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LIGHT-TRAP CATCH OF EUROPEAN CORN BORER (*OSTRINIA NUBILALIS* HBN.) DEPENDING ON THE MOONLIGHT

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Abstract

This study details the connection between the moon phases, the catching distance and the polarized moonlight, and the efficiency of the light trapping of the European Corn Borer (ECB) *(Ostrinia nubilalis* Hbn.). We used the catching data from the light-traps of the Hungarian National Light-trap Network, the fractionating light-trap of Kecskemét, and the light-traps working in different states in the USA.

The catch of the ECB was lowest at the time of a Full Moon in the earlier years and the catch of the ECB in the latest years, too. This decrease is independent of the geographical locality and the type of the light-traps used. The catches increase around the first- and last quarters. The increase of the catching distance to some 90 metres in turn increases the light trap catch with the exception of the catch of the ECB which extends to the border of the theoretical catching distance.

Our research shows a growth in light trap catch when the polarized part of moonlight is much higher. (6.6 and 8.4 %).

We can generally declare that the moonlight reduces neither the number of caught individuals by the reduced catching distance nor the flight activity at the Full Moon.

Key words: ECB, *Ostrinia nubilalis* Hbn., light-trap, Moon, Hungary

Introduction

The ECB is a prevalent pest of the corn in Hungary. Many researchers deal with its lifestyle and spreading, and the methods of the plant protection in both countries. We cite some important studies by Serbian and Hungarian authors (NAGY, 1993; ČAMPRAG, 1994; KESZTHELYI, 2004).

Some authors report an inability to detect a clear decrease in the efficiency of the light trap as a consequence of the effect of moonlight.

WILLIAMS (1936) recognized that at the time of a Full Moon far fewer insects caught the light traps than at the time of a new moon. According to WILLIAMS (1936), WILLIAMS *et al*. (1956) and EL-ZIADY (1957), the reasons for a smaller catch at a Full Moon might be as follows:

a) Moonlight reduces the activity of insects and so the active population accessible for the light trap is smaller,
b) The light of the lamp collects moths from a smaller area in a moonlit environment,
c) It has a direct impact on the actual number of specimens of the population.

In recent decades no scientist could give a provable answer to this question; in fact, most have not even tried. The purpose of our investigation is to determine why there is a decrease in the number of ECB moths at the time of a full moon.

We considered the examination important because of the lack of certainty in the literature concerning the influence of the type of moonlight on the ECB light trap collection.

Material and Methods

The Full Moon time data we needed to create our lunar phase classes were downloaded from the Astronomical Applications Department of the US Naval Observatory: http://aa.usno.navy.mil/cgi-bin/aap/ap.pl. Further data required for our studies were found at the following sites: sunrise, sunset, beginning and end of civil twilight: http://aa.usno.navy.mil/cgi-bin/aa_pap.pl, the rise, set and phase of the Moon: http://aa.usno.navy.mil/cgi-bin/aa_pap.pl and http://aa.usno.navy.mil/data/docs/ MoonPhase.html, and the height of the Moon above the horizon: http://aa.usno.navy.mil/cgi-bin/aa_altazw.pl. We have arranged data by PELLICORI (1971) on the relative polarization of moonlight into classes of phase angle divisions. Data on the illumination of the environment were calculated with our own software. This software for TI 59 computer was produced by the late astronomer György TÓTH specifically for our joint work at the time (NOWINSZKY & TÓTH, 1987). The software was transcribed for modern computers by assistant professor Miklós KISS: we are extremely grateful for his work. The software calculates the illumination of the Sun at dusk, the light of the Moon and the illumination of the starry sky – all in lux – for any given geographical place, day and time, separately or summarized. It also calculates with cloudiness.

All our data on clouds were taken from the Annals of the Hungarian Meteorological Service. Data in these books are recorded for every 3rd hour in okta. We have used the value provided for a given hour and for the two hours following as well.

In addition to the above, we also considered light pollution data in calculating theoretical collecting distances. Our estimation was based on a study by CINZANO *et al*. (2001), according to lunar illumination data. In our work, we calculated with average illumination by a Full Moon. The collecting distance can be calculated with the help of the following formula:

$$r_0 = \sqrt{\frac{I}{E_S + E_M + E_{NS} + E_{LP}}}$$

Where: r_0 = collecting distance, I = illumination from the lamp [candela], E = the illumination coming from the environment [lux] the latter consisting of the light of the setting or rising Sun (E_S), the Moon (E_M), the starry sky (E_{NS}) and light pollution (E_{LP}).

