Seasonal dynamics of the cabbage armyworm (*Mamestra brassicae* [L.]) and the bright-line brown-eyes moth (*Mamestra oleracea* [L.]) in Slovenia

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Abstract

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The cabbage armyworm (*Mamestra brassicae* L.) and the bright-line brown-eyes moth (*Mamestra oleracea* L.) are polyphagous insect species. From 2008 to 2010, we monitored the seasonal dynamics of both pests in two locations in Slovenia, Ljubljana and the Nova Gorica region. Pheromone traps (VARL + type) were used to precisely determine the occurrence of adults, i.e., the beginning and end of generations and the peaks of the populations. This allowed us to examine the relationship between the quantity of pests, average daily air temperature and average daily precipitation. Our results established that there were two generations of *Mamestra brassicae* per year in both locations; however, the seasonal dynamics of *Mamestra oleracea* was not as clear due to low trap catch. During 2008–2010 in Ljubljana, the average temperature during the peaks of the first generation of *M. brassicae* ranged from 16–19°C (sum of effective temperatures (SET) from 250°C to 375°C) and 20°C (SET from 986°C to 1,290°C) during the peaks of the second generation. We found no correlation between the average number of cabbage armyworm adults during the peaks of both generations and the mean air temperature 35 and 70 days prior to the peaks.

Keywords: abiotic factors; bionomics; monitoring; noctuids; pheromone traps

Pheromone traps are considered to be one of the most effective methods to monitor and study the seasonal dynamics of adult male insects (Vanparys 1994; Giron-Perez et al. 2009; Cohnstaedt et al. 2012). The selectiveness of sex pheromones is widely known and makes these traps ideal for the determination of the abundance of a single species. They can also be used for mass trapping of pests (Oltean et al. 2009). Pheromone traps were successfully used to determine the first occurrence of adult males and to consequently estimate the timing of damage to plants caused by pests (Lima, McNeil 2009; Devetak et al. 2010; Cruz et al. 2012).

In addition to monitoring the occurrence and quantity of pests, the use of pheromone traps can assist in the determination of the most advanta-

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geous time to apply insecticides. Thus, pheromone traps contribute to an effective and economical pest control program. Nevertheless, the number of adults found in pheromone traps is not a direct indicator of the number of larvae present, which is the life stage that damages cabbage plants (Cartea et al. 2009; 2010). Pheromones can also be used to prevent the mating of insects (Călin et al. 2009).

The cabbage armyworm predominately feeds on cabbage, sugar beet, tobacco, sunflower and grain crops. In addition, it can cause damage to spinach, tomato, potato, mangold, lettuce and pepper. The bright-line brown-eyes moth feeds on tomato, lettuce, cabbage, celery and mangold. In addition, this moth can also feed on soybeans, tobacco, and sugar beet. This pest can be attracted to fruit trees, primarily apple and peach (Pollini 2006).

The owlet moth caterpillars develop well during wet summers, which have been quite frequent during the last decade. Harmful lepidopteran species, appearing in increasing numbers throughout Europe due to favourable climatic conditions, include cabbage armyworms (*Mamestra* spp.) and other pests (Legarrea et al. 2012). In Slovenia, the populations of these species have not been monitored systematically, but the cabbage armyworm and bright-line brown-eyes moth are known to be the most numerous and most frequently observed pests of this group. For the cabbage armyworm, it was established that, in central Europe, it has two generations per year (Čamprag, Jovanić 2005). Some authors claim that this pest can have up to three generations per year (Oku, Kobayashi 1974). In northern Europe, it was reported that the cabbage armyworm is a univoltine species (Johansen 1997; Metspalu et al. 2004). In central Europe, the bright-line brown-eyes moth also has two generations (Čamprag, Jovanić 2005).

During this three-year experiment, we studied the seasonal dynamics of the cabbage armyworm and the bright-line brown-eyes moth adults with a special emphasis on correlating the number of adult specimens of the pests with the average air temperatures and average precipitation in the regions of Ljubljana and Nova Gorica.

