THE EFFECTIVENESS OF CATCHING CUTWORM (LEPIDOPTERA: NOCTUIDAE: NOCTUINAE) (= AGROTINAE) IN PHEROMONE TRAPS AND LIGHT TRAPS, FOR SHORT-TERM FORECASTING

Magdalena Jakubowska[1]*, *Jan Bocianowski*[2]

[1] Department of Pest Methods Forecasting and Plant Protection Economy, Institute of Plant Protection – National Research Institute, Władysława Węgorka 20, 60-318 Poznań, Poland
[2] Department of Mathematical and Statistical Methods, Poznań University of Life Science, Wojska Polskiego 28, 60-637 Poznań

Received: September 26, 2012
Accepted: July 17, 2013

Abstract: In recent years, a local, growing population of cutworm in agricultural fields with various plants such as vegetables, horticultural, and ornamental plants has been observed. The scope of our research covered the observation of two species of cutworms: *Agrotis segetum* (Schiff.) and *A. exclamationis* (L.), which are the most dominant species in Poland. Cutworms were monitored in the 2005–2009 season with the use of Delta type pheromone traps with synthetic sexual pheromone and self-catch traps with a light source. The purpose of the research was to determine the dependence between the dynamics of the catches and the location of the traps, in fields with sugar beet, winter barley, and winter wheat in two municipalities: Winna Góra and Więcławice for the two studied cutworm species. Moreover, we used light traps in our analysis of the two studied cutworm species', flight dynamics in Poznań, Winna Góra, and Więcławice in the 2003–2006 time period. The overall results can be used for adjusting the currently used monitoring methods for short-term and long-term forecasting of cutworm flights, and for optimizing chemical control of the cutworm.

Key words: cutworm, effectiveness, forecasting, light traps, monitoring, pheromone traps

INTRODUCTION

Common cutworms: Turnip moth [*Agrotis segetum* (Den. et Schiff.)] and Heart and Dart moth (*A. exclamationis* L.), are serious polyphagous pests of different crops. Cutworms attack a wide range of plant species in their various growth stages. The Turnip moth and Heart and Dart moth produce one generation in Poland, though it is possible for the Turnip moth has an incomplete second generation. Even in years with a very warm vegetative period, only specimens of pupae and larvae of a second generation of Heart and Dart moth have been found. The quantity and quality changes which repeat every year in specific seasons, are the result of differences in the biotic cycles of the species (Jakubowska 2011).

The larvae are nocturnal in habits, spending the day hiding in the litter or in the soil. Farmers often only notice the presence of the larvae after the damage already occurred (Garnis and Dąbrowski 2008).

In agricultural plant protection, signaling that there is a pest to crops has been rarely used, except in respect of a few phytophage species (Walczak *et al*. 2010). In order to determine the optimal time for controlling agrophages, first the appropriate monitoring of the agrophages must be conducted (Walczak 1999). Such monitoring involves systematic observation to determine the severity of the disease or the stage of development and the population size of the pests. If the threshold of economic harmfulness is exceeded, the decision must be made about whether or not to start chemical treatment (Walczak 2007, 2008). Research on the practical application of assessment methods and techniques used in monitoring the Turnip moth and the Heart and Dart moth has resulted from numerous reports on the growing population size of cutworm in farms, in recent years. Reports have been submitted by manufacturers, and farmers as well as plant and seed protection inspectors (Esbjerg *et al*. 1986; Esbjerg 2003; Jakubowska and Walczak 2008, 2009). Harmfulness of the Turnip moth (*A. segetum*) and the Heart and Dart moth (*A. exclamationis*) is determined first of all by the population size of the cutworm, which is effected largely by the weather conditions (Allen 1976; Esbjerg *et al*. 1986; Esbjerg 1988; Meržeevskaya 1989; Buszko and Nowacki 1990, 1991; Artyszak 2011). Effectiveness of cutworm control depends largely on the duration of the moth flight, and then of the caterpillar incubation. It is difficult to predict the time and the place of cutworm mass appearances. In our study and that of other authors (Garnis and Dąbrowski 2008), observations showed that producers often spray their fields with the recommended insecticides, but they did so when the cutworms were already in the

*Corresponding address:
M.Jakubowska@iorpib.poznan.pl

mature larvae stages. Experience outside Poland suggests that prophylactic use of granular insecticides is not economically justified due to the irregular presence of cutworms in individual fields.

