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.

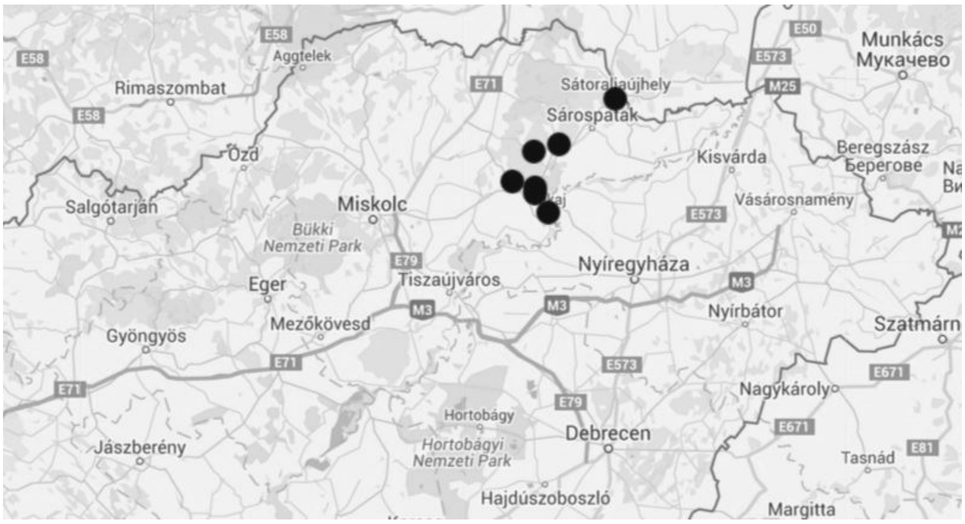
The catch of the European Vine Moth (*Lobesia botrana* Den. et Schiff.) and the Codling Moth (*Cydia pomonella L.)* is higher in the First Quarter. The catch is higher in the Last Quarter of Peach Twig Borer (*Anarsia lineatella* Z.), *Eupoecilia ambiguella* Hbn., *Grapholita funebrana* Tr. and *Grapholita 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

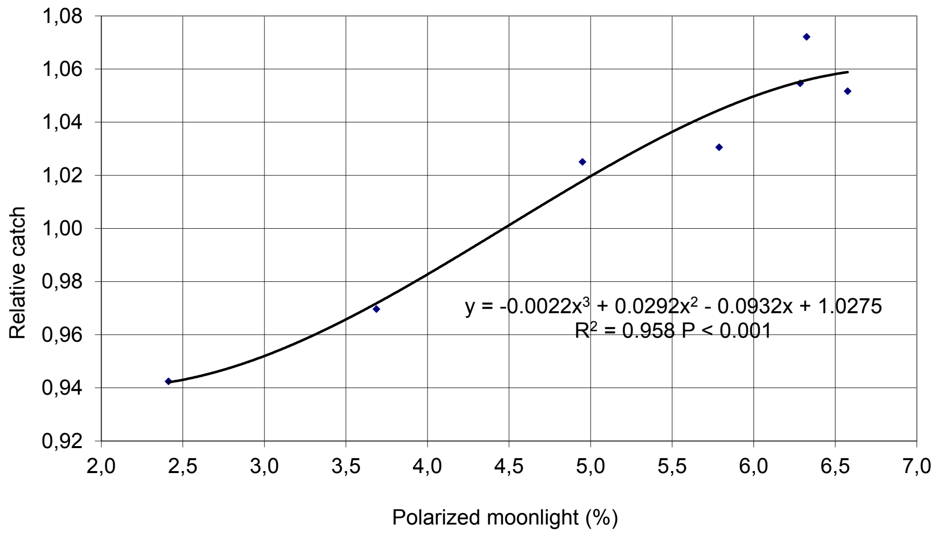


Figure 7. 4. 1.

