range is small, why is low to moderate activity, indicated by the low catch?

Otherwise, when the daily temperature range is high, why increase the number of captured moths, although some species have reduced the catch of the highest temperature range values? We hypothesize that this phenomenon may be due to those days when the daily temperature range is large, the temperature is relatively rapidly and significantly rise in body temperature rises as the insects as well. The significant increase in body temperature and locomotor activity also increases, which can result in an increase in the catch. The daily temperature range is lower to a lesser extent the increase in body temperature of insects, such as locomotor activity to a lesser extent increases. However, further studies probably confirm our hypothesis.

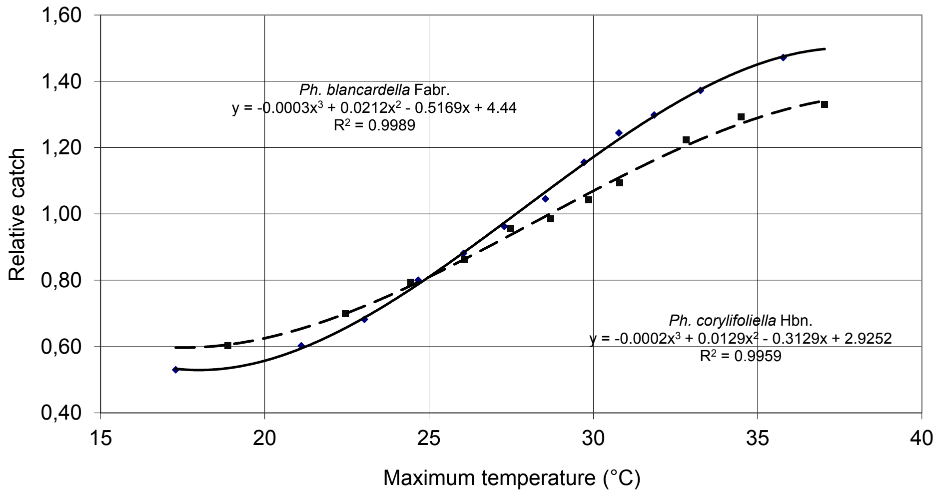

Figure 10. 4. 1.

Figure 10. 4. 1. Pheromone trap catch of the *Phyllonorycter blancardella* Fabricius and *Phyllonorycter corylifoliella* Hübner in connection with the maximum temperature

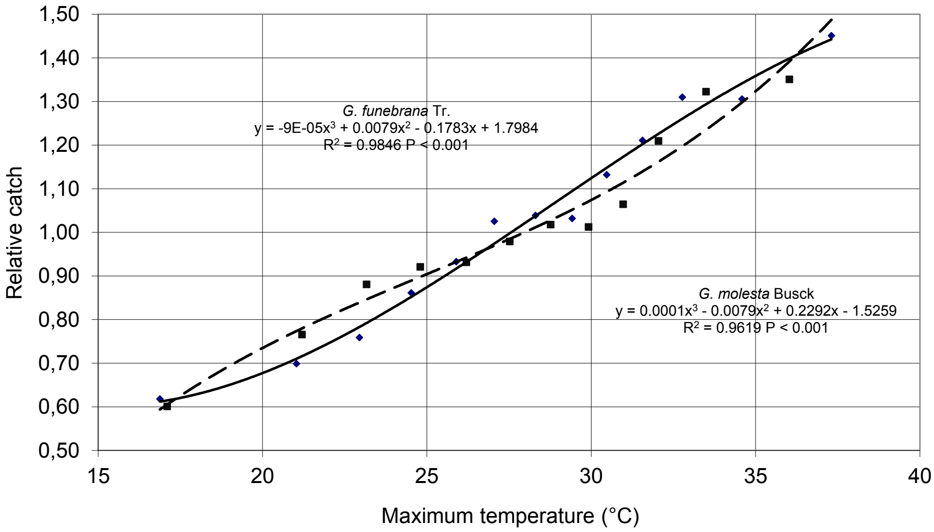

Figure 10. 4. 2.

Figure 10. 4. 2. Pheromone trap catch of the *Grapholita funebrana* Treitschke and *Grapholita molesta* Busck in connection with the maximum temperature

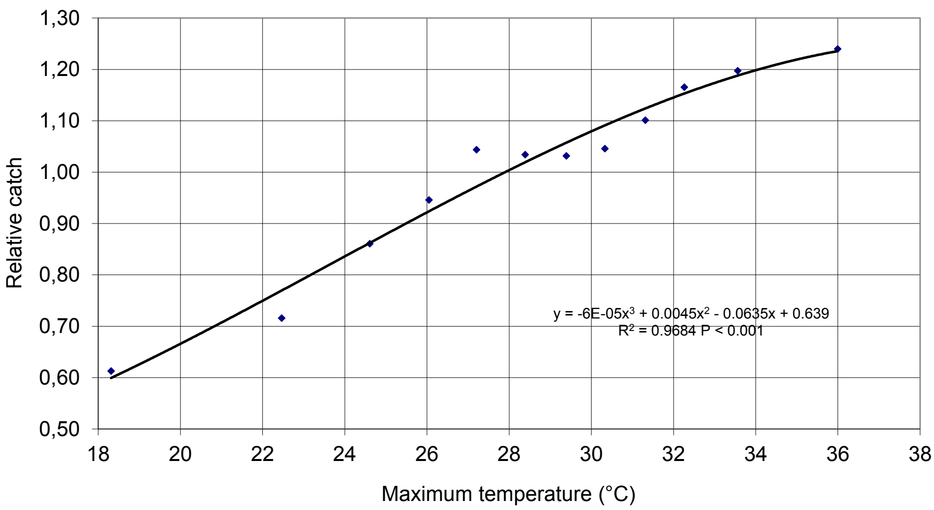

Figure 10. 4. 3.