We have defined the concept of real collecting distance as a section of the theoretical collecting distance along which an increase of the catch is observable.

Numerous factors influence the theoretical collection distance; the more important among the all-time theoretical collection distance can be found: configuration of the terrain, character of the terrain, buildings, covering of vegetation, disturbing lights, vagility of species, and the distance of insect response to a light stimulus.

The fractionating light-trap had as its light source three 40 W F33 fluorescent tubes, each 120 cm long, placed above one other, with a colour temperature of 4300 K. The material caught was identified by hours and levels by JÁRFÁS (1979). Using a light trap equipped with a 100 W normal bulb, our light trap caught data coming in part from the five-decade material of the National Agricultural and Forestry Light Trap Network of Hungary. We have downloaded 12 years of data on the ECB from the light traps working in the different states of the USA.

Table I. Catching data of European Corn Borer (*Ostrinia nubilalis* Hbn.)

Light-traps	**Years**	**Moths**	**Data**	**Nights**
Kecskemét (fractionating light-trap)	1967–1969	1408	707	190
Hungarian National light-trap network	1959–1963	16315	4190	501
Hungarian National light-trap network	1967–1969	17681	2433	390
Hungarian National light-trap network	2001–2006	93509	11264	937
USA (Nebraska, North-Carolina, Illinois)	1994–2005	81103	3677	1091

For every midnight of the flight periods (UT = 0 h) and – in the case of fractionating light traps – for the 30th minute of every hour we have calculated phase angle data of the Moon. For the 360 phase angle degrees of the full lunation we established 30 phase angle divisions. The phase angle division including a Full Moon (0º or 360º) and values 0 ± 6º was named 0. Beginning with this group through the First Quarter until a New Moon, divisions were marked as -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The next division was ±15, including the New Moon. From the Full Moon through the Last Quarter in the direction of the New Moon divisions, divisions were marked as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. Each division consisted of 12 degrees (NOWINSZKY, 2003). 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 and – when processing hourly data – also separately for hours with and without moonlight. Relative catch (RC) is the ratio of the number of specimens caught in a given sample unit of time (1 hour or 1 night) and the average number of specimens caught in the same time unit calculated for the whole brood. If the number of the specimens trapped equals the average, the value of relative catch is: 1. Only nights and hours with some catch were included in the calculations, as our earlier works (NOWINSZKY, 2003) had convinced us that although the Moon has an influence on the efficiency of trapping, it never makes collecting impossible. For the relative catch values we assigned the phase angle belonging to the given night or an hour to groups, and then averaged them.

First we studied the catch of species as a function of lunar phases based on the data of the National Light Trap Network in the different years. While comparing the catch results of earlier decades with those of recent years, we tried to detect differences that might indicate the possible impact of light pollution.

Likewise in relation with the lunar phases we examined data available on the Internet on the ECB from North-Carolina, Nebraska and Illinois between 1994 and 2006.

In our examination of the influence of lunar phases, we compared the catch of different trap types, over and above considering the distribution of the catch of the different species between the phase angle divisions. From the data of the fractionating trap of Kecskemét between the years 1967-1969 we examined the behaviour of ECB. We compared the catch of those species based on catch data of the National Light Trap Network in the same period.

We calculated the theoretical catching distances from the data of the fractionating light trap, then examined the efficiency of the trapping in the function of this.

The material from the fractionating light trap of Kecskemét also made it possible for us to examine separately the catch in the hours with or without moonlight and their difference in the First and the Last Quarter. Naturally, this study would have made no sense at a Full Moon or at a New Moon. Based on this material, we have investigated the relationship between collecting and the position of the Moon above the horizon. We examined it because of the measure of illumination coming from the Moon, and the proportion of the polarized moonlight in connection with the trapping. We examined whether the efficiency of the trapping differs if the moonlight is horizontal, or in vertical plane oscillates (negative or positive polarisation).

