Research Article

BIOMEDICAL
Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2023.51.008078

Influence of Solar Activity and Geomagnetism on Moth Species Collected by Pheromone Traps in North Carolina

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ARTICLE INFO

Received: June 19, 2023

Published: June 27, 2023

Citation: Puskás J, Hill L, Kiss M and Nowinszky L. Influence of Solar Activity and Geomagnetism on Moth Species Collected by Pheromone Traps in North Carolina. Biomed J Sci & Tech Res 51(2)-2023. BJSTR. MS.ID.008078.

ABSTRACT

The relationship between the activity of moths, as indicated by pheromone traps, to solar activity and Earth magnetism was investigated in North Carolina, USA. Relationships were found but species differed in their responses. These results are similar to those found in light- and pheromone trapping data on moth and caddisfly species in Hungary and Australia.

Keywords: Pheromone; Trapping; Moths; Solar Activity; Geomagnetism

Introduction

Pheromone traps are used around the world in the fight against harmful insects. The catch indicates the presence of pest species, the start of its swarming, the population size and the swarming process in a place of interest. For plant protection prognosis, it is usually sufficient to count the captured insects at 2- or 3-day intervals. The light-trap is another collecting device that is used for various scientific purposes and its uses predates the use of pheromone traps. Early in their use, researchers recognized that the effectiveness of light-traps is affected by several environmental effects. Many scientific publications on this topic have appeared in many countries of the world. We have investigated environmental factors for decades such as in our recent book (Nowinszky, Puskás, Hill [1]), which includes references to earlier work by us and others. Most pertinently to the current study, we had the opportunity to study environmental effects on pheromone trap collection data in Hungary. Plant protection entomologist, Gábor Barczikay counted and trapped the pheromone trapping results of 8 harmful moth species daily between 1982 and 2013 in a Hungarian orchard. Using this rare daily data set, we published a number of studies together with him including in a book (Nowinszky, Puskás [2]). In the current report, we investigated the influence of solar activity and Earth magnetism, as among the most important environmental factors, using the data of moth species collected in the state of North Carolina, USA.

Material

The activity of the Sun is the common name for a group of local disturbances of the Sun's radiation. Solar electromagnetic and corpuscular radiation affects the geophysical parameters on Earth, which in turn affects the biosphere. The solar activity includes all the information about the Sun's surface that can be detected by using several methods. The most important activity is the 10.7 cm solar radio flux. The solar radio flux at 10.7 cm (2800 MHz) is an excellent indicator of solar activity. It correlates well with the sunspots, flares and a number of ultraviolet (UV) and visible solar irradiance records. The F10.7 has been measured consistently in Canada since 1947, first at Ottawa, Ontario and then at the Penticton Radio Observatory in British Colum-

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bia. Unlike many solar indices, it can easily be measured reliably on a day-to-day basis from the Earth's surface, in all types of weather. The data we use was published by British Geological Survey (http://www.geomag.bgs.ac.uk/data_service/space_weather/solar.html).

A derivative of solar activity is the D_{st} (Disturbance Storm Time) index, which has been measured since 1957/58. It characterizes the earthly manifestations of space weather by measuring the strength of the ring current around the Earth, which is created by protons and electrons originating from the Sun. The so-called geomagnetic storms are large disturbances of the Earth's magnetic field that can be defined by changes in the D_{st} index. This index describes the globally averaged change of the horizontal component of the Earth's magnetic field at the magnetic equator. It is calculated hourly by using measurements from a few stations at low latitudes (Honolulu, San Juan, Hermanus, and Kakioka). The size of a geomagnetic storm is classified as moderate (−50 nT > minimum of D_{st} > −100 nT), intense (−100 nT > minimum D_{st} > −250 nT) or super-storm (minimum of D_{st} < −250 nT). In quiet times the D_{st} ranges between +20 and −20 nanoTesla (nT). We used the data of hourly equatorial D_{st} values (Final) published by WDC Kyoto Observatory. Moth (Lepidoptera) species have been trapped in pheromone traps in the state of the North Carolina (USA) for many years at several localities: Lenoire, Sampson County and Johnston County. This catch data was available on the internet for the years 1996, 1998, 1999, 2000 and 2002.The catching data used for the calculations are summarized in Table 1.