MATERIAL AND METHODS

Field monitoring using pheromone traps. The field trial to monitor the seasonal dynamics of cabbage armyworm (*Mamestra brassicae* L.) and bright-line brown-eyes moth (*Mamestra oleracea* L.) males was performed in two locations. These locations were the Laboratory Field of the Biotechnical Faculty in Ljubljana (296.4 m a.s.l., 46°2'58''N, 14°28'28''E) during 2008–2010 and the Nova Gorica region during 2008–2009. In 2008, monitoring was conducted in a field near the town of Miren (50.3 m a.s.l., 45°53'28''N, 13°35'42''E), while in the year 2009 (due to the flood of the river Vipava in Miren), monitoring was performed at two locations. Trapping started near Orehovlje (48.1 m a.s.l., 45°53'18''N, 13°36'51''E), then on May 31, the traps were moved to the previous location near Miren, where they were maintained until September 12, 2009. After the crops were harvested, the traps were moved to a location near Orehovlje, where some cultivars of late cabbage were grown. At the Laboratory Field of the Biotechnical Faculty, the pheromone traps were placed in an area where different vegetable crops were grown from April until November; cabbage and lettuce were the main crops. In the region of Nova Gorica, in addition to cabbage and Savoy cabbage, other vegetables were grown, including lettuce and potato. Near the site of the trial field in Orehovlje, there was a peach orchard and a vineyard. To monitor the seasonal dynamics of the pests as accurately as possible, meteorological data (average daily temperatures and average daily precipitation) were included in the study. The data for the 2008–2010 period were recorded at the meteorological station in Ljubljana-Bežigrad (299 m a.s.l. , 46°04'N, 14°31'E), and those in Bilje at Nova Gorica (55 m a.s.l., 45°54'N, 13°38'E) were taken into consideration.

VARL + Csalomon® (Plant Protection Institute, Budapest, Hungary) pheromone traps were used in this experiment. The traps were fixed on wooden sticks, approximately 1.5 m above the ground, and the distance between traps was approximately 10 m. They were located on the outer borders of the fields planted with cabbage. Traps designed to catch cabbage armyworm males were alternated with those designed to catch bright-line brown-eyes moth (i.e., a trap containing bright-line brown-eyes moth female pheromones). In total, eight pheromone traps were placed on both fields under investigation, four for each insect species. To catch the max. number of specimens, the pheromone dispensers were changed at four to six week intervals as recommended by the manufacturer.

The traps were inspected every seven to thirteen days. Occasionally, the traps had to be replaced due

to damage by inclement weather, especially wind. The pheromone dispensers were kept in a refrigerator prior to the use (–17°C).

Data evaluation. The results from monitoring the moths in the selected intervals are shown as the average numbers of males caught per trap per day (± standard error) related to the average temperatures (°C) and average precipitation (mm). The latter two values were divided by 100 to make the graphs more readable. The beginning of the occurrence of both species is shown in relation to the sum of the effective temperatures (SET). The SET was calculated as the average daily temperature minus 10; the hypothetical lower temperature threshold for both pests is considered to be 10°C. The calculation began with January 1 (the days when the average daily temperature was below 10°C were ignored) and ended with the date when the first adult males appeared. In addition to the occurrence of the males of the first generation, the peak and end of the occurrence were also determined. Additionally, we determined the beginning, peak and end of the occurrence of the second generation of males.

The SET was calculated as follows:

$$EFT_{daily} = T_{daily} - 10$$

where:

EFT_{daily} – effective temperature of each day from January 1 of the year of observation until the last day of the experiment (pheromone traps at the location)

T_{daily} – average daily temperature of air

$$SET = \sum EFT_{daily}$$

where:

SET – sum of the effective temperatures

$\sum EFT_{daily}$ – sum of the effective daily temperatures

Correlations between the mean number of cabbage armyworm adults per trap during the peaks of both generations and the mean air temperature and mean precipitation in the last 5 and 10 time intervals before both peaks in Ljubljana (in the period 2009–2010) were examined using linear regression analysis ($y = kx + n$) with the Statgraphics Plus For Windows 4.0 (Statistical Graphics Corp., Manugistics, Inc., Warrenton, USA) computer program.