Figure 10. 4. 3. Pheromone trap catch of *Cydia pomonella* Linnaeus in connection with maximum temperature

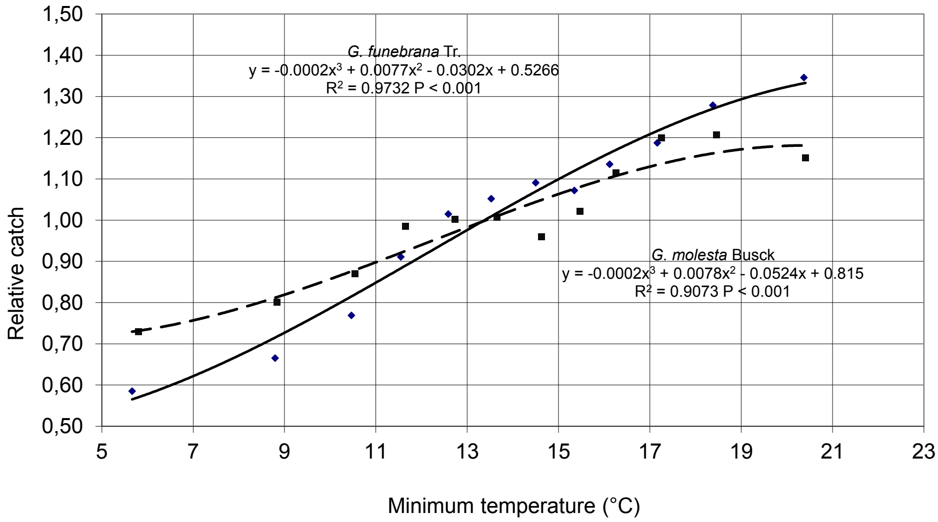

Figure 10. 4. 5.

Figure 10. 4. 5. Pheromone trap catch of the *Grapholita funebrana* Treitschke and *Grapholita molesta* Busck in connection with the minimum temperature

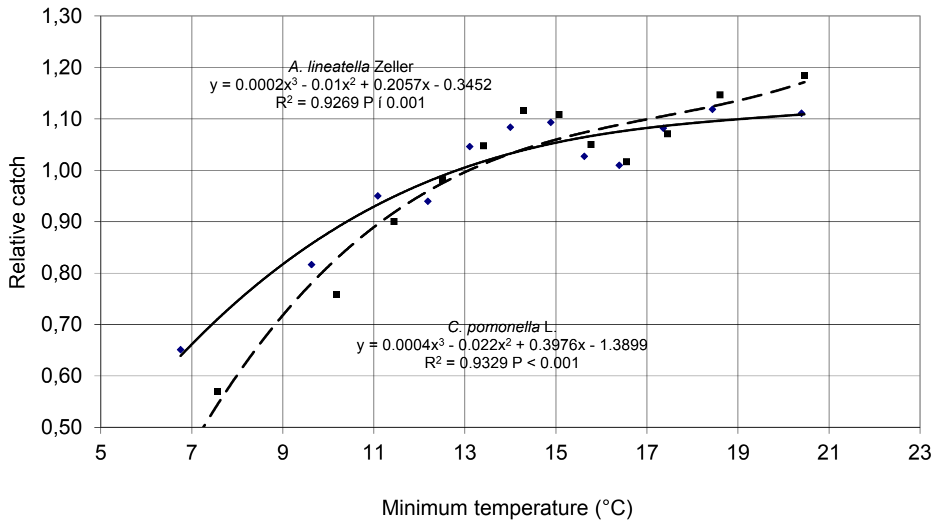

Figure 10. 4. 6.

Figure 10. 4. 6. Pheromone trap catch of the *Anarsia lineatella* Zeller and *Cydia pomonella* Linnaeus in connection with the minimum temperature

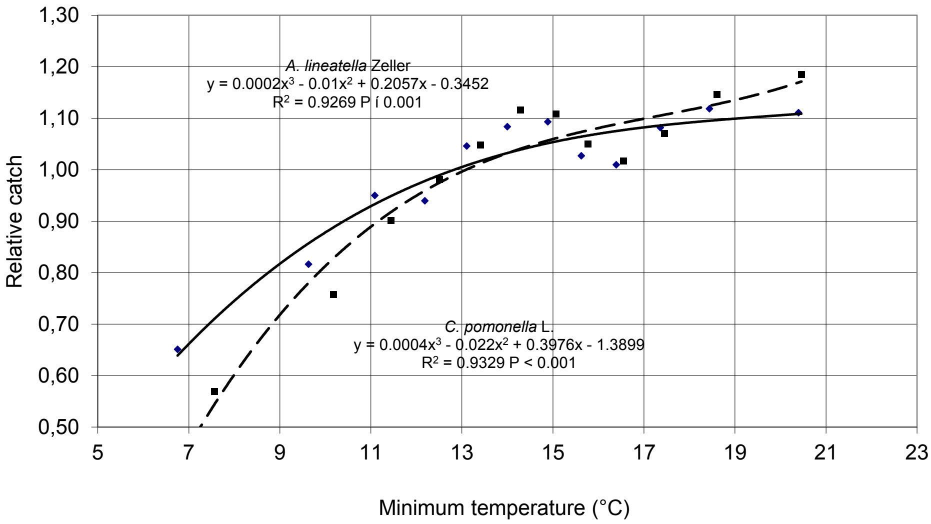

Figure 10. 4. 6.

