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Light trapping of Turnip Moth (*Agrotis segetum* Den. et Schiff.) connected with vertical component of geomagnetic field intensity

A vetési bagolylepke (*Agrotis segetum* Den. et Schiff.) fénycsapdás fogása a földmágneses térerő vertikális komponensével összefüggésben
(Lepidoptera: Noctuidae)

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Abstract – The study deals with the change of light-trap catch of the Turnip Moth (*Agrotis segetum* Den. et Schiff.), in connection with the vertical component of geomagnetic field and the moon phases. The numbers of specimens caught by generation relative catch values were calculated. These hourly relative catch data were assigned to the hourly values of vertical component of geomagnetic field. They were separated by the moonlit and moonless hours of the four quarter of the Moon (New Moon, First Quarter, Full Moon and Last Quarter) were classified. We correlated the hourly catch results pertaining to the hourly values of both the vertical component and moonlit or moonless hours of four moon quarters. After that we made correlation calculations to demonstrate the assumed connection. Our calculations 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.

Összefoglalás – A tanulmány a vetési bagolylepke (*Agrotis segetum* Den. et Schiff.) fénycsapdás fogásának eredményességét vizsgálja a holdfázisok és a földmágneses térerő vertikális komponensével összefüggésben. A befogott lepkék számából relatív fogás értékeket számítottunk. A relatív fogás a mintavételi időegységben (egy óra) befogott egyedek és a mintavételi időegység átlagos egyedszámának a hányadosa. A relatív fogás adatokat óránként hozzárendeltük a földmágneses térerő vertikális komponensének óránkénti adataihoz. Az adatpárokat szétválasztottuk a négy holdnegyed és ezeken belül a holdfény nélküli és a holdfényes órák szerint. A továbbiakban korrelációszámításokat végeztünk a feltételezett kapcsolat kimutatására. Számításaink azt mutatják, hogy az eltérő holdfázisokban és holdfényes és holdfény nélküli órákban eltérő a vertikális térerő fénycsapdás fogásra gyakorolt befolyása. Újholdkor, amikor nincs mérhető holdfény, a fénycsapdás fogás csökken a vertikális térerő magasabb értékeivel párhuzamosan. Holdtöltekor és első- és utolsó negyed holdfény nélküli óráiban a vertikális komponens növekedéséve párhuzamosan növekszik a fogás. Holdfényes órákban nem egyértelmű a földmágneses térerő befolyása.

Keywords – Lepidoptera, Noctuidae, *Agrotis segetum*, Turnip Moth, Geomagnetic field, lunar month, Hungary

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Introduction and literature background

It has been known for decades that different species of insects perceive geomagnetism, besides they use it for spatial orientation. A number of laboratory experiment and comprehensive reports deal with the physiological fundamentals and means of orientation of insects. These were summarised particularly in one of our studies (Tóth and Nowinszky1994), so here are referred only to the most important studies. Iso-Iivari and Koponen (1976) studied the effect of geomagnetism on light-trap catches of insects in the northernmost part of Finland. In their experiments they used the K-index values measured three-hourly, and the ΣK and δH values. A poor, but significant correlation was found between the geomagnetic parameters and the number of insects caught. Studying the few spotted ermel (*Hyponomeuta rorellus* Hbn.) Pristavko and Karasov (1970) found correlation between the C and SK values and the number of collected individuals. In a later study (Pristavko and Karasov 1981) they

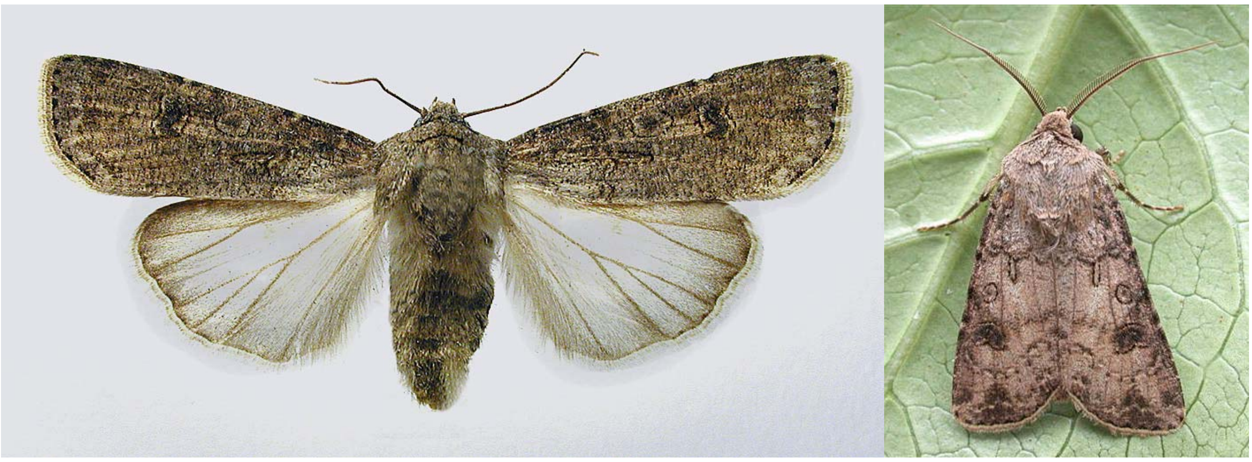

Fig. 1. *Agrotis segetum*, adult

found that ΣK had a greater influence on the flying activity of the above species at the time of geomagnetic storms. The influence is significant even in the years in which ΣK is not higher than 16-26. According to another interesting observation, if ΣK is 26, an increase of the flying activity follows the same day. With ΣK = 27-30, it happens the next day, and with ΣK = 33-41, only on the second or third day.