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

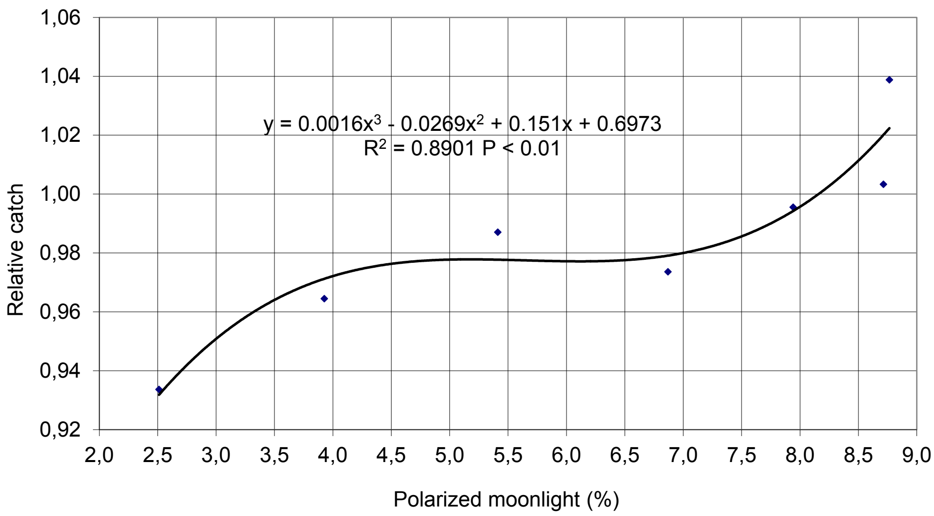


Figure 7. 4. 2.

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

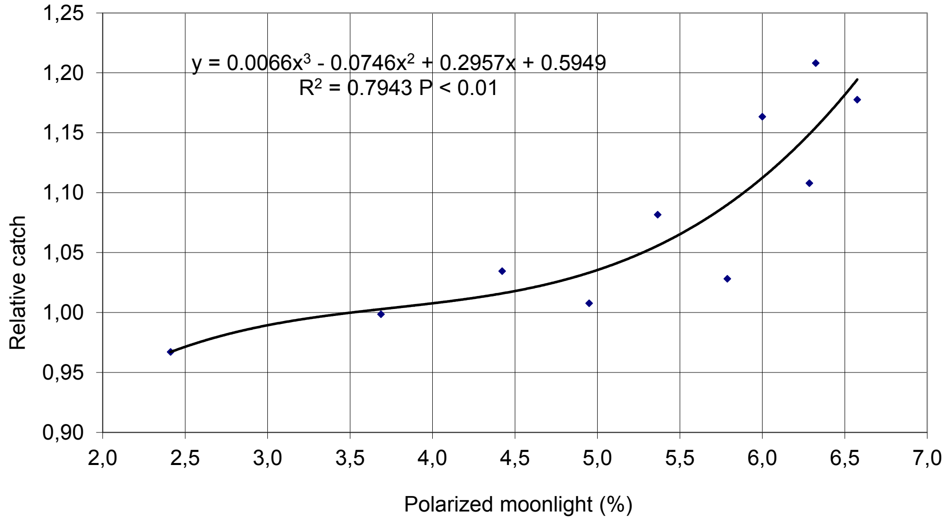


Figure 7. 4. 3.

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

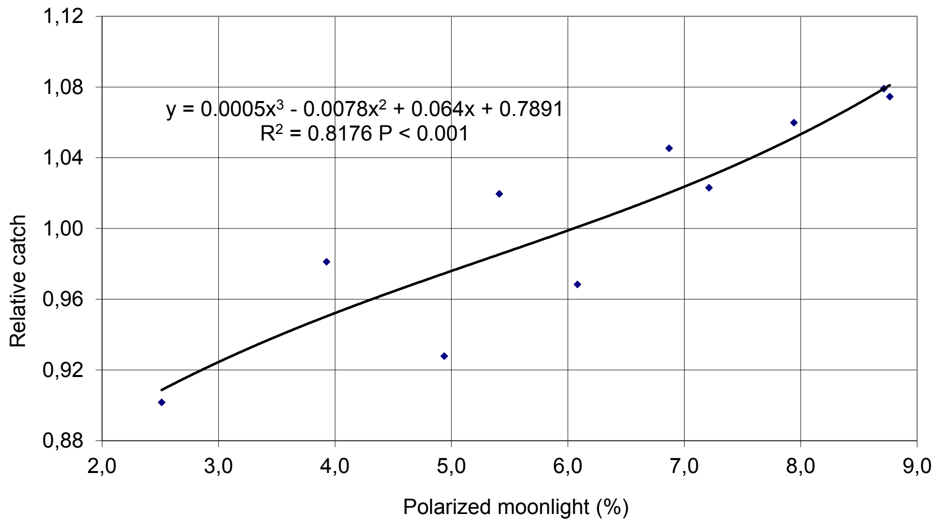


Figure 7. 4. 4.