Figure 10. 4. 6. Pheromone trap catch of the *Anarsia lineatella* Zeller and *Cydia pomonella* Linnaeus in connection with the minimum temperature

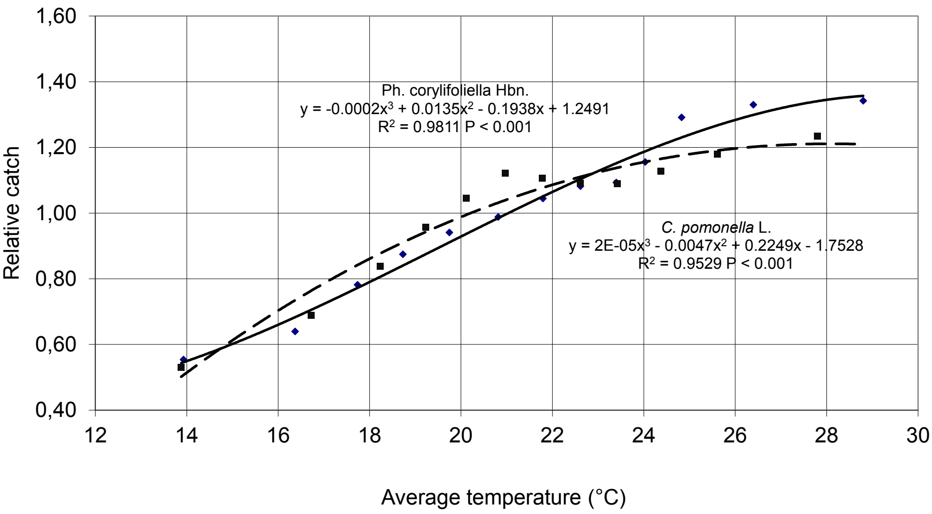

Figure 10. 4. 7.

Figure 10. 4. 7. Pheromone trap catch of the *Phyllonorycter corylifoliella* Hübner and *Cydia pomonella* Linnaeus in connection with the average temperature

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Chapter 11.

Pheromone Trap Catch of Harmful Microlepidoptera Species in Connection with the Air Pollutants

L. Nowinszky[1], J. Puskás[1], G. Barczikay[2]

[1]University of West Hungary Savaria University Centre
H-9700 Szombathely, Károlyi Gáspár Square 4.
E-mail: lnowinszky@gmail.com and pjanos@gmail.com
[2]County Borsod-Abaúj-Zemplén Agricultural Office of Plant Protection and Soil Conservation Directorate, H-3917 Bodrogkisfalud, Vasút Street 22.

Abstract: In this study, seven species of Microlepidoptera pest pheromone trap collection presents the results of the everyday function of the chemical air pollutants (SO_2, NO, NO_2, NO_x, CO, PM10, O_3). Between 2004 and 2013 Csalomon type pheromone traps were operating in Bodrogkisfalud (48°10'N; 21°21E; Borsod-Abaúj-Zemplén County, Hungary, Europe). The data were processed of following species: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hübner, 1796), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758). We found that the behaviour of the studied species can be divided into three types: if the air pollution increases the catch increase or decrease. In the third group there is an increase first and then a decrease will appear. The relation can be characterized with tertiary polynomial functions.

Keywords: Microlepidoptera, pests, pheromone traps, air pollution

11. 1. Introduction

Since the last century, air pollution has become a major environmental problem, mostly over large cities and industrial areas (Cassiani et al. 2013).

It is natural that the air pollutant chemicals influence the life phenomena of insects, such as flight activity as well.

According to Buttler and Trumble (2008) the pollutants are harmful onto the plants of the terrestrial ecosystems and the insects, including air pollutants, such as ozone, sulphur oxides (SO_x), nitrogen oxides (NO_x), carbon oxides (CO_x), fluoride and acid rain (fog and rain) and polluting metals and heavy metals.

The population density reduction can be most frequently explained by the toxicity of pollutants (Kozlov et al., 1996). However, there are some species which prefer pollutants, they can product strong growth and consequently cause serious damage to the polluted forests (Baltensweiler, 1985). There is a response of insect populations change from negative to positive environmental pollution (Führer, 1985).

There are some hypotheses which refer to the polluting effect on plant consuming insects. These are following:
(1) it causes a change in the quality of the habitat on plant consuming ones,
(2) it may modify the quality of the plant,
(3) it is harmful for the natural enemy, so they decrease because of this or they disappear (Zvereva and Kozlov, 2000).

Kozlov and Haukioja (1993) publish the densities of males of the Large Fruit-tree Tortrix *Archips podana* Scopoli which were determined by pheromone traps in the Lipetsk district, central Russia, in 1991.

The sulphur dioxide was significant at Lipetsk among industrial emissions. The individual density of *Archips podana* Scopoli reached a peak at about 3-7 km from the nearest source of emission.

According to Malinowski (1992) there are differences among the answers of different animal groups given to the air pollution. Sometimes these separate clearly the different subgroups, in other cases, their susceptibility or resistance seems to be individual against air pollution against air pollution.

Some examples are given below:
Terrestrial insects: distinct types of response to SO_2 pollution have been identified which distinguish some groups of land-living insect, for example: Very sensitive: e.g. many butterflies and moths; moderately sensitive, e.g. the Pine Engraver (*Ips dentatus* Sturm) and the Pine Flat-bug *Aradus cinnamoneus* Panz.; very tolerant and sometimes benefitted by SO_2 pollution: aphids. The Migratory Grasshopper (*Melanoplus sanguinipes* Fabricius density tended to decrease with increasing SO_2 concentration. Sulphur dioxide did not alter the relative proportions of this species in the total population (Mcnary et al. (1981).

The abundance and dynamics of the European Spruce Bark Beetle (*Ips typographus* Linnaeus) populations was evaluated by Grodzki et al. (2014) in 60-80 year old spruce stands in Norway. The mean daily capture of beetles in pheromone traps was significantly higher at sites where the O_3 level was higher.