In our examination of the catch and the lunar phases, we plotted relative catch values against phase angle divisions. We analyzed the difference between the catch results of the 4 quarters with a t-test. We also plotted relative catch results against collecting distance, the position of the Moon above the horizon, the illumination caused by the Moon and polarized moonlight. For these curves, we calculated regression equations, the strength of correlation and significance level.

Results and Discussion

Results are shown in Figs. 1 – 8 and Tab. II.

We compared the catch results of the ECB in the periods 1959-1963 and 2000-2006. The catch results were very similar. In both periods, catch maxima fell to the vicinity of the First and the Last Quarter and minima to a Full Moon. Light pollution has evidently been on the increase in recent years, so the difference between the collecting distance at a New and a Full Moon decreased. Still, the catch minimum observed at a Full Moon is similar in dimension. Despite a compensation for the difference between collecting distances, low catches at a Full Moon are still observable. Consequently, in this period the catch of this species decreases for other reasons also (Fig. 1).

Table II. Results of light trapping depending on the positive and negative polarized moonlight (Kecskemét, 1967-1969).

Species	Negative pol. %	RC	N	Positive pol. %	RC	N	P
European Corn Borer *Ostrinia nubilalis* Hbn.	– 0.52	1.037	63	0.64	0.796	10	–
	– 1.06	0.786	7	1.52	0.927	19	–

Notes: The polarisation plane lays in the visual plane on the polarisation case of a negative; in case of positive polarisation the polarisation plane onto the visual plane perpendicular.

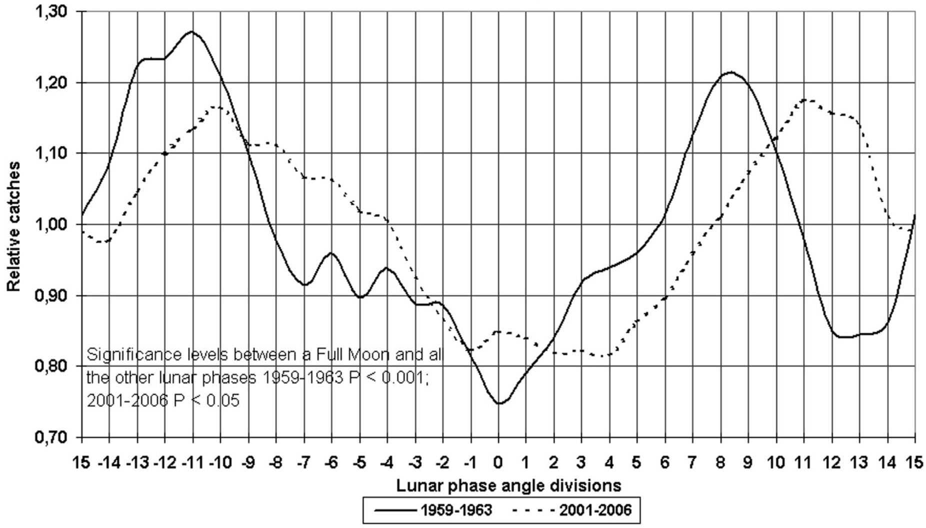

Figure 1. Light-trap catch of *Ostrinia nubilalis* as a function of lunar phases, based on data of Hungarian National Light-trap Network for the periods 1959-1963 and 2001-2006.

The USA is one of the most light polluted territories in the world. Thus, it was expected, that – as the difference between the collecting distance at a New and a Full Moon is nearly the same – there would be no significant change in the catch results at a Full Moon. However, a strong decrease is in fact observable in the catch at a Full Moon. The reason for this, though, has nothing to do with the collecting distance (Fig. 2).