From a practical point of view, the simplest solution to be used by farmers in their fields is the pheromone trap. Success of the trap is based on secretion of a specific synthesized compound (sex pheromone), which allows the males of the species to be caught. Pheromone traps are used successfully with such crops as vegetables to monitor the flight of harmful species (Toth *et al*. 1992; Walczak 1998; Gameno and Haynes 2000; Wiech *et al*. 2001; Verma and Verma 2001; Rogowska 2005; Baranowski and Gaczkowska 2006; Rogowska and Wrzodak 2006; Szwejda and Wrzodak 2006; Bereś and Sionek 2010; Bereś 2011, 2012). Light traps are another research method used to determine the population size of pests.

The first aim of the study was to determine the harmfulness of the Turnip moth and the Heart and Dart moth based on moths caught. The second aim was to investigate the suitability of pheromone traps available on the Polish market, which are used for monitoring short-term flight of the Noctuinae to farms of fields of selected crops.

MATERIALS AND METHODS

The experiment was conducted in Poland, in the Wielkopolska Region, in Winna Góra (52°12'N, 17°27'E) (municipality of Środa Wlkp.) during the 2005–2009 time period, and in the Kujawsko-Pomorskie Region, in Więcławice (52°84'N, 18°30'E) (municipality of Gniewkowo) during the 2005–2007 time period. Observations were made on sugar beet, winter wheat, and winter barley to monitor the presence of Agrotis moths. We used Polish "Medchem" pheromone traps of the Delta trap type with Hungarian pheromone dispensers, for catching the male Turnip and Heart and Dart moths. Traps were placed on the farm fields in mid-May, approximately 3–5 m from the field edge. One trap was placed on each field. The average size of the field was from 1 hectare (winter barley, and sugar beet) to up to 1.6 hectares (sugar beet). The sticky floors were checked systematically 2–3 times a weeks. The population size of caught males was recorded for each individual species. The dispensers were changed every 4–5 weeks as necessary. The monitoring of cutworms with the use of pheromone traps was maintained till the third decade of August. In Winna Góra, there were 12 sample catches from pheromone traps, and in Więcławicach 8 catch samples.

Cutworms were caught in a light trap with a glow tube (250 W mercury lamp mix) supplied from an AC source. Moths were caught in light traps at nights from dusk till early morning (a time clock regulated the operation of the light traps from 9:00 p.m. to 6:00 a.m. the next morning). Moths picked from the light traps were systematically segregated and marked. Those collected cutworms with the best preserved taxonomic characteristics were marked and identified. Specialist keys, catalogs, and comparative collections were used for identifying the material caught. Light traps were used each year to catch Agrotis moths in the period from May to October in the 2003–2006 season, conducted in the cities of Poznań, Winna Góra and Więcławice. In each of the three localities there was one light trap set up to catch the moths. Traps were set in Więcławice and Winna Góra adjacent to the sugar beet fields. In Poznań trap was put in the phenological garden which had a microplot for breeding two species of moths. Light traps were an average of 70 to 120 km from each other. In the research carried out, on average, 19 samples catches were made by light traps.

Statistical analysis

Results collected from pheromone traps were statistically analyzed. Firstly, the normality of distribution for the studied traits was tested using the Shapiro-Wilk's normality test (Shapiro and Wilk 1965). One-way analysis of variance (one-way ANOVA) was performed in order to verify the hypothesis concerning no impact of years on the population size of *A. segetum* and *A. exclamationis*. Similarly one-way analyses of variance were performed to disclose differences between locations and fields (independently) in respect to the occurrence of *A. segetum* and *A. exclamationis* moths. The Tukey's honestly significant difference (HSD) test was done for the population size of *A. segetum* and *A. exclamationis*. Based on the calculation, homogeneous groups (not significantly different from each other) were determined for analyzing the traits. The relationship between the population size of *A. segetum* and *A. exclamationis* moths was assessed based on the Pearson product-moment correlation coefficient. All calculations in the area of statistical analyses were performed using the GenStat v.10.1 statistical package (GenStat 2007).

Tests on the effectiveness of the pheromone trap and light trap did not synchronize with each other.

RESULTS

Evaluation of the population size of the *A. segetum* and *A. exclamationis* moths caught by means of pheromone traps during the 2005–2009 time period

During the study years, the weather conditions were very diversified. Weather conditions were particularly beneficial for cutworm development during the 2006–2009 time period. The high temperatures and moderate rainfalls were advantageous for moths flights and caterpillars feeding. In 2007, due to intensive rainfalls in July, a decreased harmfulness of cutworms was observed. In 2008, the weather in May was warm and sunny, which caused earlier flights of cutworm imagines. Pheromone trap monitoring conformed that these devices are very useful for determining the population size of the Noctuinae moths on the fields under study (Table 1).