Table 1: Catching data of examined species.

Species	Years	Number of Moths	Data
Crambidae, Pyraustinae			
European Corn Borer	1996, 1998, 1999	1,305	98
Ostrinia nubilalis Hübner, 1796			
Southwestern Corn Borer	1998, 1999	7,533	106
Diathraea grandisella Dyar, 1911			
Noctudae, Heliothinae			
Tobacco Budworm Moth	1996, 1998, 2000	3,571	370
Chloridea virescens Fabricius, 1777			
Corn Earworm	1998, 2002	8,313	221
Heliothis zea Boddie, 1850			
Noctuidae, Noctuinae			
Western Bean Cutworm	1999	5,680	51
Striacosta albicosta Smith, 1888			

Methods

Basic data were the number of individuals of each of five species caught in one night. In order to compare the differing sampling data, relative values were calculated. The relative catch value (RC) was the quotient of the number of specimens caught during one night per the average nightly catch of individuals within the relevant sampling period. The RC was one when the actual nightly catch was equal to the average nightly catch across the whole trapping period (Nowinszky [3]). All catch data by species were considered as a single sample and the relative catch values were counted from these. However, some of the data represented trapping over 2-3 nights recorded as a single date. In these cases, the 10.7 cm solar radio flux and D_{st} data were added to these dates and processed. The D_{st} data were also available hourly, and since moths are most active in the first half of the night, local time data of 21 hours was taken into account. The relative catch values were added separately for each species to the 10.7 cm solar radio flux and D_{st} values of each night. After that, groups were formed from the data pairs with the number of groups or classes calculated according to Sturges' method (Odor, Iglói [4]). We averaged within groups the 10.7 cm solar radio flux, D_{st} index and relative catch and plotted them.

Results

Our results are shown in Figures 1-10. The catch of four of the five investigated species increased in parallel with the increase in the value of the 10.7 cm solar radio flux. The exception was the Tobacco Budworm Moth (*Chloridea virescens* Fabricius, 1777), whose catch increased initially and then decreased. Examples of different responses by different species in our previous studies include: Most caddisfly (Trichoptera) species increase activity with increasing 10.7 cm solar radio flux: *Neureclipsis bimaculata* Linnaeus, 1758, *Hydropsyche contubernalis* McLahlan, 1865, *Hydropsyche bulgaromanorum* Malicky, 1877, *Brachycentrus subnubilus* Curtis, 1834, *Halesus digitatus* Schrank, 1781 (Kiss et al., 2021). Likewise, an Australian moth species: Tree Lucerne Moth (*Uresiphita ornithopteralis* Guenée, 1854) (Nowinszky, et al. [5]). Increasing then decreasing: *Ecnomus tenellus,* Rambur, 1842 (Trichoptera) (Kiss, et al. [6]). In regard to D_{st} index, two types of relationship were found: Decreasing and increasing then decreasing catch values as D_{st} values increased.

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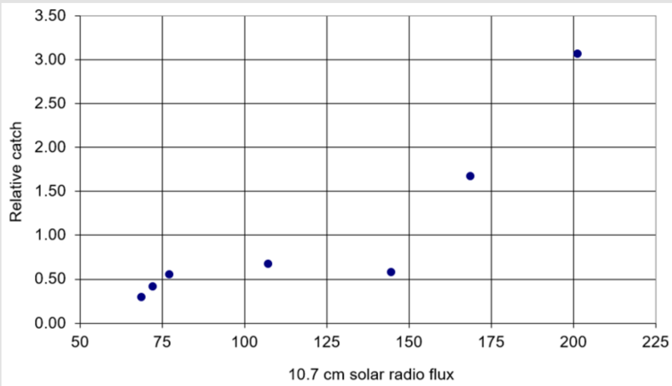

Figure 1: Pheromone trap catch of European Corn-borer (*Ostrinia nubilalis* Hübner, 1796) in connection with the 10.7 cm solar radio flux.