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

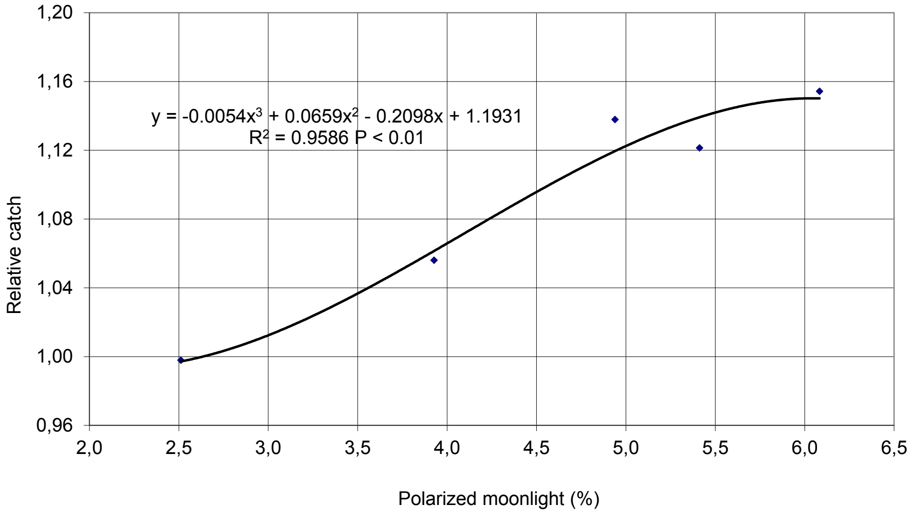


Figure 7. 4. 5.

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

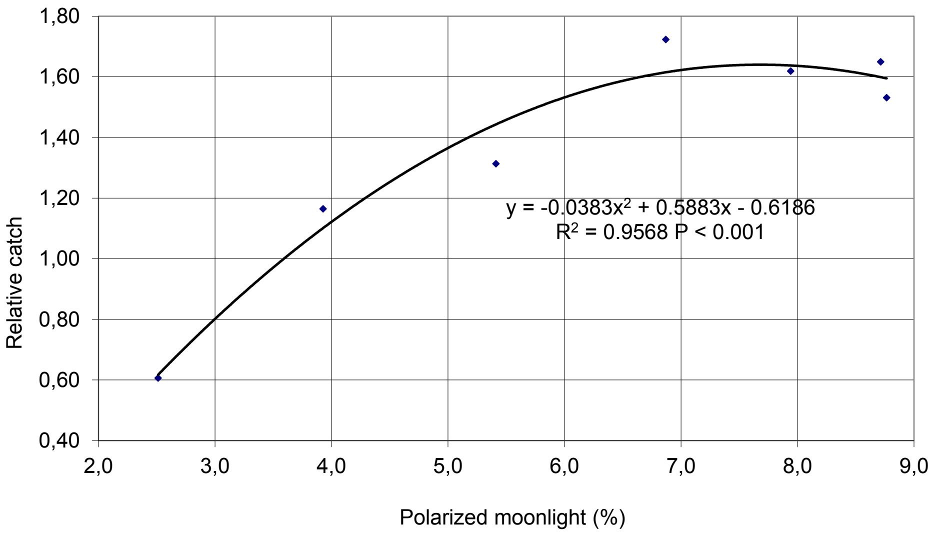


Figure 7. 4. 6.

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

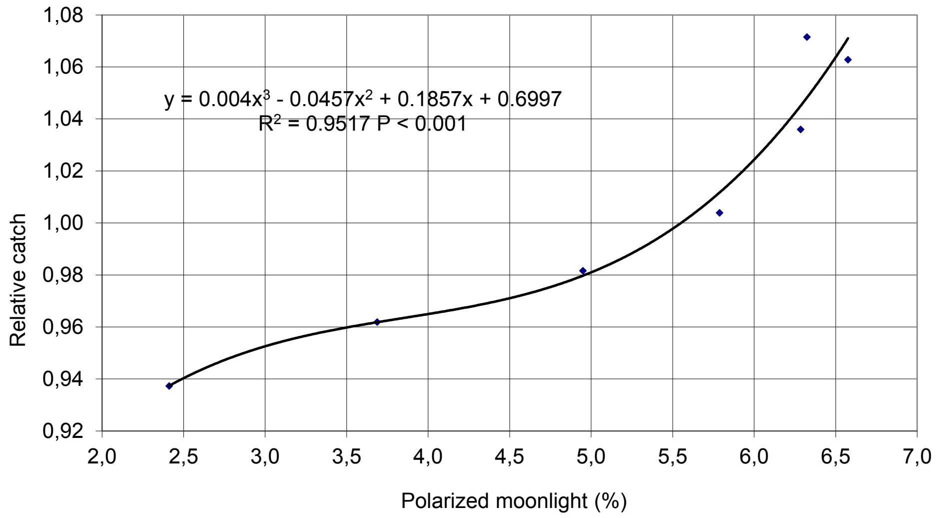


Figure 7. 4. 7.