The flight of first generation Turnip moths to the farm fields started in most years, in the beginning of June (years: 2005, 2006, 2007, and 2009), except for 2008, when the moth flight started on 16 May. In the case of the Heart and Dart moth, the first adults were caught in traps either in the first or the second decade of June. But 2008 was exceptional, and the beginning of the flight of imagines was observed at the end of May. The peak in the popula-

Table 1. Weather conditions in Winna Góra and Więcławice during years 2005–2009

Years	Winna Góra				Więcławice			
	Month				Month			
	V	VI	VII	VIII	V	VI	VII	VIII
Temperature [°C]								
2005	13.9	17.6	20.7	17.9	13.9	16.4	20.7	18.0
2006	13.8	18.5	23.9	17.3	14.1	18.7	21.4	18.8
2007	14.7	18.7	18.5	18.5	15.4	19.1	18.7	19.0
2008	13.8	18.1	19.5	18.2	–*	–	–	–
2009	13.0	15.3	19.0	19.0	–	–	–	–
Precipitation [mm]								
2005	67.5	4.4	45.2	65.9	79.7	28.1	47.3	23.7
2006	47.5	14.3	20.3	115.2	11.6	6.3	33.5	52.1
2007	78.6	88.0	136.3	62.1	49.5	72.5	121.8	59.8
2008	12.9	8.4	63.2	73.4	–	–	–	–
2009	69.2	100.3	99.4	29.9	–	–	–	–
Air humidity [%]								
2005	77.0	69.0	70.0	71.0	77.4	74.6	70.6	72.4
2006	71.4	72.2	57.6	77.8	72.1	71.4	73.4	77.2
2007	76.3	77.0	78.8	67.1	73.1	78.2	80.0	79.0
2008	73.7	62.5	65.7	79.2	–	–	–	–
2009	74.0	85.2	80.9	64.8	–	–	–	–

*lack of data

Table 2. Number of *A. segetum* moths caught in pheromone traps in Winna Góra and Więcławice on sugar beet, barley, and winter wheat in the 2005–2009 seasons

Location	Crop plant	Number of moths caught in:				
		2005	2006	2007	2008	2009
Winna Góra	sugar beet	27 abcd	8 e	30 abcd	29 abcd	34 abc
	barley	17 de	20 cde	41 a	19 cde	29 abcd
	winter wheat	21 cde	24 bcd	27 abcd	33 abc	38 ab
Więcławice	sugar beet	17 de	32 abcd	34 abc	–	–
HSD 0.05	for years: 11.98, for locations: 11.02, for crop plants: 15.33					

Means followed by the same letters are not significantly different
– no observation

Table 3. Number of *A. exclamationis* moths caught in pheromone traps in Winna Góra and Więcławice on sugar beet, barley, and winter wheat in the 2005–2009 season

Location	Crop plant	Number of moths caught in:				
		2005	2006	2007	2008	2009
Winna Góra	sugar beet	31 bc	22 c	22 c	74 a	42 abc
	barley	–	7 c	–	–	39 abc
	winter wheat	–	–	–	62 ab	28 bc
Więcławice	sugar beet	20 c	32 bc	16 c	–	–
HSD 0.05	for years: 14.73, for locations: 27.01, for crop plants: 38.25					

Means followed by the same letters are not significantly different
– no observation

Table 4. Mean squares from analysis of variance for number of *A. segetum* and *A. exclamationis*

	A. segetum		*A. exclamationis*	
		For years		
Source of variation	degrees of freedom	mean squares	degrees of freedom	mean squares
Years	4	147.08	4	1496.38*
Residual	13	47.82	8	66.17
		For location		
Source of variation	degrees of freedom	mean squares	degrees of freedom	mean squares
Location	1	3.6	1	251.5
Residual	16	75.4	11	393.9
		For crop plant		
Source of variation	degrees of freedom	mean squares	degrees of freedom	mean squares
Crop plant	3	30.9	3	329.9
Residual	14	79.81	9	439.2

*p < 0.001

tion size was observed most often from the end of June and remained intense till the second decade of July. In the years of the study, it was the first generation of the pests that had the biggest population size.

The monitoring performed by means of pheromone traps proved the presence of both species of the cutworm under study, in sugar beet, winter barley, and winter wheat. The biggest population size was recorded for *A. segetum* (Table 2). This cutworm's dominance was observed during the 2005–2007 season (Table 3). The obtained results of the variance analysis indicated no differences in the population size of *A. segetum* throughout the years, locations, or farm fields (Table 4). In tables 2 and 3, homogeneous groups are added.