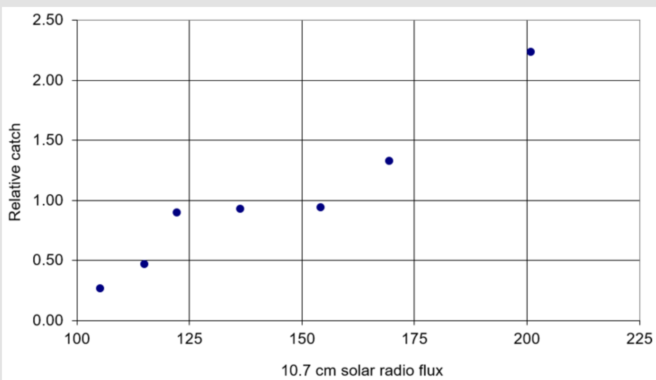

Figure 2: Pheromone Trap of Southwestern Corn Borer (*Diatraea grandiosella* Dyar, 1911) in connection with the 10.7 cm solar radio flux.

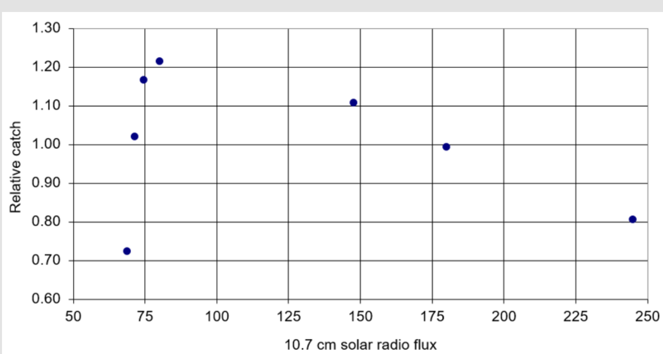

Figure 3: Pheromone trap catch of Tobacco Budworm Moth (*Chloridea virescens* Fabricius, 1777) in connection with the 10.7 cm solar radio flux.

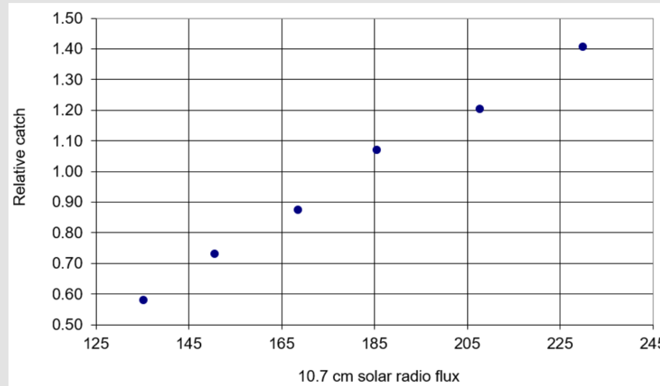

Figure 4: Pheromone trap catch of Corn Earworm (*Heliothis zea* Boddie, 1850) in connection with the 10.7 cm solar radio flux.

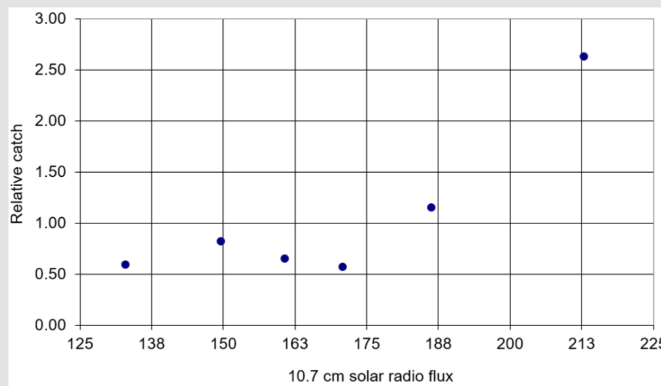

Figure 5: Pheromone trap catch of Western Bean Cutworm (*Stiacosta albicosta* Smith, 1888) in connection with the 10.7 cm solar radio flux.

