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Research Article

Results of Insect Catching with Light- and Pheromone Traps During Top Solar Flares from Three Continents

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Abstract

This study investigates the influence of extremely rare top solar flares on light- and pheromone trapping of insects. Caddisfly (Trichoptera) and moth (Lepidoptera) species were collected in Hungary, and additional moth species were collected in Australia and the USA. In most cases, the influence of top solar flares was noticeable on the night of the day of the flare, but the results were not the same, increasing or decreasing the catch. In some cases, the influence of the top solar flares did not take effect until the following night.

Keywords: Top solar flares; light- and pheromone traps; moth; caddisfly

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 [1]. 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 Hα line. During the appearance of intensive solar flares, corpuscular emission can be one thousand times stronger than in a quiet state of the Sun. From these, proton clouds move in all directions of space, including, of course, towards the Earth. Corpuscular radiation reaches the Earth's surface after about 27-28 hours, and electromagnetic radiation can already be detected on Earth with its accompanying phenomena just over 8 minutes after the appearance of the flare. Based on the X-ray radiation of the flares between 1-8 Ångström, the flares producing the highest energy are classified into classes X1, X2, ..., X9, their energy production is greater than 0.0001 W/m^2. The intensity of those larger than X10 - which are already super flares - is greater than 0.001 W/m^2. The X9s are "very strong" flares. Although flares are phenomena of the optical range, the best indicator of their appearance is the radiation flux measured in the microwave range of the Sun.

This is measured using the radio astronomy method, according to international convention, at the frequency of 2800 MHz, i.e., at the wavelength of 10.7 cm. The Q-index values developed by Turkish astronomers [2] are also good expressions of flares. The Q-index considers both the intensity and period of prevalence of the flares [3]. Flares do not leave modern technology untouched either, the current ones have caused minor or major disturbances in high-frequency radio devices and low-frequency navigation systems. The electromagnetic and corpuscular radiation of the Sun are regarded as general factors, which have a general modifying effect for weather and climate [4] suggested that solar activity, such as solar flares, may cause irregular departures from typical climatic conditions. The weather influences the symptoms of life of the insects and, of course, their multiplication and flying activity too. Therefore, it is justified to investigate the change of catches by light-trap of insects as a function of solar activity. The weather influences the symptom of life of the insects and, of course, their multiplication and flying activity too. Therefore, it is justified to investigate the change of catches by light-trap of insects as a function of solar activity.

In connection with both the 10.7 cm solar radio flux and the Q-index values, we have examined the effectiveness of light-trap insect collection in several studies. The caddisfly (Trichoptera) species could be classified into three types parallel to the Q-index values: increasing, decreasing, increasing and then decreasing [5]. The behavior of the caddisfly (Trichoptera) species in relation to the 10.7 cm solar radio flux values was also investigated. Four types were distinguished: increasing, decreasing, increasing then decreasing and decreasing then increasing [6]. In another study, the light-trap catches of 30 moth (Lepidoptera) species is examined in relation to the Q-index values. Here we have established four types of behaviour: increasing, decreasing, increasing then decreasing and decreasing then increasing [7]. In a new study were examined different moth and caddisfly species collected with light-traps in Hungary, Tasmania and Nebraska (USA). In this study only three types were identified: increasing, decreasing, increasing and then decreasing [8]. In the present paper we examined the effectiveness of light trapping of moth species from three continents and caddisfly species collected in Hungary.

Materials and Methods

SpaceWeatherLive.com has published the most important data of the Top 50 solar flares seen since 1996, such as date and intensity. From this list, we selected the 33 flares for which we found light-trap catching data. The selected flares are listed in Table 1. In Hungary (Central Europe) a standardised network of agricultural and forestry Jermy-type light-traps operated from 1958 until the present. These light-traps operating all over the country have provided researchers with an enormous amount of catching data in the past decades. As well in Hungary many caddisflies (Trichoptera) were collected for many years by Ottó Kiss. He determined and recorded all the individuals of all species collected in mountain streams and on the banks of the Danube and Tisza Rivers. The Tasmanian data derive from decades of near-continuous (1992-2019) operation of a 160W Rothamsted-design light-trap at Stony Rise. This light-trap was operated by Lionel Hill and he also determined the large amount of caught moths. In the US state Nebraska for many years, moth (Lepidoptera), beetle (Coleoptera) and bug (Heteroptera) species have been light trapped in several places. They publish their collection data on the Internet.

Table 1: The strongest solar flares since June 1996 which were used in the investigations.