During 2008 and 2009, traps were populated mostly by *A. exclamationis*. The population size of the two species of cutworm could have been influenced significantly by plants used for the study. Other host plants, including weeds, that surrounded the monitored farm fields were used in the study.

Results obtained from the analysis of variance indicated that the years were a statistically significant factor ($p < 0.001$) that varied the population size of *A. exclamationis* (Table 4). On the other hand, the location and farm field did not vary the population size of *A. exclamationis* (Table 4). The correlation between the population size of the adult *A. segetum* and *A. exclamationis* was not statistically significant ($r = 0.4713$, $p = 0.1040$).

Evaluation of the population size of the *A. segetum* and *A. exclamationis* moths caught by means of light traps during the 2003–2006 time period

The study began in a period of cutworm gradation in Poland which was observed starting from 2000. Based on moth catches, it is believed that gradation in Poznań continued in 2003 and 2004. This was proven by the large number of imagines caught in these years. In subsequent years, the population size of both species decreased significantly and it can be assumed that a collapse of the gradation (regression) started at that time (Fig. 1).

Also, in Winna Góra, there was a successive reduction of the cutworm population during the study years. Only in 2003, a very populated flight of the imagines was observed and a less populated flight was observed in 2004. A collapse of the cutworm gradation was identified in 2005. It is important to note that in Winna Góra, in the last year of the study, slightly more adults were caught as compared to 2005. Most probably, there was a latent population period from 2006 onward (Fig. 2).

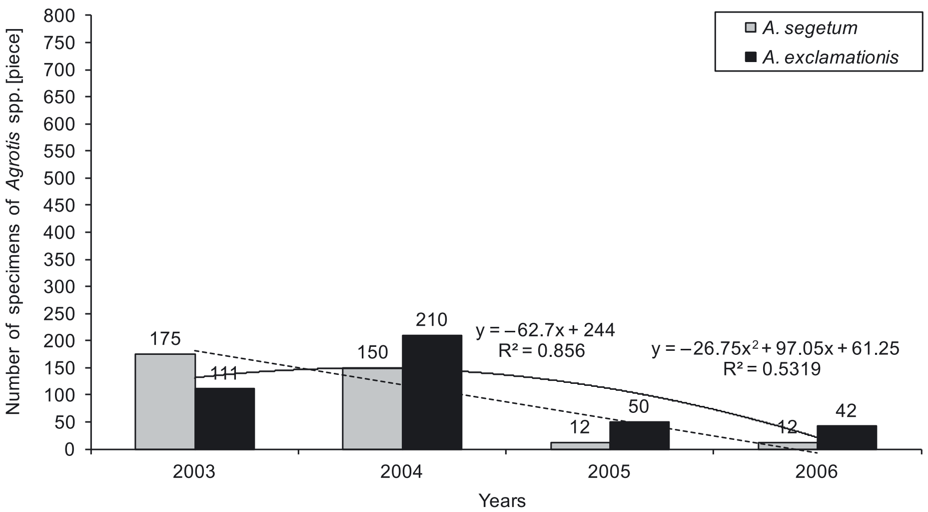

Fig. 1. Total number of *A. segetum* and *A. exclamationis* moths caught in sugar beet, in Poznań, 2003–2006

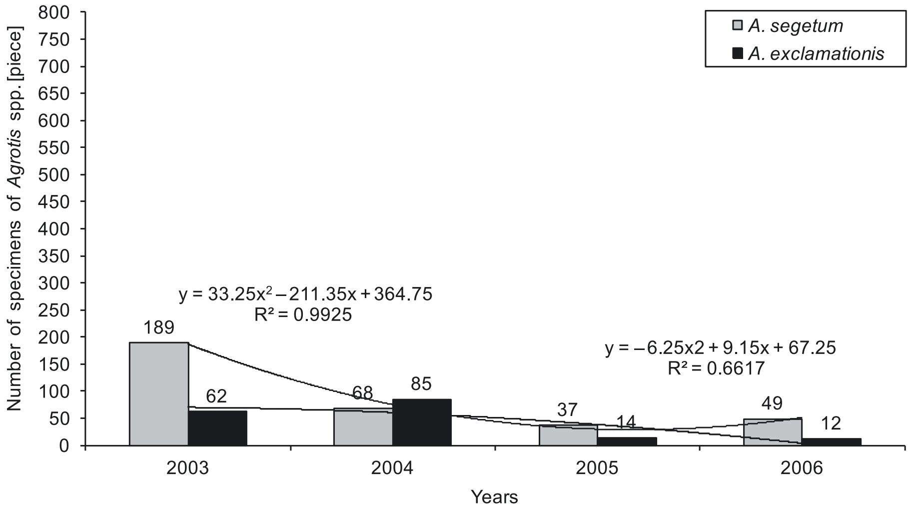

Fig. 2. Total number of *A. segetum* and *A. exclamationis* moths caught in sugar beet, in Winna Góra, 2003–2006