Studying termites (*Heterotermes indicola* Wasmann) Becker and Gerisch (1977) found a stronger correlation between the activity and the vertical component of geomagnetism (Z) than with K indices.

Tshernyshev and his colleagues have given a series of accounts of the results of their laboratory and light-trap experimentation's with different species of insects in order to reveal connection between geomagnetism and certain phenomena of life. During geomagnetic storms in Turkmen, Tshernyshev (1966) observed a multiplied increase in the counts of light-trapped beetles and plant bugs. He found a high positive correlation between the horizontal component and the volume of the trapped insects. It was impossible to show any influence of the alternating magnetic field on the activity of flies at low temperatures (22 degrees Celsius) in laboratory circumstances (Tshernyshev and Danilevsky 1966), but a significant raise was observed at 29 degrees. Tshernyshev (1968) studied the changes of biological rhythm of *Trogoderma glabrum* Herbst as a function of the perturbations of magnetic field. Assessment was based upon the K-index values over 4 (i.e. over 40 γ) measured at 6 p.m. and 9 p.m., as well as at 3 a.m. He proved that the biological rhythm of the species under study is influenced by factors corresponding to the perturbations of magnetic field. It is also his observation (1965) that the amount of light-trapped insects rises considerably during magnetic perturbations. Later, however, Tshernyshev (1971 and 1972) says that, while the light-trap catches of some *Coleoptera* and *Lepidoptera* species increase during magnetic field perturbations that of other *Lepidoptera* and *Diptera* species is reduced by the phenomenon. Again, Tshernyshev and Afonina (1971) observed the same: the activity of certain species of moths and beetles was increased by a weak and changing magnetic field in the laboratory, but in some cases the activity was reduced. A summary of contemporary knowledge of the relation between geomagnetism and the activity of insects based on international literature and his studies was given by Tshernyshev in a comprehensive study in 1989.

The examinations of the last decade have also proved some Lepidoptera species, such as *Noctua pronuba* L. (Baker and Mather 1982) and *Agrotis exclamationis* L. (Baker, 1987) use both the Moon and the geomagnetism for their orientation and, on top of all that, they are able to integrate these two kinds of information. During cloudy nights, the imagines of *Noctua pronuba* L. orientated with the help of geomagnetism. In this case, too, they preferred the direction they had chosen when orienting by the Moon and the stars. In our earlier works (Kiss et al. 1981; Nowinszky and Tóth 1983; Tóth and Nowinszky 1994), on the basis of data obtained by light-trap catches, it was found that both the Moon and the geomagnetism play part in the orientation of the Turnip Moth (*Agrotis segetum* Den. et Schiff.) and the fall webworm moth (*Hyphantria cunea* Drury). Namely, the light-trap catches of the above mentioned species are dissimilarly affected by the increase or decrease of geomagnetic field strength in different moon phases.

Material

The average field strength of the Earth as a magnetic dipole is 33 000 gamma. 1 gamma = 10^{-5} Gauss = 10^{-9} Tesla = 1 nanotesla (nT). Geophysical literature uses gamma as a unit. Geomagnetic field strength can be decomposed into three components: H = horizontal, Z = vertical and D = declination components. The magnetic and the geographic poles of the Earth do not coincide, therefore besides the geographic co-ordinates; the geomagnetic latitudes are to be distinguished, too. These latter are characteristic of the geomagnetic conditions of a given geographic location. The geographic parameters are extraordinarily different in various regions of the Earth's surface at a given moment of time. Approximately, a distance of 300 kms along the geomagnetic meridian may result in significantly differing characteristics. Regarding Hungary, the geomagnetic data measured at one single observatory supply sufficient information for the whole country. These measurements are made at Nagycenk, near Sopron, in the Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences, and at Tihany, in the Observatory of the Hungarian Loránd Eötvös Geophysical Institute.

For our research, the values of the vertical component (V) of geomagnetic field strength were taken from the yearbooks of the latter institute, in which varying values of 41 800 nT-t or those surpassing a higher basic level are published yearly.

There were used the data of Turnip Moth (*Agrotis segetum* Den. et Schiff.) from a fractioning light-trap from a three-year period. This special light-trap system was established and operated by József Járfás in Kecskemét-Katonatelep, between 1967 and 1969.