Number	Date	Start	Maximum	End	Storm
1	11-27-1997	12:59	13:17	13:20	X2.6
2	5-6-1998	7:58	8:09	8:20	X2.7
3	8-18-1998	8:14	8:24	8:32	X2.8
4	8-18-1998	22:10	22:19	22:28	X4.9
5	8-19-1998	21:35	21:45	21:50	X3.9
6	11-28-1998	4:54	5:52	6:13	X3.3
7	7-14-2000	10:03	10:24	10:43	X5.7
8	11-26-2000	16:34	16:48	16:56	X4
9	4-2-2001	21:32	21:51	22:03	X20+
10	4-6-2001	19:10	19:21	19:31	X5.6
11	4-15-2001	13:19	13:50	13:55	X14.4
12	8-25-2001	16:23	16:45	17:04	X5.3
13	12-13-2001	14:20	14:30	14:35	X6.2
14	7-15-2002	19:59	20:08	20:14	X3
15	7-20-2002	21:04	21:30	21:54	X3.3
16	7-23-2002	0:18	0:35	0:47	X4.8
17	8-24-2002	0:49	1:12	1:31	X3.1
18	5-28-2003	0:17	0:27	0:39	X3.6
19	10-28-2003	9:51	11:10	11:24	X17.2+
20	11-4-2003	19:29	19:53	20:06	X28+
21	7-16-2004	13:49	13:55	14:01	X3.6

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22	1-17-2005	6:59	9:52	10:07	X3.8
23	1-20-2005	6:36	7:01	7:26	X7.1
23	9-7-2005	17:17	17:40	18:03	X17+
25	9-8-2005	20:52	21:06	21:17	X5.4
26	9-9-2005	9:42	9:59	10:08	X3.6
27	9-9-2005	19:13	20:04	20:36	X6.2
28	12-13-2006	2:14	2:40	2:57	X3.4
29	8-9-2011	7:48	8:05	8:08	X6.9
30	5-13-2013	15:48	16:05	16:16	X2.8
31	5-14-2013	0:00	1:11	1:20	X3.2
32	11-5-2013	22:07	22:12	22:15	X3.3
33	10-24-2014	21:07	21:41	22:13	X3.1

Table 2: Catching data of moth and caddisfly species collected by light-traps in Hungary, Tasmania, Nebraska and North Carolina.

Species	Number of		Serial number of
	Individuals	Data	Top solar flares
Lepidoptera, Hungary			
Gracillariidae, Lithocolletinae			
Horse-chestnut Leaf Miner	243	35	14, 15, 16, 17, 21
Cameraria ohridella			
Deschka & Dimič, 1986			
Crambidae, Pyraustinae			
European Corn-borer	7,095	1,196	4, 5, 7, 12, 14, 15, 16, 17, 18, 25, 26, 27
Ostrinia nubilalis Hübner, 1796			
Arctiidae, Arctiinae			
Autumn Webworm	166	81	14, 15, 16, 18, 21
Hyphantria cunea Drury, 1773			
Noctuidae, Heliothinae			
Scarce Bordered Straw	869	291	4, 5, 12, 14, 15, 16, 17, 18, 21, 25, 26, 27, 29
Helicoverpa armigera Hübner, 1808			
Lepidoptera, Tasmania			
Plutellidae			
Diamond-back Moth	536	56	1, 6, 13, 19, 20, 23, 28, 31, 32, 33
Plutella xylostella Linnaeus, 1768			
Lepidoptera, Nebraska, North Carolina			
Crambidae, Pyraustinae			
European Corn-borer	1,321	81	7, 12, 21
Ostrinia nubilalis Hübner, 1796			
Noctuidae, Heliothinae			
Corn Earworm	1,790	42	7,12, 21
Heliothis zea Boddie, 1850			
Noctuidae, Noctuinae			
Western Bean Cutworm	5,077	39	7, 21
Striacosta albicosta Smith, 1888			

Trichoptera, Hungary			
Trichoptera complex	299	65	3, 4, 7, 16, 17, 18, 21, 26, 27, 28

Table 3: Catching data of moth species collected by pheromone traps in Hungary.

Species	Number of		Serial number of
	Individuals	Data	Top solar flares
Gracillariidae, Lithocolletinae			
Spotted Tentiform Leafminer *Phyllonorycter blancardella* Fabricius, 1781	1899	84	3, 4, 7, 18, 21, 29, 30, 31
Hawthorn Red Midget Moth *Phyllonorycter corylifoliella* Hübner, 1796	161	30	29, 30, 31
Gelechiidae, Anacampsinae			
Peach Twig Borer *Anarsia lineatella* Zeller, 1839	220	81	3, 4, 12, 14, 15, 16, 21, 30, 31
Tortricidae, Olethreutinae			
European Vine Moth *Lobesia botrana* Denis et Schiffermüller, 1775	598	82	2, 7, 12, 14-16, 19, 21, 23, 25-27
Codling Moth *Cydia pomonella* Linnaeus, 1758	452	106	7, 15, 16, 18, 21, 24, 25-27, 29-31
Oriental Fruit Moth *Grapholita molesta* Busck, 1916	703	130	2-4, 7, 12, 15-17, 18, 25-26, 29, 30
Plum Fruit Moth *Grapholita funebrana* Treitschke, 1835	1303	153	2-4, 7, 12, 14-17, 21, 29-31