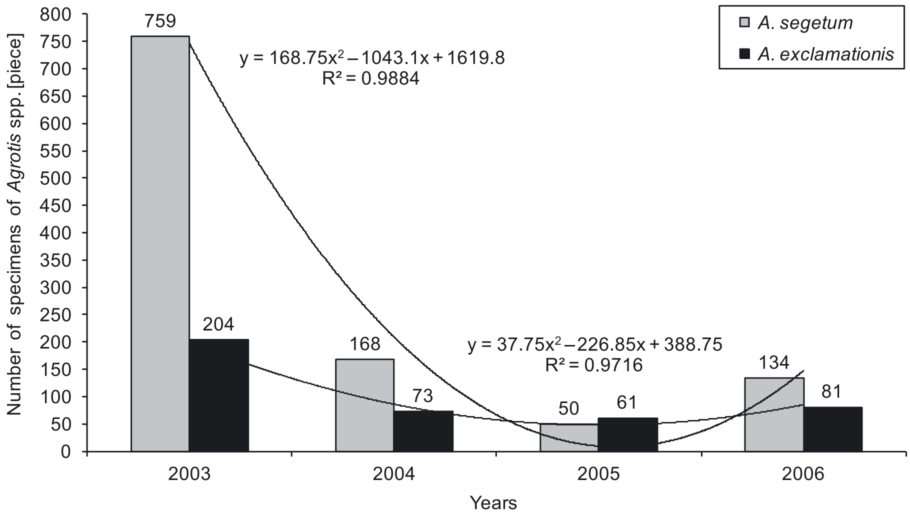

Fig. 3. Total number of *A. segetum* and *A. exclamationis* moths caught in sugar beet, in Więcławice, 2003–2006

Więcławice is located in the Kujawy region, where higher class soils prevail. These soils are mostly for wheat and beets. The conditions are favorable for cutworm population development, which is reflected in the numbers of moths caught in this region. In all years of the study, there was a particularly large amount of cutworm adults caught in Więcławice. This was also true of Winna Góra and Więcławice. The collapse of the gradation started in 2005 (Fig. 3).

DISCUSSION

The results of the present study may have practical applications in pest management strategies. The information will be used to share the forecasting of insect attack, as a central part of Integrated Pest Management (IPM) and Integrated Production (IP). In recent years, great importance has been put on integrated plant protection programs that affect the use of multiple methods of pest control. A large impact can be made if many methods are applied to control agrophages; keeping populations of the pest below the level of the economic threshold while reducing the number of chemical treatments (Walczak *et al.* 2004, 2010).

In the studies of the Noctuidae fauna, imagine catches were most commonly used and there were different baits providing quantitative data that can be analyzed statistically. From traps only light baits, and food baits provide material which can be used both qualitatively as well as quantitatively (Buszko and Nowacki 1990, 1991; Garnis and Dąbrowski 2008). In the present study, imagines were caught using light traps, and the moths were used as the collected material. A quality evaluation for determining the dynamics of the flight of *A. segetum* and *A. exclamationis* was also done in our study. Both species are dominating pests occurring in sugar beet fields (Węgorek 1966; Małachowska 1987; Walczak and Jakubowska 2001; Jakubowska and Walczak 2009). Our data on the flight dynamics of *A. segetum* and *A. exclamationis* during the 2003–2006 season, showed that the years 2003 and 2004 were a continuation of the rise in the number of cutworms, which had been observed in Poland since 2000. The result was a large number of moths caught in those years. During the following years, there was a significant decrease in the numbers of both species. It may be assumed, that a pest regression had started. In the Winna Góra period as well as the period of Więcławicach, the breakdown graduation year was 2005. Then, already from 2006, there was a very small increase in the numbers. Presumably, this was the beginning of the period with the rise in population. However, the breakdown of the Poznan flight dynamics was in 2006. Our data showed much higher catches which corresponds to the observations made by Jakubowska and Walczak (2007), Jakubowska (2009) as well as Bereś (2011).