The trap catch of cabbage armyworm and bright-line brown-eyes moth males is presented in association with the SET values, according to the methods of Dochkova (1972), Devetak and Trdan (2011).

RESULTS AND DISCUSSION

Monitoring of cabbage armyworm males in Ljubljana during 2008–2010

The population of cabbage armyworm in the Ljubljana region was monitored from 2008 to 2010. The SET results related to the beginning, peak and end of the distinct generations are presented in Table 1.

In 2008, the number of cabbage armyworm males caught in Ljubljana was extremely low. The first specimen appeared between June 2–9 (0.75 ± 0.60 males/trap/day), which was also the time of the highest peak of the first generation. There were three records of catching adult specimens of cabbage armyworm males during the periods June 16–23 (0.25 ± 0.20 males/trap/day), July 7–14 (0.22 ± 0.21 males/trap/day) and July 14–21 (0.22 ± 0.20). Because of the small number of specimens caught, the potential bivoltinism of the population could not be confirmed. The first speci-

Table 1. Occurrence of cabbage armyworm in Ljubljana in 2008–2010

Year		First generation			Second generation		
		occurrence	peak	end	occurrence	peak	end
2008	date	June 2–9	–	June 16–23	July 7–14	–	July 14–21
	SET (°C)	336.9	–	461	734.6	–	806.7
2009	date	April 16–22	May 26–June 3	June 17–24	July 9–17	August 12–24	September 10–18
	SET (°C)	85	374.6	655.2	807.9	1,289	1,500.3
2010	date	April 28–May 5	May 26–June 7	June 24–July 7	July 7–16	July 26–August 4	September 1–9
	SET (°C)	104.3	298.7	637.5	782.6	986.1	1,312.3