The particulate matter adsorb toxic materials (e.g. metals, mutagenic substances) as well as bacteria, viruses, fungi and promote their getting into the body. PM10 can be cause irritation in the lung and mucous membrane (Dockery 2009). 211 lives could have been saved in Hungary yearly by the reduction of PM10 to yearly mean of 20 $\mu g/m^3$ (Bobvos et al. 2014). Research groups studied in Europe in several cities of PM10 pollution (Makra et al. 2011, 2013; Papanastasiou & Melas 2004, 2008, 2009; Papanastasiou et al. 2010). According to Vaskövi et al. (2014) and Chłopek (2013) the yearly mean concentration of PM10 is generally higher near the main traffic roads than in areas with less traffic.

However, the studies examining the activity and daily pheromone trapping the insects in connection with air pollution we not found in the literature.

11. 2. Material

Between 2004 and 2013 Csalomon type pheromone traps were operating in Bodrogkisfalud (48°10' N, 21°21' E; Borsod-Abaúj-Zemplén County, Hungary, Europe). These traps attracted seven Microlepidoptera species. Every year 2-2 traps per species were collected; one night after a 2-2 catching, data were available. The caught species were the followings: Spotted Tentiform Leafminer (*Phyllonorycter blancardella* Fabricius, 1781), Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hübner), Peach Twig Borer (*Anarsia lineatella* Zeller, 1839), European Vine Moth (*Lobesia botrana* Denis et Schiffermüller, 1775), Plum Fruit Moth (*Grapholita funebrana* Treitschke, 1846), Oriental Fruit Moth (*Grapholita molesta* Busck, 1916) and Codling Moth (*Cydia pomonella* Linnaeus, 1758).

Data on the Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hbn.) were collected between 2008 and 2013 only. The catch data of the collected species is displayed in Table 11. 2. 1.

The distance between the traps were 50 meters and they were in operation all the year on the same branch of leafy trees or vines. The height of each species was different from 1.5 to 2 meters. The traps operated from start of April to the end

Table 11. 2. 1. The number and observing data of the examined species

Species	Number of	
	moths	data
Gracillariidae »Lithocolletinae Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	65,478	2,991
Gracillariidae »Lithocolletinae Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	10,156	1,820
Gelechiidae » Anacampsinae Peach Twig Borer *Anarsia lineatella* Zeller, 1839	9,090	2,352
Tortricidae » Olethreutinae European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	9,751	2,639
Tortricidae » Olethreutinae Plum Fruit Moth *Grapholita funebrana* Treitschke, 1846	30,534	3,118
Tortricidae» Tortricinae Oriental Fruit Moth *Grapholita molesta* Busck, 1916	17,402	3,117
Tortricidae » Olethreutinae Codling Moth *Cydia pomonella* Linnaeus, 1758	10,490	2,857

of September. The capsules exchange was in every 6-8 weeks as it was proposed by Tóth (2003). The number of caught moths was daily recorded. This is different from the general practice, because generally the catch of the traps is counted two or three days together in most cases.

The values of the chemical air pollutants: SO_2, NO, NO_2, NO_x, CO, PM10, O_3 (in milligram per cubic meter) was measured in nearest automatic measurement station Hernádszurdok (48°28'98″N, 21°12'38″E). Distance between the two villages from each other is 37 km as the crow flies.

11. 3. Methods

From the catching data of the examined species, relative catch (RC) data were calculated for each observation posts and days. The RC is the quotient of the number of individuals caught during a sampling time unit (1 day) per the average number of individuals of the same generation falling to the same time unit. In case of the expected averaged individual number the RC value is 1 (Nowinszky, 2003). The introduction of RC enables us to carry out a joint evaluation of materials collected in different years and at different traps.

The data from different years were treated with combined. The number of the chemical air pollutants and the moths caught was calculated with consideration to the method of Sturges (Odor and Iglói, 1987).

The RC values of all species were arranged into the proper classes. The results obtained are plotted. We determined the regression equations, these levels of significance, which were shown in the figures.

11. 4. Results and Discussion

All of our results are shown in Table 11. 4. 1.

We found that the behaviour of the studied species can be divided into three types: if the air pollution increases the catch increase or decrease. In the third group there is an increase first and then a decrease will appear. These types of behaviour are also presented Figures 11. 4. 1–11. 4. 11. for each pollutant.

Our results are without antecedents in the literature. Partly because the catching results of pheromone traps are not suitable for tests on daily events, and partly because of flight activity and trapping insects of our knowledge, have not been studied in entomologists.

We can only mention one of our own studies, dealing with examination between the pheromone trap catches and PM10 (Nowinszky et al. 2015).

Our results may explain at present only assumptions, but they cannot even prove or disprove. The increase the content of particular matter in air may therefore increase the catch, because the light is reflected from the solid particles, thus increasing the amount of polarized light by day and night. The pheromone traps that male moths collected throughout the day. As we have previously demonstrat-

Table 11. 4. 1. The behaviour types of the examined species (I = increasing, D = decreasing, I→D: increasing after decreasing)

Species	SO_2	NO_2	NOx	NO	CO	O_3	PM10
Ph. blancardella Fabr.	—	D	I→D	I	I	I→D	I
Ph. corylifoliella Haw.	—	I→D	I→D	I	D	I→D	I
A. lineatella Zeller	I→D	I→D	—	—	I→D	I→D	—
L. botrana Den. et Schiff.	—	I	I	I→D	—	I	I
G. funebrana Tr.	—	I	I	—	—	I	I
G. molesta Busck	I→D	I	I	—	—	I	I
C. pomonella L.	I→D	I→D	I→D	I→D	I→D	I→D	I

ed the polarized light increases the activity of insects (Nowinszky et al., 1979, 2010a, 2010b, 2012a, 2012b, Nowinszky & Puskás 2009, 2010, 2011, 2012, 2013a, 2013b, 2014). Another possibility is that the solid particles of the pheromone molecules bind well, so the greater activity male moths need for finding the females.

The particulate matters adsorb toxic materials (e.g. metals, mutagenic substances) as well as bacteria, viruses, fungi and promote them getting inside the body.