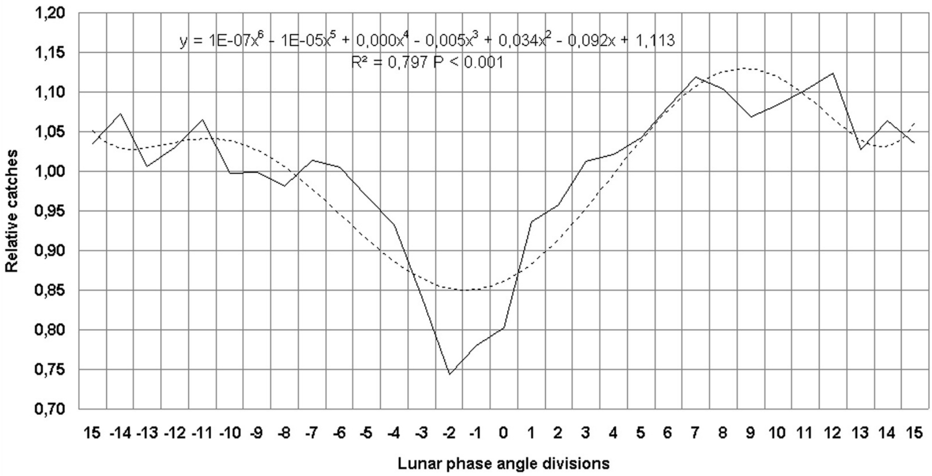

Figure 2. Light-trap catch of *Ostrinia nubilalis* as a function of lunar phases, based on data from USA (North Carolina, Nebraska and Illinois) (1994-2006).

There is a smaller peak before the first quarter in the catch of the fractionating light- trap. This is similar to the results of the national light-trap network, but there is an unambiguous maximum in the last quarter. Considerable difference can be experienced, but the catches of light-trap working with F33 light tubes, and of normal light traps operating with a 100W light bulb (Fig. 3).

Data of the light trap of Kecskemét prove a steep increase in the catch of the ECB to 90 m; this increase continues to 1015 m (Fig. 4). This is the limit of the theoretical collecting distance, so large only in heavily clouded weather. These moths have a strong capability for flight: “during their night activity they may fly a distance of several kilometres” (NAGY, 1993).

The position of the Moon above the horizon affects the trapping of the species under examination. The trapping of the ECB is more successful if the Moon is in the vicinity of the horizon, under 10 º (Fig. 5). This finding corresponds with the outcome of a study by AGEE (1969).

The efficiency of the catch is not different in moonlit and moonless hours, or in the first or last quarter (Fig. 6). The illumination coming from moonlight does not reduce the flying activity with general validity.

The catch increases to an average illumination value during the first quarter and last quarter of the Moon. The catch decreases then, until illumination which can be measured at the time of the full moon entirely. This fact reflects the low catch result at the time of the full moon (Fig. 7).

Examining the relationship between polarized moonlight and collecting has gained special significance since studies by DACKE *et al*. (2003) proved that certain insects can find their bearing with the help of polarized moonlight. Our findings also show a growth of light trap catch when the polarized part of the moonlight is higher.

The catch of the ECB is then high, when the proportion of polarized moonlight measures 2.5 and 6.4 %. This corresponds with the first- and in a last quarter measured for the proportion of polarized moonlight (Fig. 8).

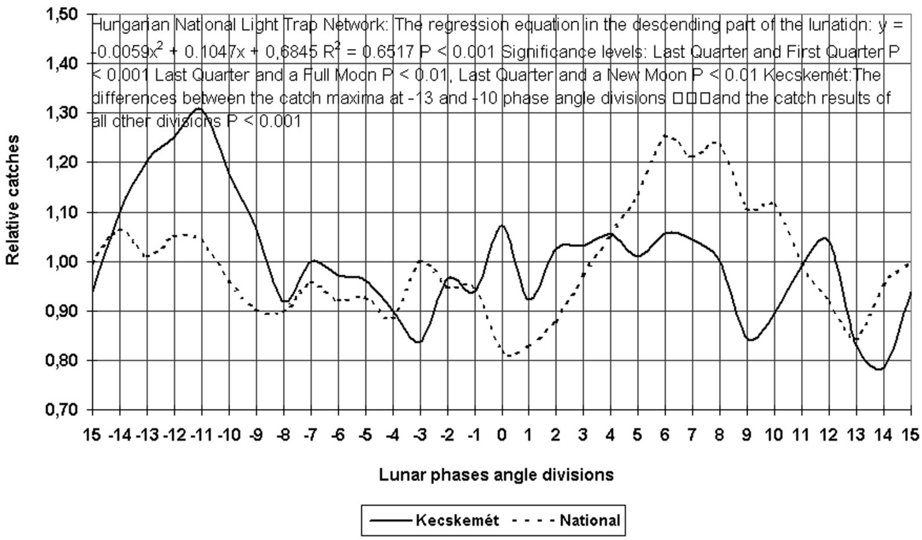

Figure 3. Light-trap catch of *Ostrinia nubilalis* as a function of lunar phases, based on data of the Kecskemét and the Hungarian National Light-trap Network from the period 1967-1969.