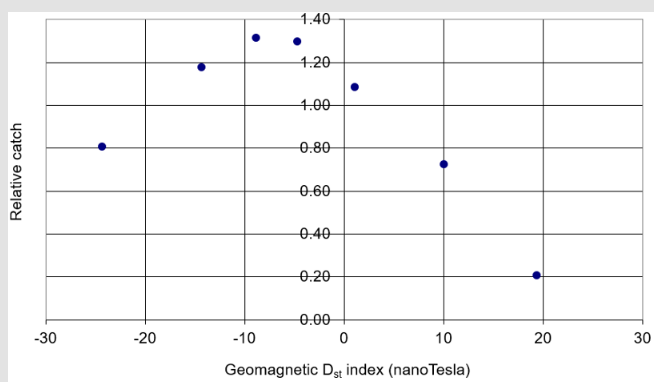

Figure 6: Pheromone trap catch of European Corn-borer (*Ostrinia nubilalis* Hübner, 1795) in connection with the geomagnetic D_{st} index.

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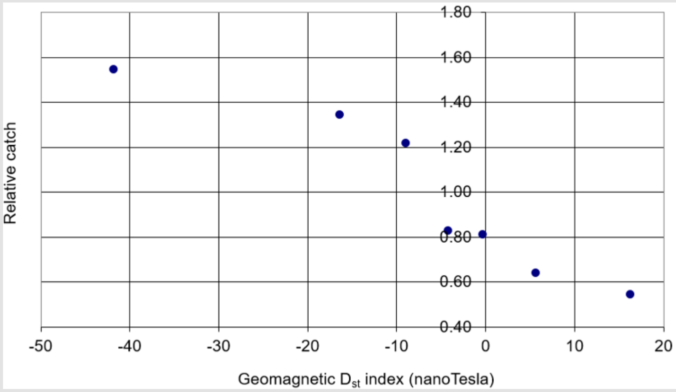

Figure 7: Pheromone trap catch of Southwestern Corn Borer (*Diatraea grandiosella* Dyar, 1911) in connection with the geomagnetic D_{st} index.

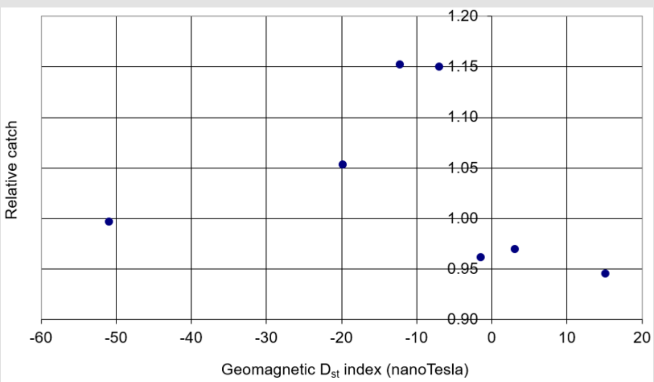

Figure 8: Pheromone trap catch of Tobacco Budworm (*Chloridea virescens* Fabricius, 1777) in connection with the geomagnetic D_{st} index.

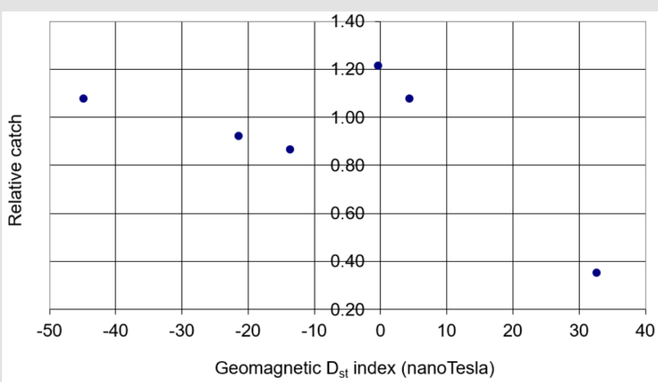

Figure 9: Pheromone trap catch of Corn Earworm (*Heliothis zea* Boddie, 1850) in connection with the geomagnetic D_{st} index.