The emission of solid materials (dust, PM10) in Hungary from the early 90s fell by almost half, initially strongly, later with declining pace. The main pollutants are the industry, energy production and the population, but growing of transport sector can be seen during last years. Today, more and more attention is paid to this pollutant. Research results have proved that the health effects of dust is far greater than previously thought. The small amount of material in the air, which is highly toxic, bind on the surface of the small size particles (PM2.5) and together with these particles they directly pass into the blood through the respiratory system. We know little about their effect has on the insects however.

The response of different insect groups (Microlepidoptera, Macrolepidoptera, Trichoptera) to environmental factors is strikingly different. The only exception is the temperature and the (polarized) moonlight. The temperature is one reason because special temperature values are necessary for the flight activity. This is not the same value for different species but at a higher temperature the activity can be higher. Another reason is that the flying period is relatively short and it is in that season when the rough changes of temperature are very rare. The moonlight and especially its polarized proportion significantly increase the flight activity (Nowinszky, 2004 and 2008). We do not know the impact of other pollutants on insect flight activity in the air.

This opposite form of behaviour may be the many reasons. The claim and tolerance to environmental factors of the species are different. Environmental factors interact with each other to exert their effects. Thus the same factor can be different effect. The species have different survival strategy (Nowinszky, 2003).

Adverse effects of two possible answers: passivity, or hiding or even increased activity, because you want to ensure the survival of the species. Therefore, the insect do "to carry out their duties in a hurry."
It may be more of the reason of this for contrary behavioural forms:

The different species needs different circumstances and tolerance to environmental factors. Environmental factors interact with each other to exert their effects. Thus the same factor can cause different influence.

It is possible two answers to the unfavourable environmental factors: passivity (e.g. hiding) or even increased activity, because the insect wants to ensure the survival of the species. Therefore, he does quickly his tasks.

The fact that on the higher and increasing values of air pollutants the catches are not suddenly, but gradually decline, we deduce that the tolerance and response of insect specimens adverse effects to individually change.

Further studies are planned. We will continue our research in other insect species and trap types for analyses.

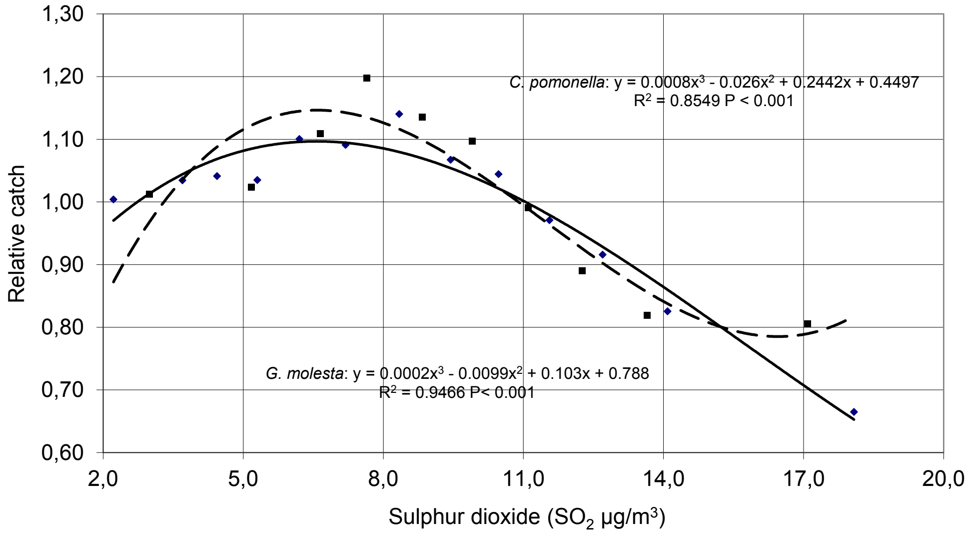

Figure 11.4.1

Figure 11. 4. 1. Pheromone trap catch of the *Grapholita molesta* Busck and *Cydia pomonella* Linnaeus in connection with the sulphur dioxide (SO_2) content of the air (Bodrogkisfalud, 2004-2013)

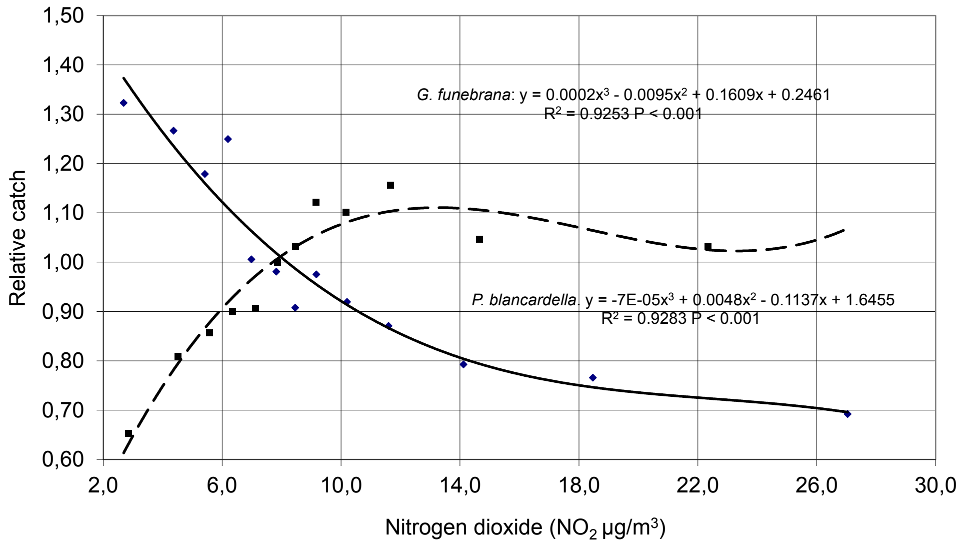

Figure 11. 4. 2

Figure 11. 4. 2. Pheromone trap catch of the *Phyllonorycter blancardella* Fabricius and *Grapholita funebrana* Treitschke in connection with the nitrogen dioxide (NO_2) content of air (Bodrogkisfalud, 2004-2013)