Biologist Gábor Barczikay† operated pheromone traps between 1982 and 1990 in nine villages in the orchards of Borsod-Abaúj-Zemplén county of Hungary. An additional two traps operated between 1993 and 2013. The catch data of the collected species is given in Tables 2 & 3. Despite the fact that strong flares are quite rare, we found enough catching data to attempt to investigate the effect of strong flares on trapping results. We searched for the catch data for the day of the flares for each of the species available to us. The data of the -2 days and +2 before and after the flares were also selected. In total, we selected 5 days of data per species for each flare. We totaled the number of insects for these days per species. The catch data for each day was calculated as a percentage of the total catch of the five days. Our results are presented in Figures.

Results and Discussion

Our results are shown in Figures 1 & 2. (Figures 1-16). As a result of the top solar flares, the catching with light- and pheromone traps of the examined species could be classified into six types.

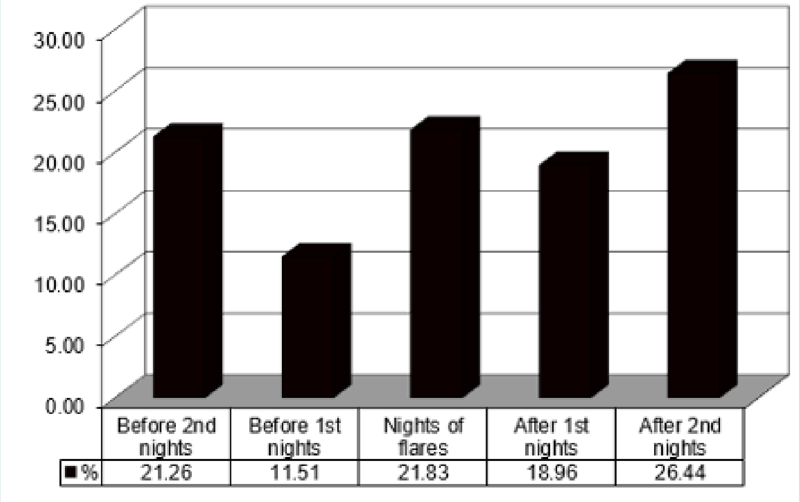

Figure 1: Light-trap catch of Horse-chestnut Leaf Miner (Cameria ochridella Deschka & Dimic, 1986) in connection with the top solar flares.

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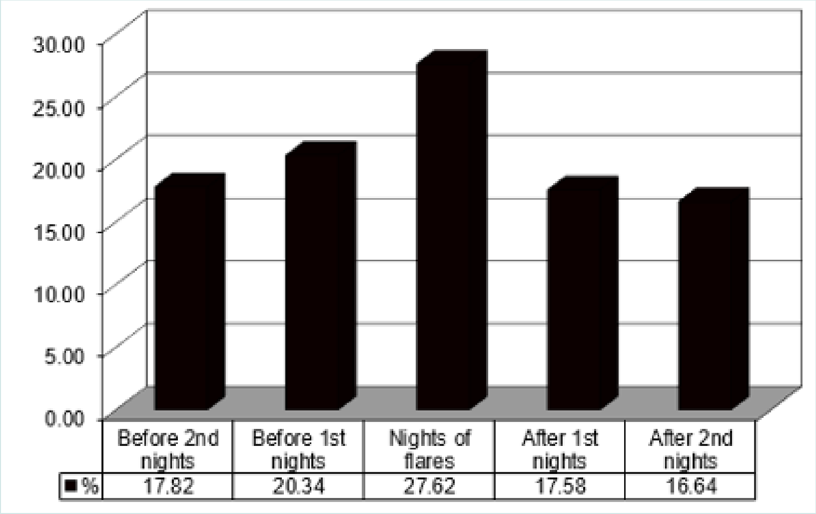

Figure 2: Light-trap catch of European Corn-borer (Ostrinia nubilalis Huber, 1796) in connection with top solar flares (Hungary).