A. exclamationis is a very common species in Poland. Observations of *A. exclamationis* flight dynamics showed that the mass occurs in June and July. Asides from this period *A. exclamationis* is quite a rare species, and this was also observed by Adamczewski (1992). In this study, larger numbers of Turnip moth were caught than of the Heart and Dart moth. When different numbers of the moths of both species are caught, a greater tolerance of the organism of the species to the specific environmental factors can probably be noted (Meržheevskaya 1989; Buszko and Nowacki 1990, 1991). The Heart and Dart moth is a more stenothermic species and therefore its larvae easily die during the first cold weather in late summer and early autumn (Meržheevskaya 1989). However, the reason for the larger catches of *A. segetum* imagines in the light traps compared to the catches of *A. exclamationis* is the presence of a larger phototaktizm of *A. segetum* (Meržheevskaya 1989; Buszko and Nowacki 1990).

In this study, we also used pheromone traps to catch male *A. segetum* and *A. exclamationis* imagines. Research conducted by Walczak (1998), Wiech *et al.* (2001), Rogowska and Wrzodak (2006), and Szwejda and Wrzodak (2006) confirm that over the past few years, in research and in the practice of plant protection traps using pheromones are most commonly used to determine the flight of the imagine pests. The role of forecasting cutworm damage with the use of sex pheromone traps, was developed and implemented in Denmark and Sweden (Ejsberg *et al*. 1986), Hungary (Toth *et al*. 1992) and other countries. Such observations have also been confirmed by other authors studying cutworms (Verma and Verma 2001; Jakubowska and Walczak 2007; Garnis and Dąbrowski 2008; Jakubowska 2008; Bereś 2011). Similar results have been presented by Walczak *et al.* (2004). Currently, the use of traps containing synthetic sex pheromone dispensers is considered to be useful for a variety of pest monitoring system, in particular cutworms.

In our study, the effectiveness of using pheromone traps to catch *A. segetum* and *A. exclamationis* is shown in tables 1–3. A short trap testing period, different temperature conditions, and the limited capacity of the applied pheromone attractants are taken into account as some of the reasons for the results.

CONCLUSIONS

The periodic changes in the intensity of the seasonal flights of *A. segetum* and *A. exclamationis* have a great influence on plant protection. The need for introducing constant monitoring of the flights dynamics of *A. segetum* and *A. exclamationis,* for the purpose of signaling the presence of the discussed pests, is justified. In conclusion, wider use of pheromone traps, regular field observations for monitoring the pests, and monitoring the weather conditions, should improved decision making and eliminate differences involving the chemical control use against cutworms.

Based on the our study, it was found that a light trap is a good solution for forecasting the critical date (the beginning of the moth flight) - noting the appropriate time for chemical control. However, because it is a labor intense method, it is used by only a small percentage of farmers.

REFERENCES

Adamczewski S.F. 1992. Zagadnienia migratyzmu u motyli (filogenetyczne i etologiczne uwarunkowania wędrówek motyli i ich ukształtowanie w środowisku różnych biomów). [Migrate issues with butterflies (phylogenetic and ethological conditions of migration of butterflies and their formation in the environment of different biomes)] Praca wydana nakładem żony Autora i J. Heitzego. PWN, Warszawa, 126 pp.

Allen J.C. 1976. A modified sine wale method for calculating degree days. Environ. Entomol. 5 (1): 388–396.

Artyszak A. 2011. Szkodliwość rolnic w różnych sposobach uprawy buraka cukrowego. [Harmfulness of cutworms in different methods of cultivation on sugar beet]. Prog. Plant Prot./Post. Ochr. Roślin 51 (4): 1805–1810.

Baranowski T., Gaczkowska K. 2006. Skuteczność pułapek feromonowych w wyłapywaniu motyli szrotówka kasztanowcowiaczka (*Cameraria ohridella*). [The effectiveness of pheromone traps in catching butterflies *Cameraria ohridella*]. Prog. Plant Prot./Post. Ochr. Roślin 46 (2): 403–405.

Bereś P.K. 2011. Występowanie oraz szkodliwość rolnic (*Agrotinae*) dla kukurydzy (*Zea mays* L.) w południowo-wschodniej Polsce w latach 2004–2010. [Occurrence and harmfulness of cutworms (Agrotinae) on maize (*Zea mays* L.) in south-east Poland in 2004–2010]. Prog. Plant Prot./Post. Ochr. Roślin 51 (2): 593–598.

Bereś P.K. 2012. Flight dynamics of *Ostrinia nubilalis* Hbn. (*Lep., Crambidae*) based on the light and pheromone trap catches in Nienadówka (South-Eastern Poland) in 2006–2008. J. Plant Prot. Res. 52 (1): 130–138.