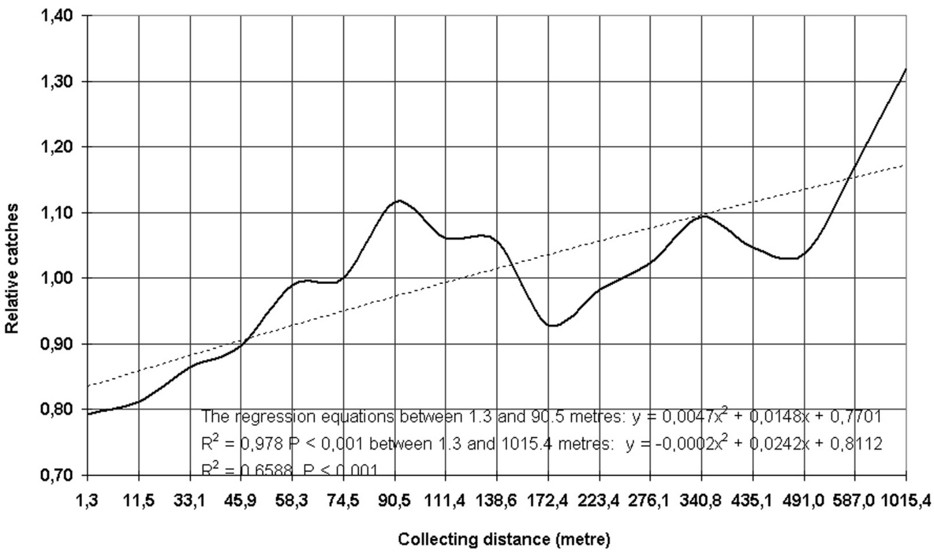

Figure 4. Light-trap catch of *Ostrinia nubilalis* as a function of collecting distance (Kecskemét, 1967-1969).

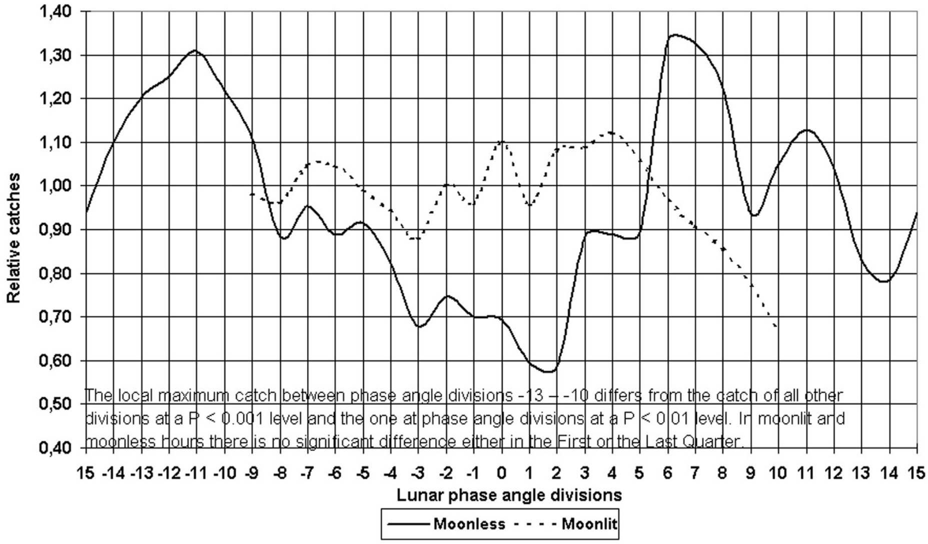

Figure 5. Light-trap catch of *Ostrinia nubilalis* in moonlight and moonless hours as a function of lunar phases (Kecskemét, 1967-1969).