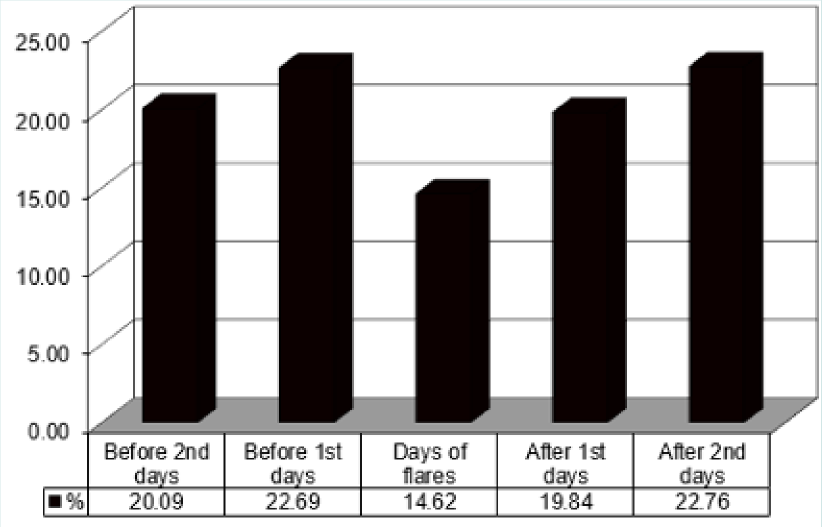

Figure 3: Light-trap catch of Autumn webworm (Hyphantria cunea Dury, 1773) in connection with top solar flares.

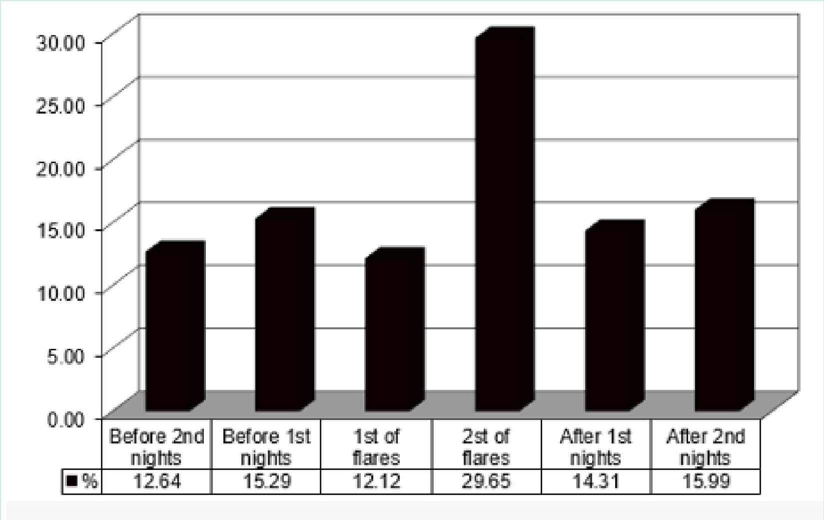

Figure 4: Light-trap catch of Scarce Bordered Straw (Helicoverpa armigera Hubner, 1808) in connection with top solar flares.

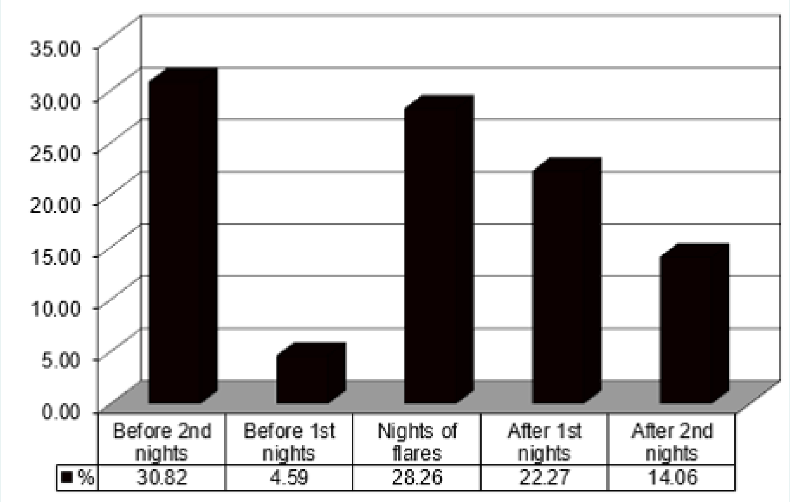

Figure 5: Light-trap catch of Diamond-back Moth (Plutella xylostella Linnaeus, 1758) in connection with the top solar flares.