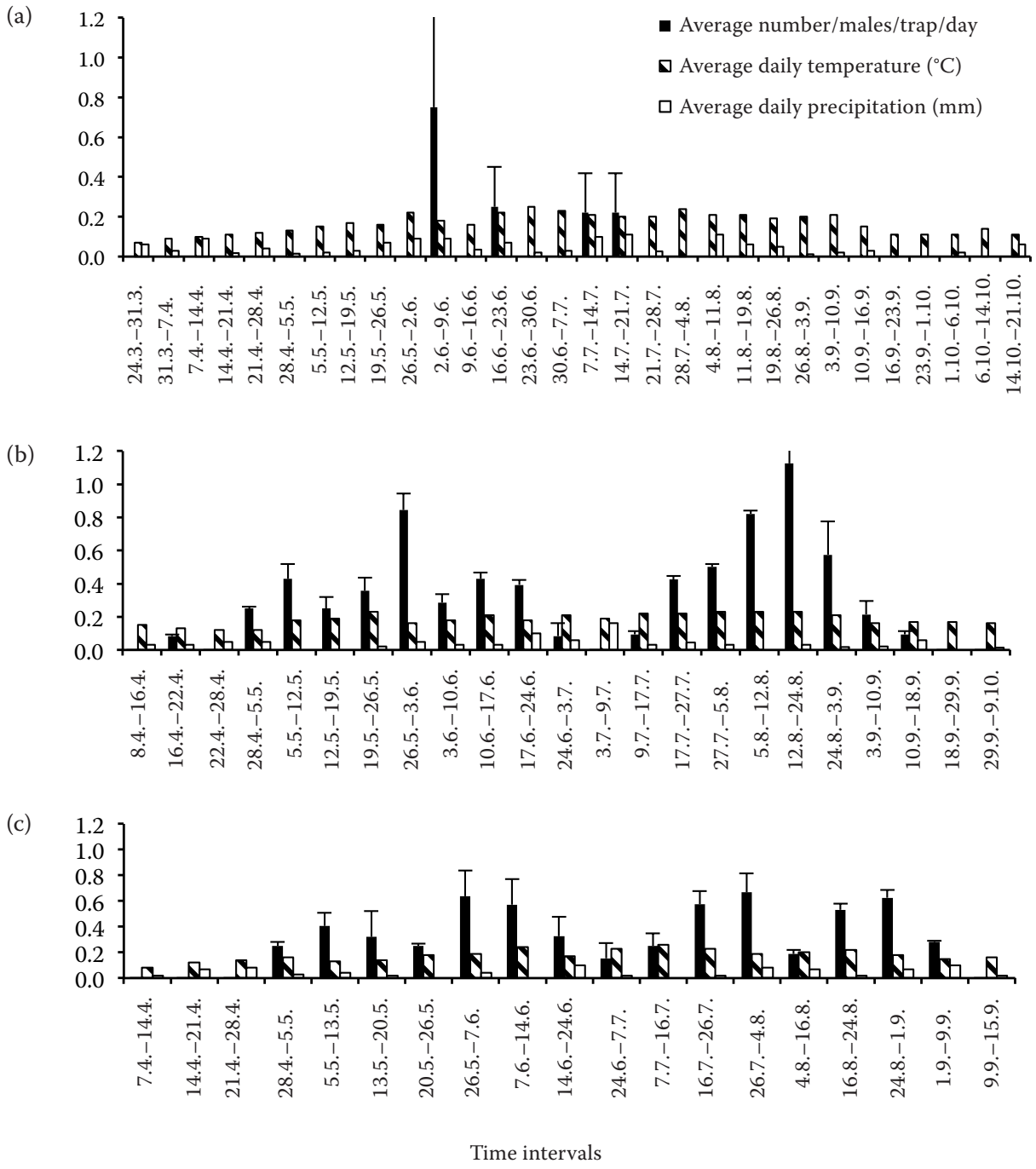

Fig. 1. Seasonal dynamics of cabbage armyworm males in Ljubljana during (a) 2008, (b) 2009 and (c) 2010
values for average daily temperature (°C) and average daily precipitation (mm) were divided by 100 for clarity

men was caught at the average temperature of 18°C (SET = 336.9°C) and the last one at the average temperature of 20°C (SET = 806.7°C) (Table 1). The highest number of males was trapped during the period June 2–9 (0.75 ± 0.60 males/trap/day) (Fig. 1a). The average precipitation in the period from June 7 to 21, when males were detected, was greater than 10 mm.

During 2009, the number of cabbage moth males exceeded that of the previous year. Six cabbage armyworm males were caught in 2008, and 246 were caught in 2009. The data indicated two distinctly separated generations. The highest number trapped in 2009 occurred between August 12 and 24 (1.13 ± 0.03 males/trap/day) (Fig. 1b) at an average temperature of 23°C (SET = 1,289°C) (Table 1). After this pe-