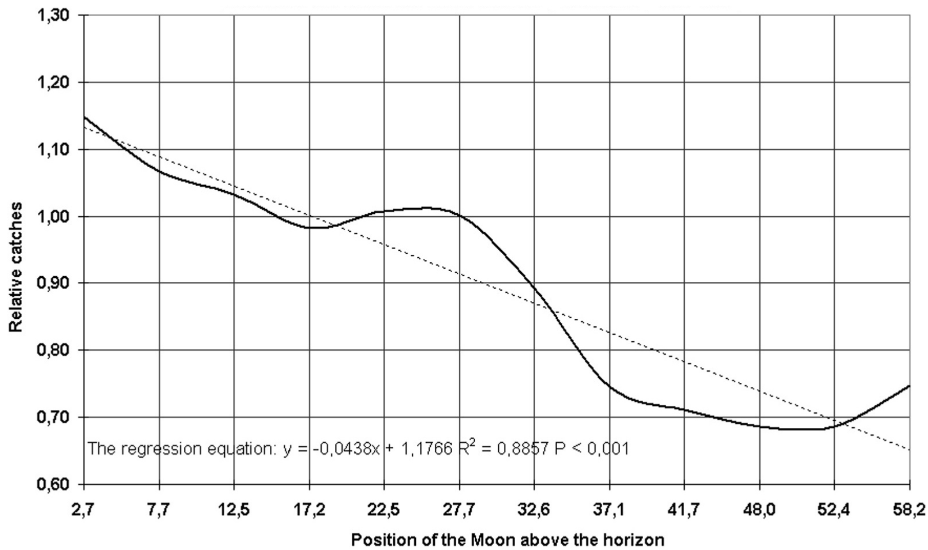

Figure 6. Light-trap catch of *Ostrinia nubilalis* as a function of the position of the Moon above the horizon (Kecskemét, 1967-1969).

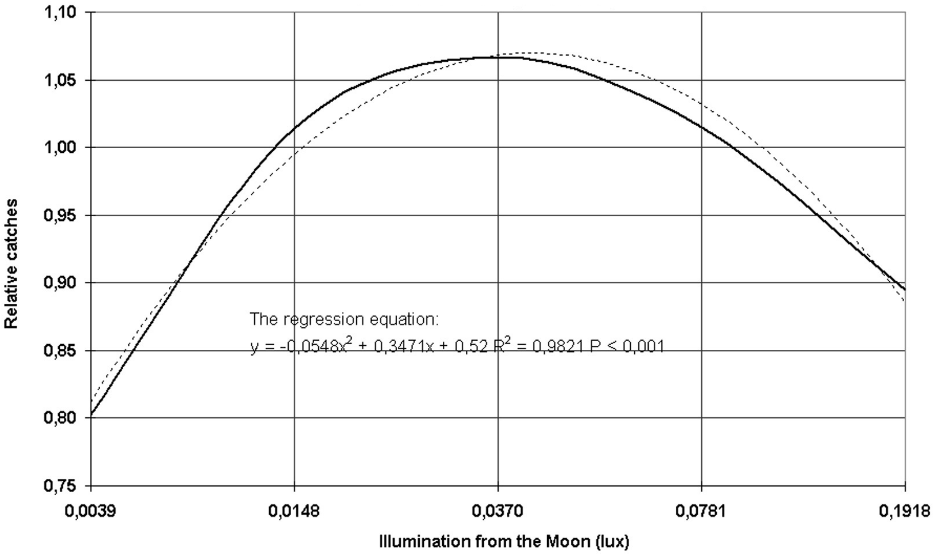

Figure 7. Light-trap catch of *Ostrinia nubilalis* as a function of illumination from the moon (Kecskemét, 1967-1969).