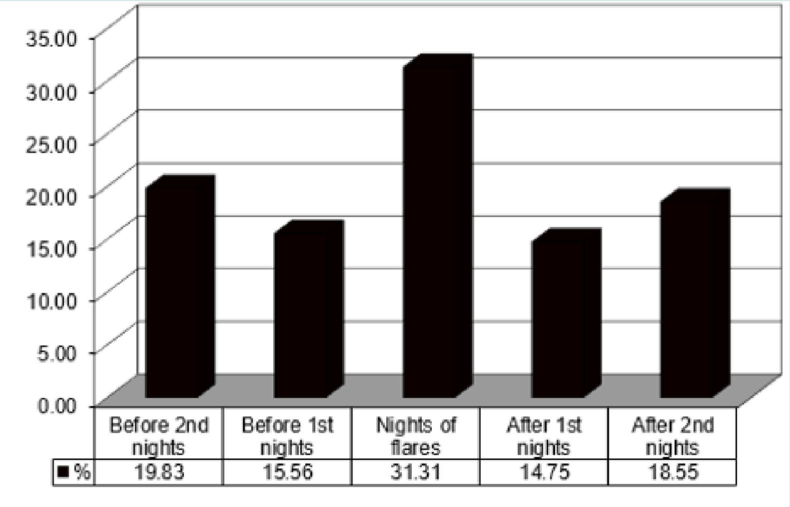

Figure 6: Light-trap catch of European Corn-borer (Ostrinia nubilalis Huber, 1796) in connection with top solar flares (North Carolina).

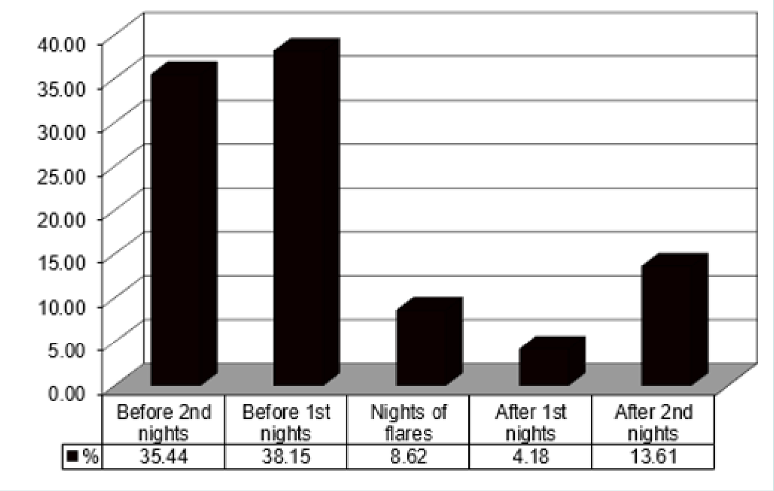

Figure 7: Light-trap catch of Corn Earworm (Heliothis Zea Boddies, 1850) in connection with top solar flares.

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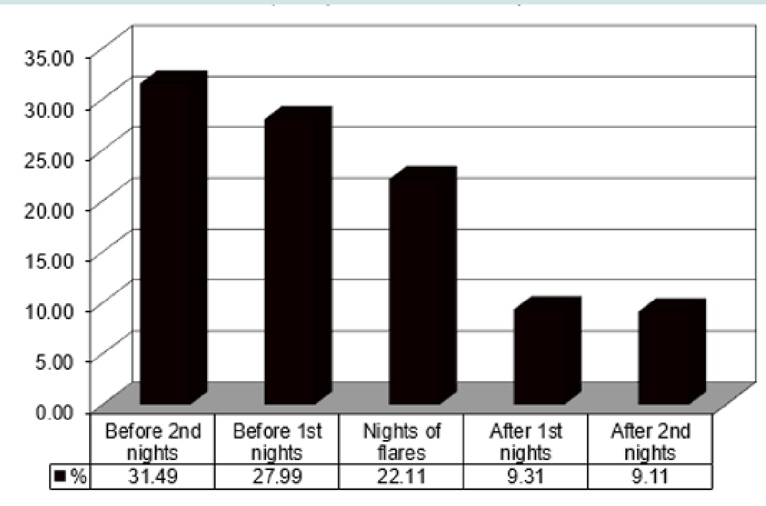

Figure 8: Light-trap catch of Western Bean Cutworm (Striacosta alibicosta smith, 1888) in connection with top solar flares.