The fractioning light-trap had as its light source three F-33 type fluorescent tubes; one installed above the other, 120 cm long each, with colour temperature of 4300 ºK. The trapping time was between 6 p.m. and 4 a.m. (UT) daily. The storing bottles were changed every hour by a changing device. József Járfás identified the collected insects separately, according to hours, levels and species. There was neither difference between moths coming from first and second generation nor ones caught on different levels. Although each swarming was examined separately, the results were got after the joint evaluation.

Methods

We could work with values above 41 800 nT when the light-trap catch data were worked up, because there was no significant difference between the values of vertical component of geomagnetic field intensity in years 1967–1969.

Relative catch (RC) values were calculated from the number of caught samples of Turnip Moth (*Agrotis segetum* Den. et Schiff.) for each generation. It was established in our former works (Kiss et al. 1981; Tóth and Nowinszky 1994) it is not expedient to examine the influence of geomagnetism for trapping independently of light conditions. That is why the relative catch data were separated to cases with moonlight and without it according to Moon phase-angle around the four quarters of the moon.

The Moon phase-angle values were calculated for the 12 p. m. (UT) during all the nights in the swarming time of each species. There were made 30 phase-angle groups from the 360 phase-angle values of whole lunation. The notation of group with phase-angle values surrounding of Full Moon (0° or 360°) ± 6° is 0. The notation of groups from 0 through the First Quarter to New Moon is -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13 and -14. The notation of groups from Full Moon through the Last Quarter to New Moon is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The notation of phase group with New Moon is ±15. The following phase-angle groups are in the characteristic quarter of moon: Full Moon (-2 – +2), Last Quarter (3 – 9), New Moon (10 – -10) and First Quarter (-9 – -3).

There was made a comparison between the hourly light-trap catch results of Turnip Moth (*Agrotis segetum* Den. et Schiff.) and the hourly values of vertical component. There were made groups for the connected value pairs. The geomagnetic and relative catch values were averaged in each group, and weighted moving average was calculated using our own method (Nowinszky 1994) and relative catch values. After it correlation calculations were made to show the supposed connections.

Results and Discussion

The weighted moving average belonging to the vertical component values of Turnip Moth (*Agrotis segetum* Den. et Schiff.) is shown in Table 1.

Our results are almost the same as the results of our above-mentioned former work (Tóth and Nowinszky, 1994), in which the influence of horizontal component of geomagnetic field intensity was examined for some species and also the Turnip Moth (*Agrotis segetum* Den. et Schiff.).

At New Moon, when there is no measurable moonlight, decreasing relative catch can be found with higher values of vertical component. At the time of other moon phases, in surrounding of First Quarter, Full Moon and Last Quarter when there is no moonlight, the relative catch increases linearly with the increasing values of horizontal component. In those hours, when there is moonlight, the difference is that the catch decreases on the higher values of vertical component. This decrease could not be recognised in the examination of horizontal component. It seems in the period of lunation when during a part of night the presence of Moon can give orientation information for moths; the insects' orientation can be helped firstly by light stimulus although the Moon is not above the horizon. The geomagnetic field intensity can increase the insects' flight activity, but the light stimulus is most important factor in orientation, so trapping is more successful. Surrounding of New Moon when insects cannot get any information from the Moon for their orientation during the whole night, it can be supposed the increasing geomagnetic field intensity gets bigger part in the orientation in contradiction to light stimulus, which increases the safety of orientation. Recently, a similar correlation was detected the horizontal component of the geomagnetic field and the light-trap catch of the Turnip Moth (Nowinszky and Puskás, 2011).

Table 1.Relative catch of turnip moth (*Agrotis segetum* Schiff.) on hourly values of above 41 800 nT vertical component (Z) of geomagnetic field intensity

Hours without moonlight new moon			Hours without moonlight full moon, first- and last quarter			Hours with moonlight independently from moon phases		
Z	RC	N	Z	RC	N	Z	RC	N
91.5	2.195	22	87.3	0.462	87	88.8	0.873	67
94.3	1.857	21	93.5	0.600	84	95.4	1.012	69
96.5	1.124	27	95.8	0.654	113	97.0	1.104	57
98.8	0.702	31	97.5	0.805	164	98.0	1.256	63
100.7	0.626	35	99.4	0.839	150	99.0	1.145	83
102.0	0.567	16	101.0	0.902	121	100.0	1.134	41
103.0	0.714	27	102.7	0.894	103	101.0	0.999	62
104.0	0.756	25	102.7	0.894	103	101.0	1.061	75
109.9	0.836	31	108.2	1.073	81	106.2	0.821	62
			124.8	1.449	62	110.5	0.642	53
$y = -8.2303Ln(x) + 38.939$ $R^2 = 0.6045$ $P < 0.05$			$y = 0.0268x - 1.8589$ $R^2 = 0.9782$ $P < 0.001$			$y = -0.0031x^2 + 0.5981x - 28.082$ $R^2 = 0.8535$ $P < 0.01$		

Note: N = number of observing data

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