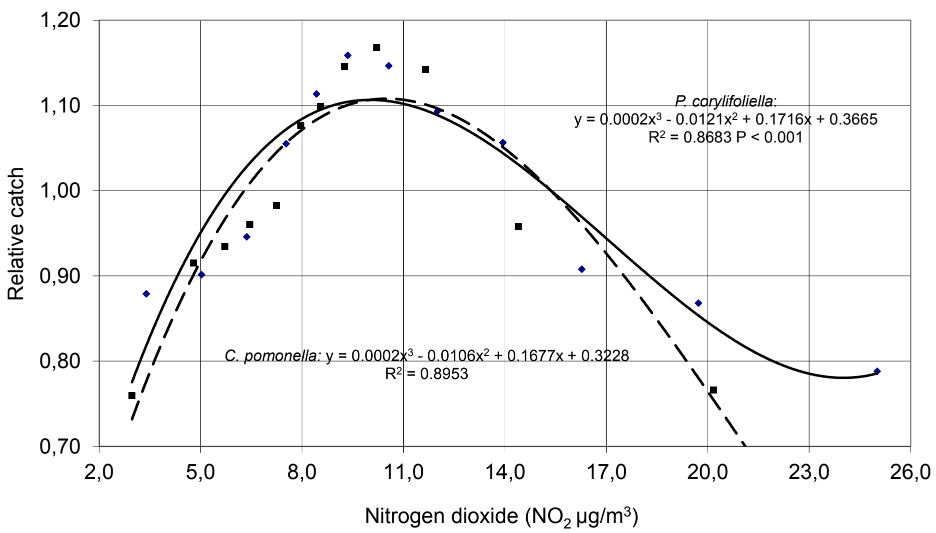

Figure 11. 4. 3.

Figure 11. 4. 3. Pheromone trap catch of the *Phyllonorycter corylifoliella* Hübner and *Cydia pomonella* Linnaeus in connection with the nitrogen dioxide (NO_2) content of air (Bodrogkisfalud, 2008-2013 and 2003-2013)

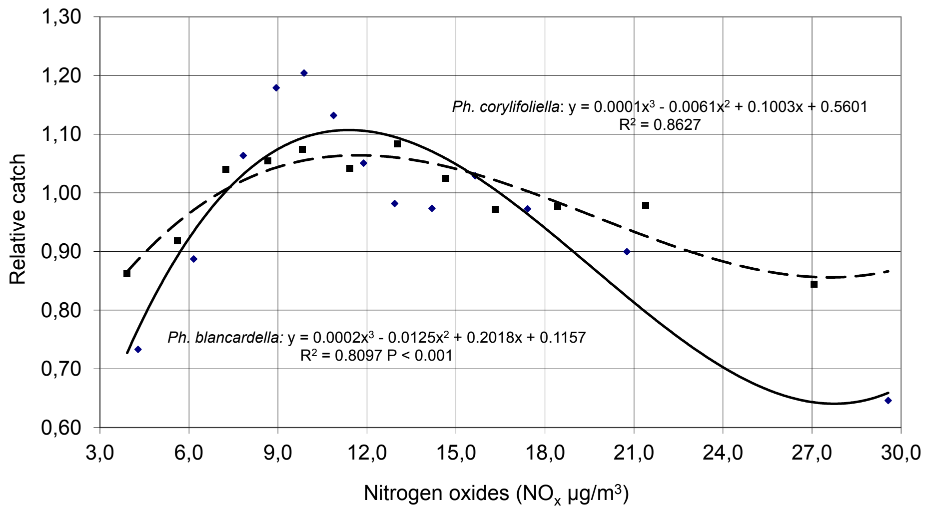

Figure 11. 4. 4.

Figure 11. 4. 4. Pheromone trap catch of *Phyllonorycter blancardella* Fabricius and *Phyllonorycter corylifoliella* Hübner in connection with the nitrogen oxides (NO_x) contents of air (Bodrogkisfalud 2004-2013 and 2008-2013)

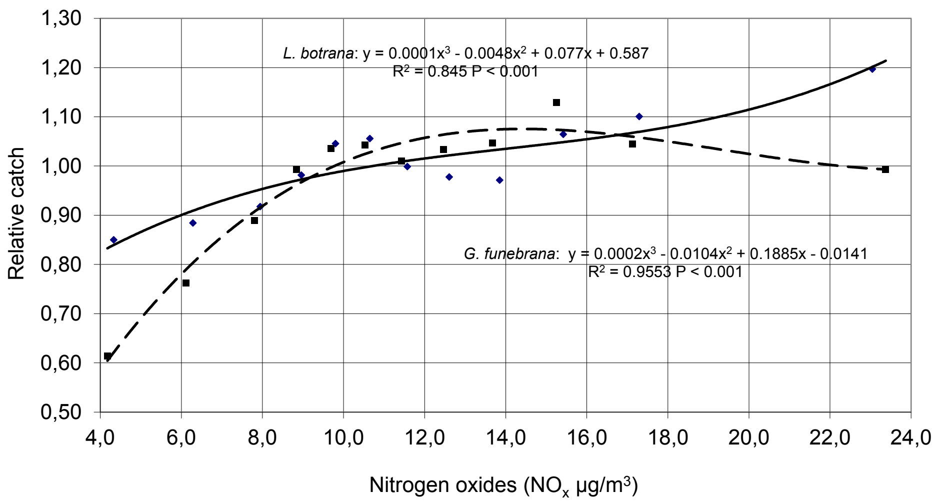

Figure 11. 4. 5.