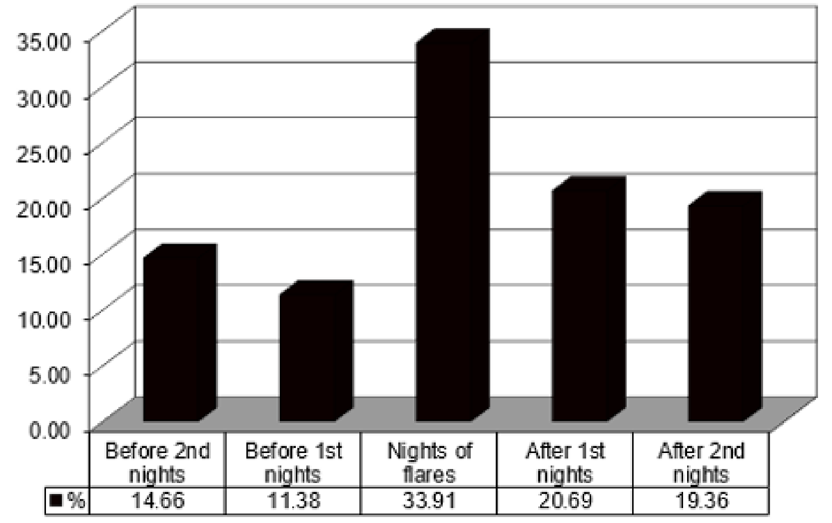

Figure 9: Light-trap catch of Trichoptera complex in connection with top solar flares.

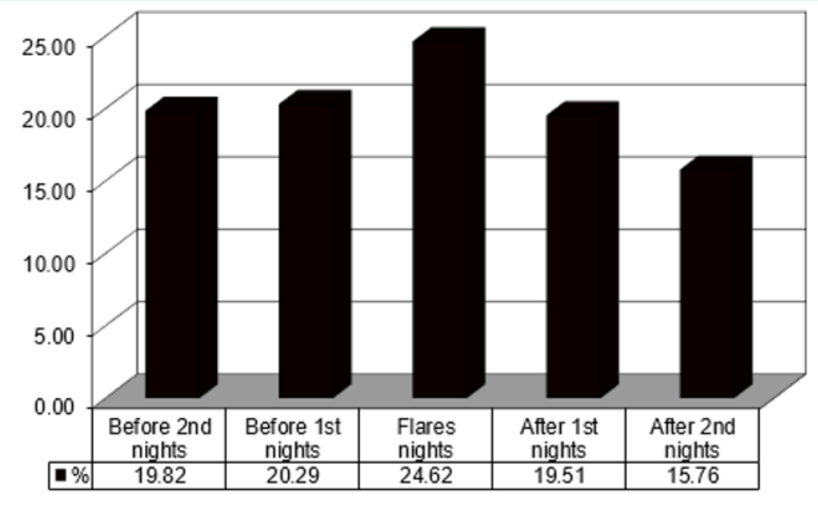

Figure 10: Pheromone trap catch of Spotted Tentiform Leafminer (Phyllonorycter blancardella Fabricius, 1781) in connection with top solar flares.

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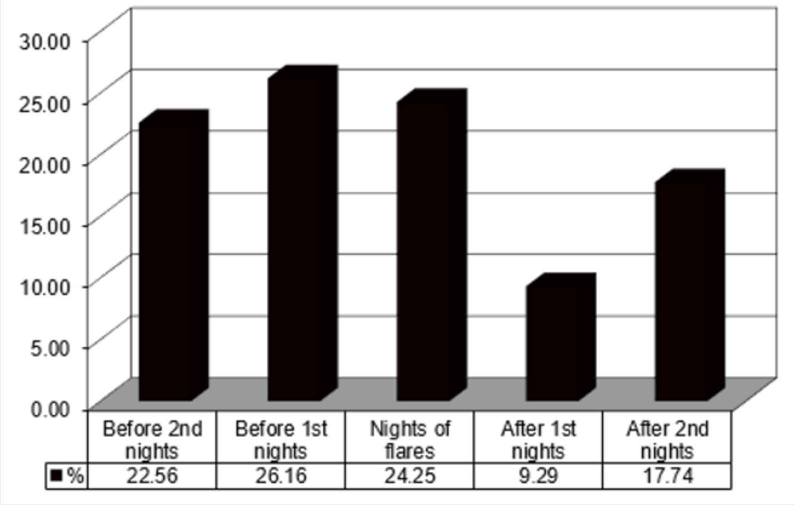

Figure 11: Pheromone trap catch of Hawthorn Midget (Phyllonorycter corylifoliella Hubener, 1796) in connection with top solar flares.