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

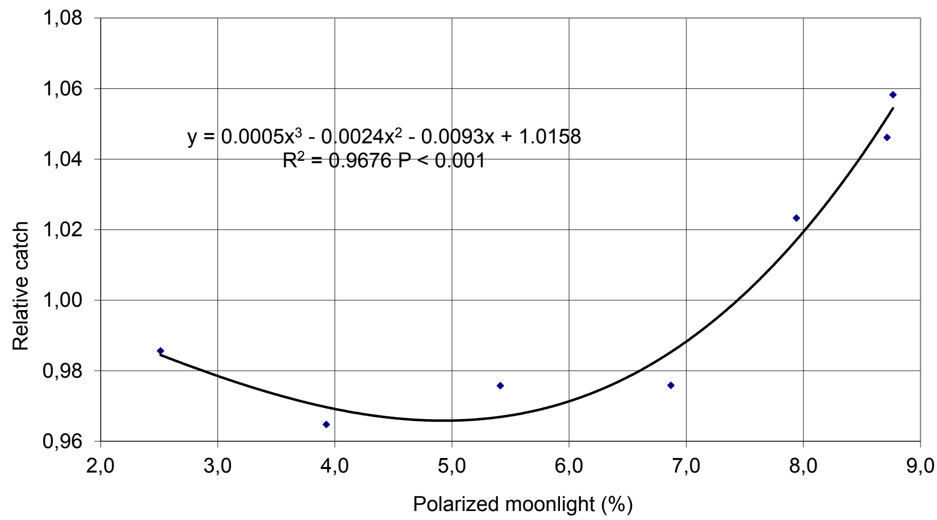


Figure 7. 4. 8.

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

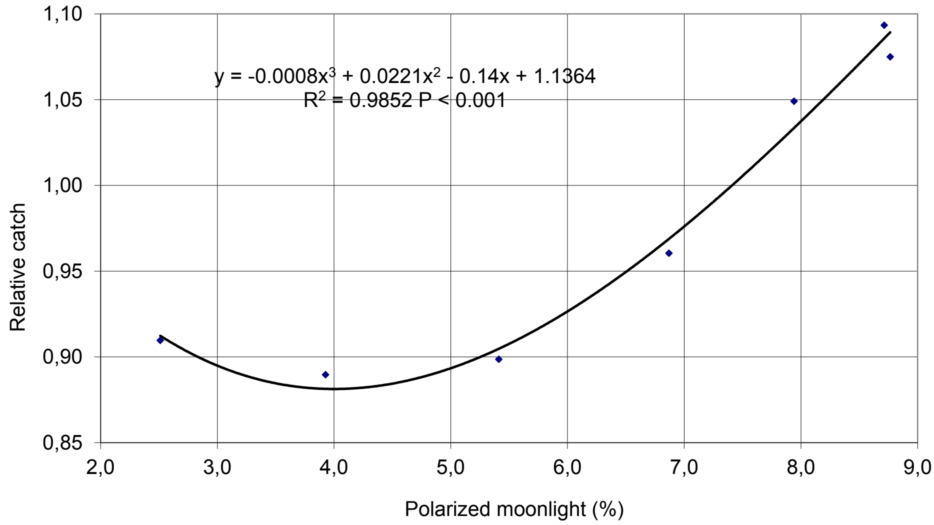


Figure 7. 4. 9.

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

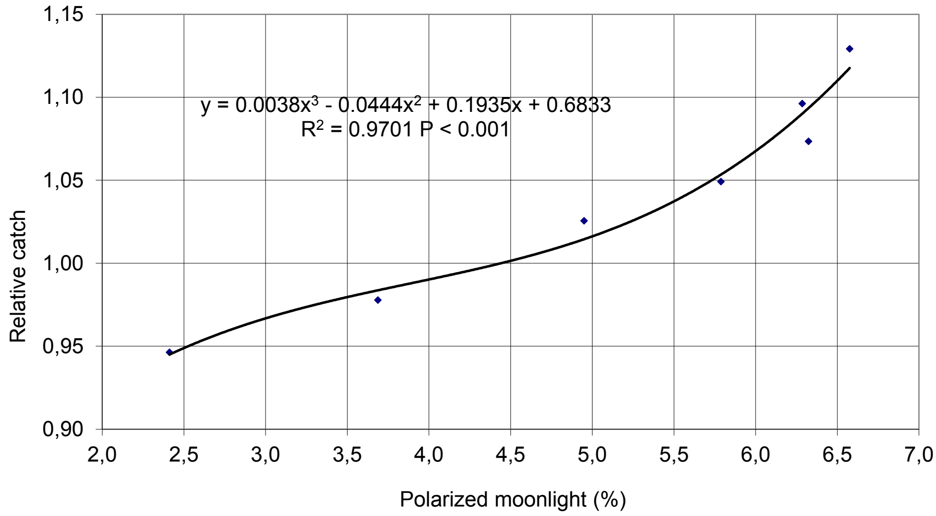


Figure 7. 4. 10.

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

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