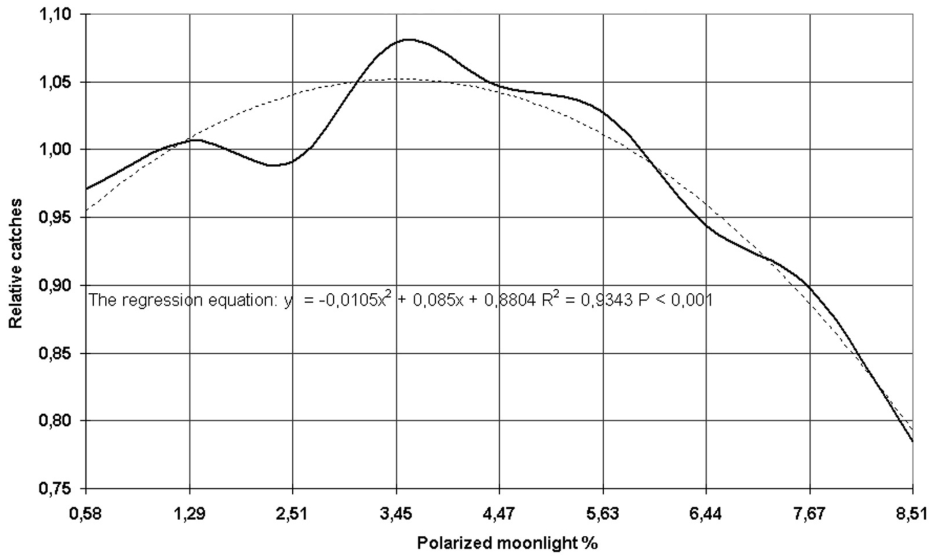

Figure 8. Light-trap catch of *Ostrinia nubilalis* as a function of polarized moonlight (Kecskemét, 1967-1969).

At the time of a full moon all the national light-trap network, all the fractionating light- trap, all though from the data of the American light-traps we observed a decrease in the catch. These results do not, however, confirm one of the assumptions by WILLIAMS (1936) concerning the cause of the inefficiency experienced at this time.

It is true that the increase in the catching distance yielded an increase in the catch in the Kecskemét light-trap. However, in the second half of the 1960s it was not yet necessary to reckon with considerable light pollution. The moderate catch result may have been due to the very small collection distance at the time of that full moon. The catches, all of which have decreased in recent years at the time of a full moon in Hungary, all though on USA's area. At present light pollution is so high that the difference in theoretical catching distances around the time of a full moon and a new moon is negligible (NOWINSZKY, 2006, 2008).

The cause of the catching minimum at the time of a full moon may in fact not be relatively strong illumination which, according to WILLIAMS (1936), reduces the flight activity of insects. The daily flying of most insect species occurs at twilight (NOWINSZKY *et al*., 2008). But, the illumination measured at twilight has a higher order of magnitude than it has in moonlight. In our opinion, based on experiments of DACKE *et al*. (2003), the activity of insects could not decrease when the proportion of polarized moonlight is high. The data in Table II prove the different direction of the oscillation plane of the polarized moonlight at the first quarter and last quarter and contrast around Full Moon does not produce significant difference in the catch.

According to EL-ZIADY (1957) the catching result around the Full Moon is moderate perhaps because the insects fly in higher air boundaries at this time. Because we have no catching data from light-traps operating at higher altitudes, we cannot examine this possibility in Hungary in terms of the ECB. or verify or confute the assumption of El-Ziady. We suggest the istallation of the light traps operating at an altitude of at least 10 metres.

Our new findings serve as fresh proof to confirm the influence of the Moon in modifying light trap catch which, in spite of decades of research, remains one of the most complicated and least clarified problems.

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ЗАВИСНОСТ УЛОВА ЕВРОПСКОГ КУКУРУЗНОГ ПЛАМЕНЦА (*OSTRINIA NUBILALIS* HBN.) ПОМОЋУ СВЕТЛОСНИХ КЛОПКИ ОД МЕСЕЧЕВЕ СВЕТЛОСТИ

ЛАСЛО НОВИНСКИ и ЈАНОШ ПУШКАШ

Извод

У раду је детаљно описана веза између месечевих мена, дистанце на којој је могуће привлачење лептира (catching distance), поларизоване месечеве светлости и деловања светлосних клопки на европског кукурузног пламенца *(Ostrinia nubilalis* Hbn.). Користили смо податке о улову помоћу светлосних клопки Мађарске Националне мреже за светлосне клопке, посебно клопки из Кечкемета, као и светлосних клопки постављених у различитим деловина Сједињених Америчких Држава.

Најмањи улов кукурузног пламенца био је за време пуног месеца у почетку и на крају периода за који смо пратили улов. Ово смањење броја уловљених примерака није било зависно од географског положаја локалитета и типа светлосне клопке. Улов се повећавао око прве и последње месечеве мене.

Наша истраживања су показала да ефикасност лова помоћу светлосних клопки расте када је удео поларизоване светлости у месечевој светлости виши (6,6 и 8,4 %).

Уопштено говорећи, месечева светлост не смањује ефикасност лова помоћу светлосних клопки путем скраћивања дистанци на којима је могуће привући лептира нити утиче на активност летења током фазе пуног месеца.

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