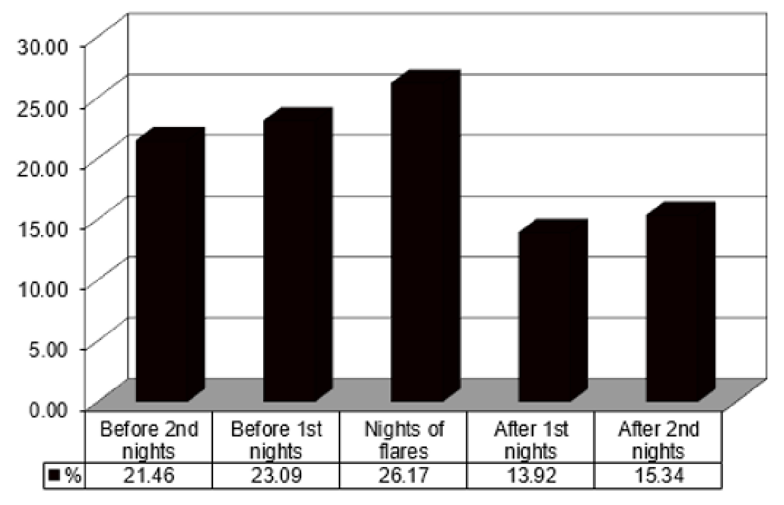

Figure 12: Pheromone trap catch of Peach Twig Borer (Anarsia lineatella Zeller, 1839) in connection with top solar flares.

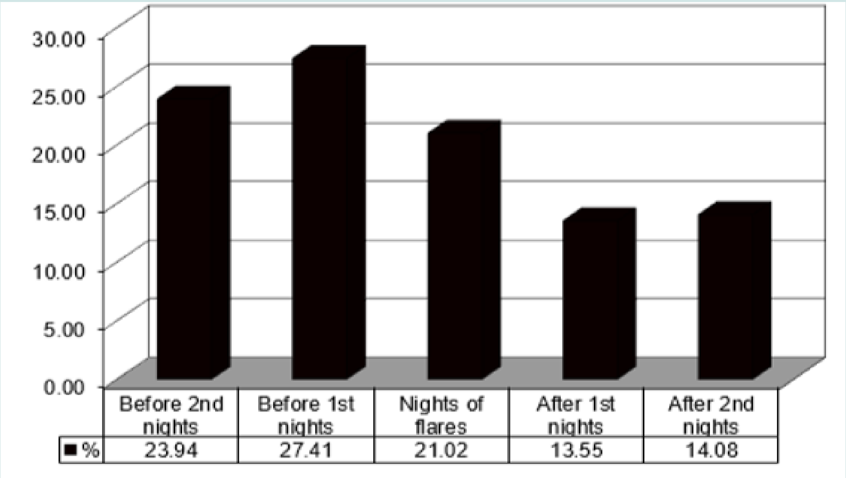

Figure 13: Pheromone trap catch of European Vine Moth (Lobesia botrana Denis & Schiffermuller, 1775) in connection with top solar flares.

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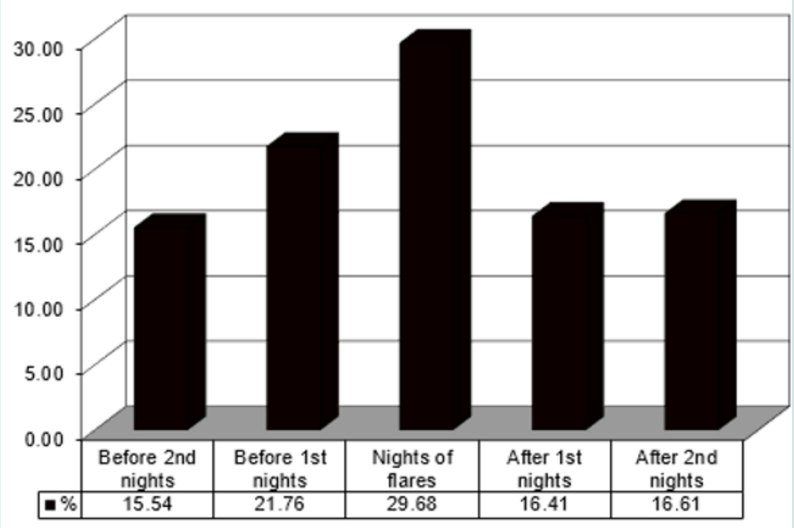

Figure 14: Pheromone trap catch of Codling Moth (Cydia pomonella Linnaeus, 1758) in connection with top solar flares.