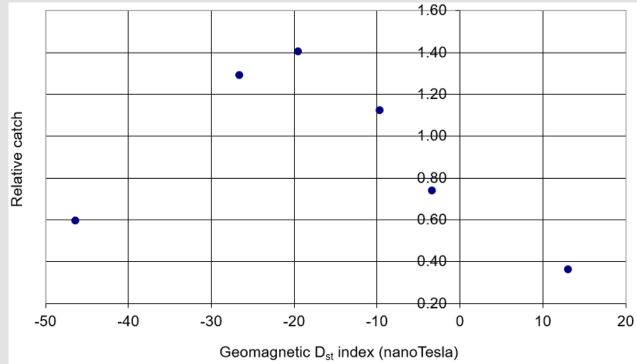

Figure 10: Pheromone trap catch of Western Bean Cutworm (*Striacosta albicosta* Smith, 1888) in connection with the geomagnetic D_{st} index.

The two species showing decreasing activity were the Southwest Corn Borer (*Diathraea grandisella* Dyar, 1911) and Corn Earworm (*Heliothis zea* Boddie, 1850). The increasing and then decreasing type of response occurred in the other three species: European Corn-borer (*Ostrinia nubilalis* Hübner, 1796), Tobacco Budworm (*Chloridea virescens* Fabricius, 1777) and Western Bean Cutworm (*Striacosta albicosta* Smith, 1888).We could not obtain significant results from such a small number of catch data. This problem always arises when we are not able to perform our calculations with very large data sets. A solution to this is offered by the hypothesis that we previously proposed (Nowinszky, et al. [7]). We propose that results that meet two conditions can be considered real. One is that results from multiple independent samples are essentially the same. The other condition is that the results can be interpreted based on our prior knowledge. The results of our previous studies based on other species in other continents are extremely like our current results. One of our studies (Nowinszky, et al. [8]), examined the effectiveness of light trapping of 8 caddisfly (Trichoptera) species in relation to geomagnetic D_{st} index values. The catch results of two caddisfly species increased and then decreased: *Hydropsyche bulgaromanorum* Malicky, 1977 and *Setodes puctatum* Fabricius, 1793.

In another study (Nowinszky, et al. [7]) we processed data from a Mészáros-type light-trap operated in Bečej (Serbia) also in connection with the D_{st} values. This high-performance light-trap collects many moths. Among them, we found the decreasing type of response in the Green Oak Tortrix (*Tortrix viridana* Linnaeus, 1758) while the European Corn-borer (*Ostrinia nubilalis* Hübner, 1796), Lesser Belle (*Colobochyla salicalis* Denis & Schiffermüller, 1775) and the Ruby Tiger (*Phragmatobia fuliginosa* Linnaeus, 1758) displayed the increasing and then decreasing type of response to increasing D_{st} index. In a recent study (Nowinszky, et al. [9]) we found similar behavior of moths collected in pheromone traps in Hungary. In analyzing data for seven species, we found that two species belonged to the increasing then decreasing type: Hawthorn Red Midget Moth (*Phyllonorycter corylifoliella* Hübner, 1796) Oriental Fruit Moth (*Grapholita molesta* Busck, 1916). In all cases, independence is clear and the types of behavior can also be interpreted from a professional point of view. The explanation for the decreasing type can be that negative values of D_{st} are favorable and positive values are unfavorable for insects. In the case of the increasing and then decreasing type, increasing D_{st} values initially favor the increase in flight activity, but above a certain value, they inhibit it. Although pheromone traps are primarily used for prognosis of pest activity, we consider it worthwhile to study the collected data in connection with the impacts of environmental factors on insect activity.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2023.51.008078

Nowinszky L. Biomed J Sci & Tech Res