Bereś P.K., Sionek R. 2010. The occurrence and sex ratio of *Diabrotica virgifera* Le Conte beetles on sweet maize (*Zea mays* var. *saccharata*) in south-eastern Poland near Rzeszów in 2007–2009. Veget. Crops Res. Bull. 73 (1): 87–97.

Buszko J., Nowacki J. 1990. Łowność sówkowatych (*Lepidoptera, Noctuidae)* na światło i przynętę pokarmową w zależności od temperatury i wilgotności powietrza. Wiad. Entom. 9 (1–2): 13–20.

Buszko J., Nowacki J. 1991. Aktywność zimowa sówkowatych (Lep., Noctuidae). Wiad. Entom. 10 (1): 35–41.

Esbjerg P. 1988. Behavior of 1st- and 2nd-instar cutworms (*Agrotis segetum*) (Lep., Noctuidae): The influence of soil moisture. J. Appl. Entomol. 105 (1–5): 295–302.

Esbjerg P. 2003. Cutworm (*Agrotis segetum*) forecasting. Two decades of scientific and practical development in Denmark. Bull. OILB/SROP 26 (3): 239–244.

Esbjerg P., Nielsen J., Philipsen H., Zethner O., Øgård L. 1986. Soil moisture as mortality factor for cutworms [*Agrotis segetum* (Den. et Schiff.), Lep. Noctuidae]. J. Appl. Entomol. 102: 277–285.

Garnis J., Dąbrowski Z. T. 2008. Effect of crop plant species on the efficacy of pheromone traps for monitoring of the Turnip moth [(*Agrotis segetum* (Schiff.)] (Lep., Noctuidae). Veget. Crops Res. Bull. 68 (1): 81–91.

Gemeno C., Haynes K.F. 2000. Periodical and age-related variation in chemical communication system of black cutworm moth, *Agrotis ipsilon*. J. Chem. Ecol. 26 (2): 329–340.

GenStat. 2007. GenStat Release 10 Reference Manual. Lawes Agricultural Trust, Rothamsted, UK.

Jakubowska M. 2008. Występowanie szkodników glebowych w buraku cukrowym na plantacjach przemysłowych w latach 2005–2007. [Occurrence of soil pests in sugar beet of industrial farm in 2005–2007]. Prog. Plant Prot./Post. Ochr. Roślin 48 (2): 854–858.

Jakubowska M. 2009. Doskonalenie prognozowania krótkoterminowego chemicznej ochrony buraka cukrowego przed *Agrotis segetum* (Den. et Schiff.) i *Agrotis exclamationis* (L.) (Lepidoptera: Noctuinae). [Improving the forecasting of short-term chemical protection of sugar beet against *Agrotis segetum* (Den. et Schiff.) and *Agrotis exclamationis* (L.) (Lepidoptera: Noctuinae)]. PhD thesis, Institute of Plant Protection – National Research Institute. Poznań, Poland, 196 pp.

Jakubowska M. 2011. Quality structure of the Noctuidae family in selected habitats of the agricultural landscape. J. Plant Prot. Res. 51 (2): 166–170.

Jakubowska M., Walczak F. 2007. Wyznaczenie optymalnego terminu zwalczania rolnic w uprawach buraka cukrowego przy użyciu pułapek świetlnych i feromonowych. [Determination of optimum timing for chemical control of cutworms using light traps and pheromone traps]. Prog. Plant Prot./Post. Ochr. Roślin 47 (1): 238–243.

Jakubowska M., Walczak F. 2008. Wpływ temperatury i wilgotności powietrza na wybrane stadia rozwojowe rolnicy zbożówki (*A. segetum* Den. et Schiff.) dla potrzeb prognozowania krótkoterminowego. [Influence of temperature and relative humidity on chosen development stages of *Agrotis segetum* Den. et Schiff. for requirements of short-term forecasting]. Prog. Plant Prot./Post. Ochr. Roślin 48 (3): 859–863.

Jakubowska M., Walczak F., 2009. Aktualne problemy ochrony buraków cukrowych przed rolnicą zbożówką i czopówką. [Current problems of sugar beet plants against Turnip moth and Heart and Dart moth]. Prog. Plant Prot./Post. Ochr. Roślin 49 (1): 116–121.

Małachowska D. 1987. Metody sygnalizacji terminu zwalczania i wyniki badań nad zwalczaniem rolnicy zbożówki w Polsce. [The period signal control methods and results of studies of Turnip moth in Poland]. Gazeta Cukrownicza 3: 68–70.