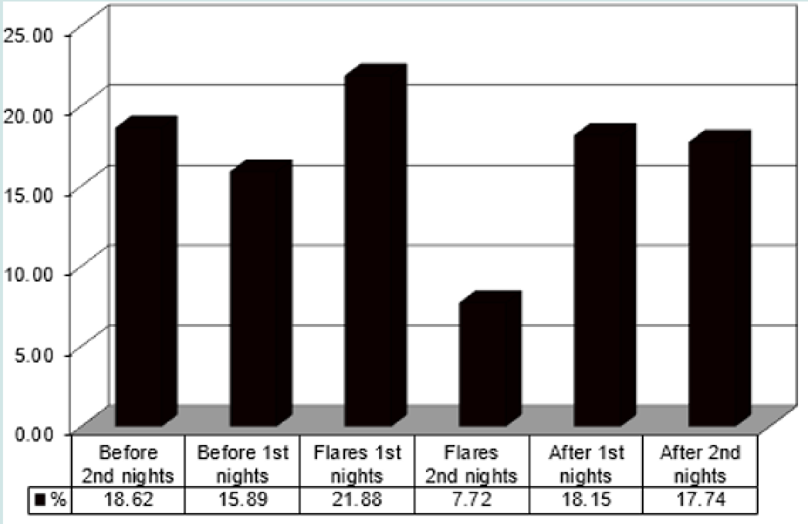

Figure 15: Pheromone trap catch of Oriental Fruit Moth (Grapholita molesta Bruck, 1916) in connection with top solar flares.

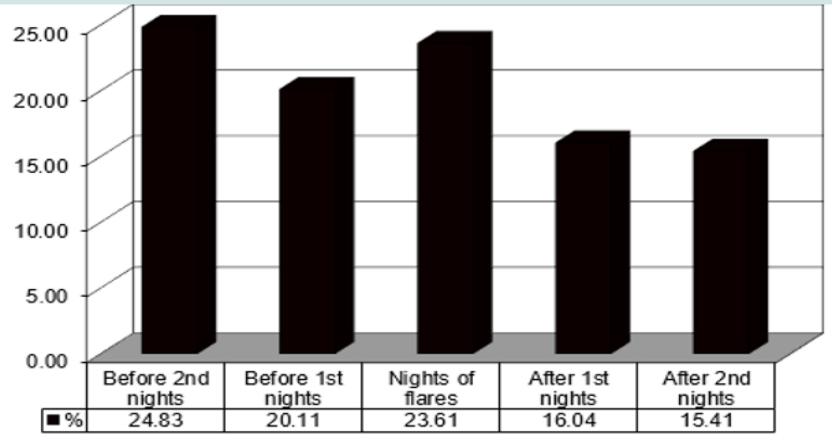

Figure 16: Pheromone trap catch of Plum Fruit Moth (Grapholita funebrana Treitschke Linnaeus, 1835) in connection with top solar flares.

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The catch drops the day before the top solar flares

This type includes two species, *Cameraria ochridella* and *Plutella xylostella*. We cannot explain this result, but it can hardly be a coincidence. Further investigations are still needed to explain it.

The catch decreases on the night of top solar flares

The following species belong to this type: (*Hyphantria cunea, Heliothis zea, Striacosta albicosta* and *Lobesia botrana*. It is striking that the decrease remains even in the days following the top solar flare, except for *Hyphantria cunea*. This type occurs in both light- and pheromone traps. It is assumed that the electromagnetic radiation from the top solar flares causes changes in the physical state of the atmosphere, to which these insects respond with a decrease in flight activity.

The catch increases on the night of top solar flares

The following species belong to this type: *Ostrinia nubilalis* both in Hungary and USA, *Trichoptera* complex, *Phyllonorycter blancardella* and *Cydia pomonella*. In contrast to the previous type, here the insects respond to atmospheric changes with an increase their flight activity, both in light- and pheromone traps.

The catch is high on the night of the top solar flares but decreases sharply the following night

The following species belong to this type: *Anarsia lineatella* and *Grapholita molesta*. Both species were caught in the pheromone trap.

The night after the top solar flare, the catch drops

Two species belong to this type, and they were also caught only by the pheromone trap: *Phyllonorycter corylifoliella* and *Grapholita funebrana*.

Only one species could be classified into the last type

If a flare appeared on two consecutive days and on the night of the second flare, the catch of *Helicoverpa armigera* was exceptionally high.

All these results (with the exception of the first type) can be explained based on our results so far. The different behavior of different species is not at all surprising. We presented many examples of this in our recently published book [9]. The effect of Ground Level Enhancements (GLE) is most similar to the current results. The GLE event also rarely occurs. Therefore, data of the GLE +2 and -2 days before and after the GLE were also examined. The results were as follows: On the night of the GLE the catch was high: *Trichoptera* complex, *Heliothis zea, Cydia pomonella, Grapholita molesta* and *Grapholita funebrana*. It was low: *Hyphantria cunea*. On the first night after the GLE, the catch is low: *Ostrinia nubilalis* both in Hungary and the USA and even *Xestia* c-nigrum. Since both top solar flares and GLEs are extremely rare events, we cannot obtain significant results with traditional significance tests, even if we work with such a huge amount of data as we do in these works. In our opinion, in such cases we can accept the results as real if they meet two conditions [10]. One requirement is that they can be repeated from independent samples, and the other is that they can be interpreted based on our professional knowledge. With the exception of the first type of top solar flares, the other results meet these conditions, so they are real.

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