Figure 11. 4. 5. Pheromone trap catch of *Lobesia botrana* Denis et Schiffermüller and *Grapholita funebrana* Treitschke in connection with the nitrogen oxides (NO_x) content of air (Bodrogkisfalud, 2004-2013)

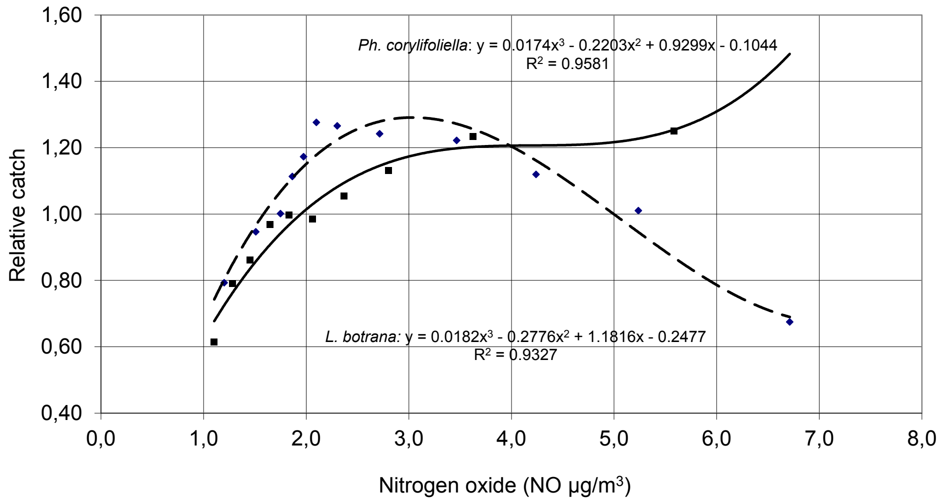

Figure 11. 4. 6.

Figure 11. 4. 6. Pheromone trap catch of the *Phyllonorycter corylifoliella* Hübner and *Lobesia botrana* Denis et Schiffermüller in connection with nitrogen oxide (NO) content of air (Bodrogkisfalud, 2008-2013 and 2004-2013)

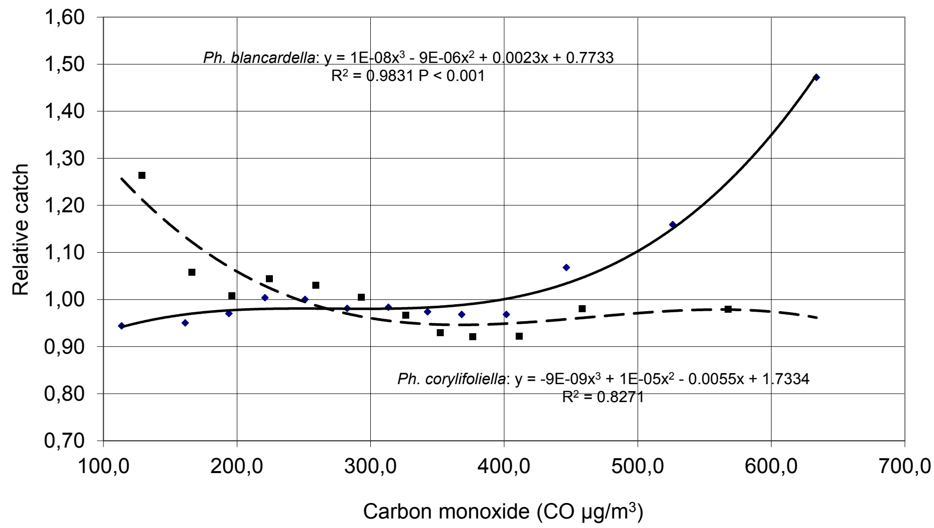

Figure 11. 4. 7.

Figure 11. 4. 7. Pheromone trap catch of the *Phyllonorycter blancardella* Fabricius and *Phyllonorycter corylifoliella* Hübner in connection with carbon monoxide (CO) content of air (Bodrogkisfalud, 2004-2013 and 2008-2013)

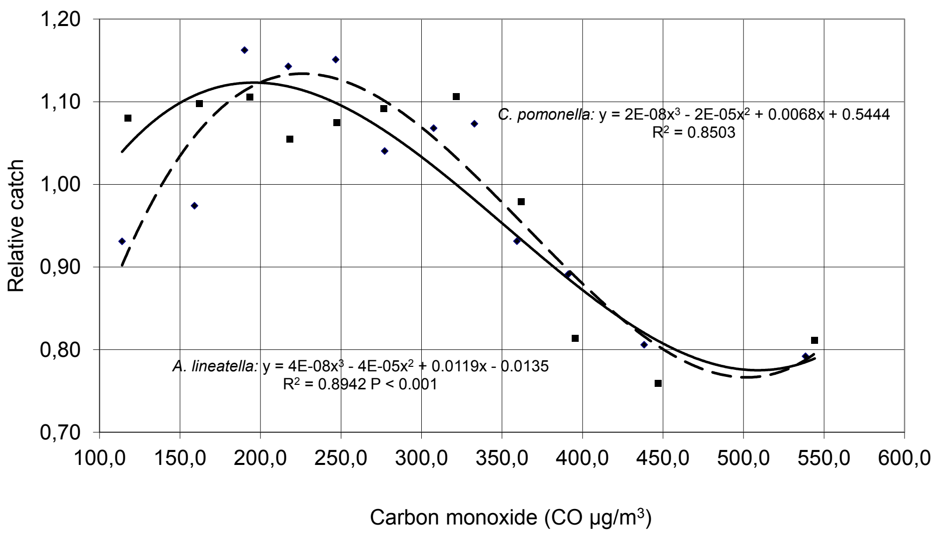

Figure 11. 4. 8.