Meržheevskaya O.I. 1989. Larvae of Owlet Moths (*Noctuidae*). Biology, Morphology, and Classification. Amerind Publishing Co. Pvt. Ltd., New Delhi, 420 pp.

Rogowska M. 2005. Stosowanie nowej pułapki feromonowej do monitorowania nalotu piętnówki kapustnicy (*Mamestra brassicae* L.) występującej na warzywach kapustowatych. [New pheromone traps to monitor the flight time *Mamestra brassicae* L. occurring on vegetables cabbage]. Ogólnopolska Konf. Upowszechnieniowa „Nauka-Praktyce". ISiW, Skierniewice: 51–53.

Rogowska M., Wrzodak R. 2006. Nowe feromony do stosowania w ochronie roślin warzywnych przed szkodnikami. [A new pheromone traps used against insect pests of vegetable crops]. Prog. Plant Prot./Post. Ochr. Roślin 46 (2): 363–366.

Shapiro S.S., Wilk M.B. 1965. An analysis of variance test for normality (complete samples). Biometrika 52 (3–4): 591–611.

Szwejda J., Wrzodak R. 2006. Ogólnopolski system monitorowania śmietki kapuścianej na plantacjach warzyw kapustowatych. [Nationwide system for monitoring of Cabbage root fly (*Delia radicum* L.) on cabbage plantations in Poland]. Prog. Plant Prot./Post. Ochr. Roślin 46 (1): 270–275.

Toth M., Löfstedt C., Blair B.W., Cabello T., Farag A.I., Hansson B.S., Kovalev B.G., Maini S., Nesterov E.A., Pajor I., Sazonov A.P., Shamshev I.V., Subchev M., Szöcs G. 1992. Attraction of male Turnip moths *Agrotis segetum* (Lepidoptera: Noctuidae) to sex pheromone components and their mixtures at 11 sites in Europe, Asia and Africa. J. Chem. Ecol. 18 (8): 1337–1347.

Walczak F. 1998. Pułapka feromonowe – metoda sygnalizacji wybranych roślin warzywnych. [Pheromone trap – signaling method selected vegetable]. Prog. Plant Prot./Post. Ochr. Roślin 38 (1): 355–357.

Walczak F. 1999. Znaczenie monitoring agrofagów roślin uprawnych dla ochrony roślin. [The importance of monitoring pests of crops to protect the plants]. Prog. Plant Prot./Post. Ochr. Roślin 39 (1): 284–288.

Walczak F., Jakubowska M. 2001. Wzrost szkodliwości rolnic (*Agrotinae*) w Polsce. [The increase in harmfulness of cutworms (*Agrotinae*) in Poland]. Prog. Plant Prot./Post. Ochr. Roślin 41 (2): 386–390.

Walczak F., Jakubowska M., Banaszak H. 2004. Rolnice – gospodarczo ważne szkodniki roślin uprawnych w Polsce. [Cutworms – the economically important pests of crops in Poland]. Prog. Plant Prot./Post. Ochr. Roślin 44 (2): 486–495.

Walczak F. (red.). 2007. Poradnik Sygnalizatora Ochrony Zbóż. [Signalling Cereals Protection Guide]. Inst. Ochr. Roślin – PIB, Poznań, 111 pp.

Walczak F. (red.). 2008. Poradnik Sygnalizatora Ochrony Rzepaku. [Signalling Rape Protection Guide]. Inst. Ochr. Roślin – PIB, Poznań, 153 pp.

Walczak F., Tratwal A., Krasiński T. 2010. Kierunki rozwoju prognozowania i sygnalizacji agrofagów w ochronie roślin rolniczych. [Directions of the development of pest forecasting and warning systems in plant protection]. Prog. Plant Prot./Post. Ochr. Roślin 50 (1): 81–86.

Węgorek W. 1966. Rolnice (*Agrotinae*) krajobrazu rolniczego Polski. [The cutworms (Agrotinae) Polish agricultural landscape]. Prace Nauk. Inst. Ochr. Roślin, Poznań 8: 5–69.

Wiech K., Kałmuk J., Pawelec A. 2001. Wykorzystanie pułapek feromonowych do prognozowania niektórych szkodników warzyw. [Use of pheromone traps for forecasting some of the pests of vegetables]. Prog. Plant Prot./Post. Ochr. Roślin 41 (2): 450–453.

Verma K.S., Verma A.K. 2001. Monitoring of adult activity of *Agrotis segetum* Denis and Schiffermüller with sex pheromone traps in Himachal Pradesh. Pest Manage. Econ. Zool. 9 (2): 171–175.