Figure 11. 4. 8. Pheromone trap catch of the *Anarsia lineatella* Zeller and *Cydia pomonella* Linnaeus in connection with the carbon monoxide (CO) content of air (Bodrogkisfalud, 2004-2013)

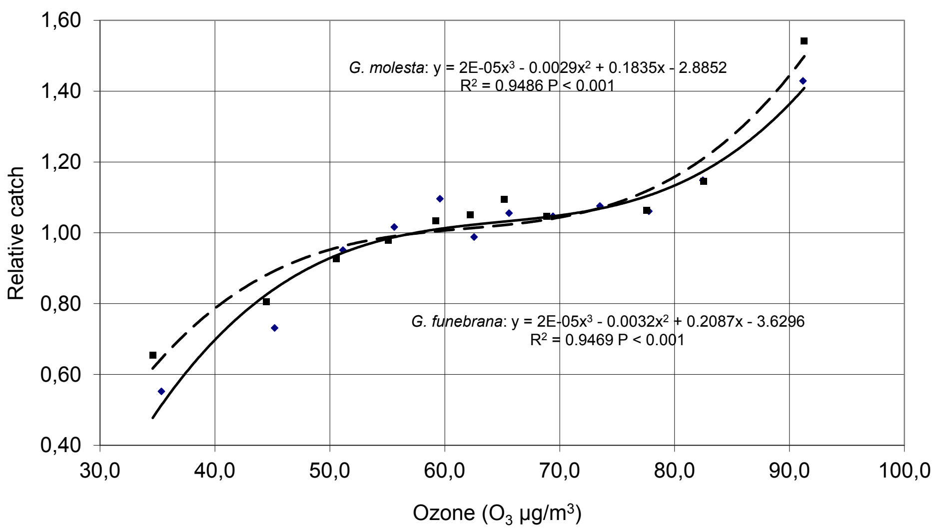

Figure 11. 4. 9.

Figure 11. 4. 9. Pheromone trap catch of the *Grapholita funebrana* Treitschke and *Grapholita molesta* Busck in connection with ozone (O_3) content of air (Bodrogkisfalud, 2004-2013)

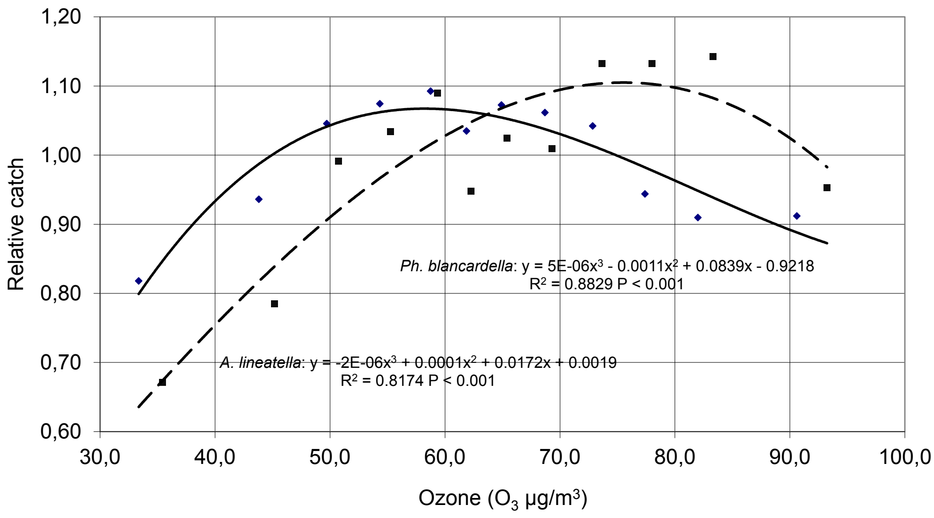

Figure 11. 4. 10.

Figure 11. 4. 10. Pheromone trap catch of the *Phyllonorycter blancardella* Fabricius and *Anarsia lineatella* Zeller in connection with the ozone (O_3) content of air (Bodrogkisfalud, 2004-2013)

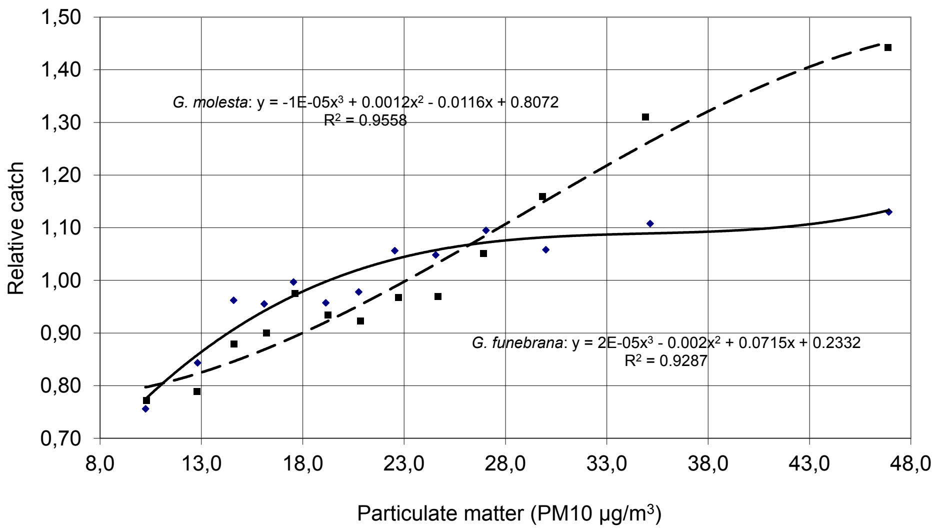

Figure 11. 4. 11.

Figure 11. 4. 11. Pheromone trap catch of the *Grapholita funebrana* Treitschke and *Grapholita molesta* Busck in connection with the particulate matter (PM10) content of air (Bodrogkisfalud, 2004-2013)

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