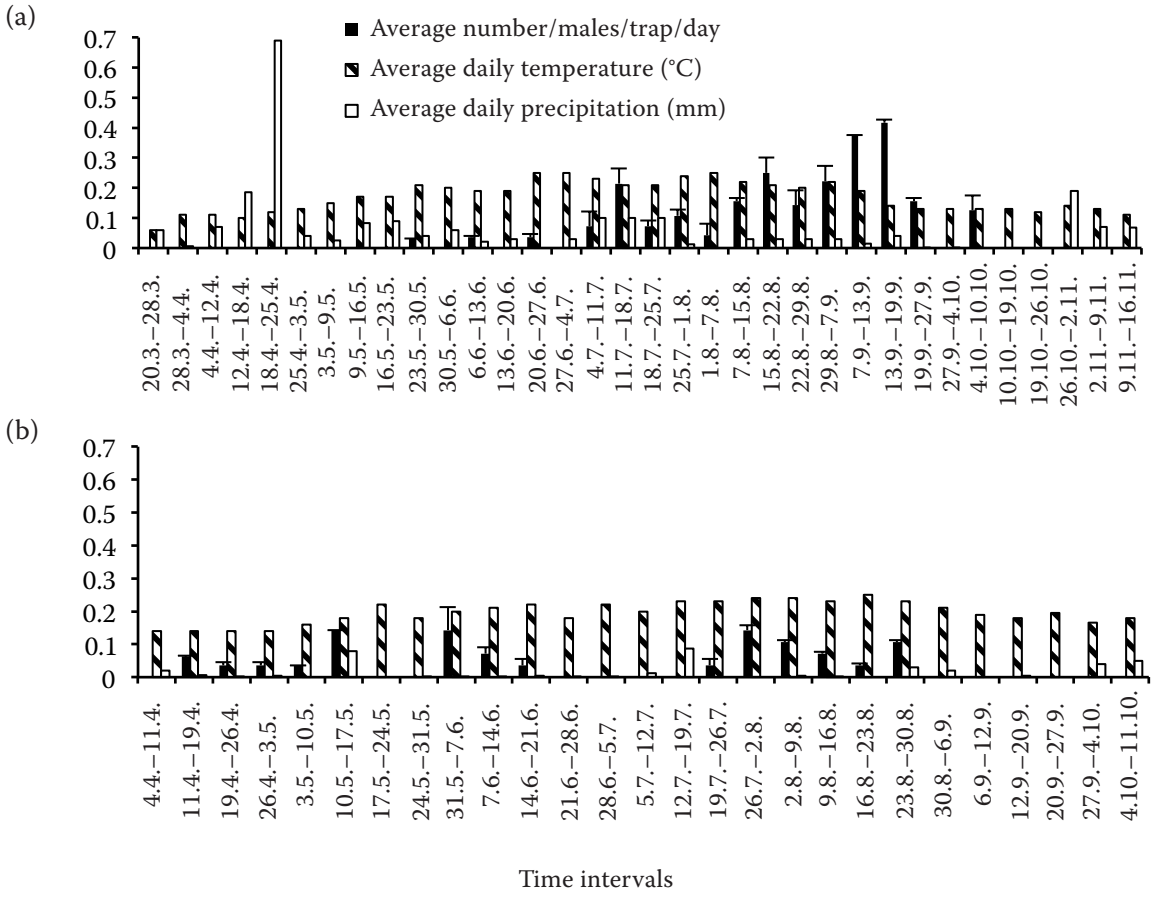

Fig. 2. Seasonal dynamics of cabbage armyworm males in the Nova Gorica region during (a) 2008 and (b) 2009 values for average daily temperature (°C) and average daily precipitation (mm) were divided by 100 for clarity

riod, the number of the specimens caught was lower. The average temperature at the occurrence of the first male moth was considerably lower compared with 2008 (year 2008: 18°C; year 2009: 13°C) (Fig. 1a,b). Additionally, the specimens appeared earlier in the second year of monitoring, with the first catch being recorded at the end of April. The peak of the first generation was determined to be between May 26 and June 3 (0.84 ± 0.01 males/trap/day) at an average temperature of 16°C (SET = 374.6°C). In the period that followed, the number of specimens decreased, and the first generation ended on June 17 (0.39 ± 0.03 males/trap/day) (Fig. 2) at an average temperature of 18°C (SET = 655.2°C) (Table 1). During the period of flying of the first and second generations of males, precipitation was scarce, with the largest amount (16 mm daily) being recorded between the flying periods (June 3 to 9).

In 2010, two population peaks were confirmed in the third year of studying the seasonal dynamics of the pest (Fig. 1c). These two peaks strongly confirmed the bivoltinism of the cabbage armyworm in the Ljubljana region. The first generation began between April 28 and May 5 (0.25 ± 0.03 males/trap/day) (Fig. 1c) at an average temperature of 16°C (SET = 104.3°C) (Table 1). The max. number (the peak of the generation) (0.64 ± 0.02 males/trap/day) was recorded at the average temperature of 19°C (SET = 298.7°C). The end of the occurrence of the first and the beginning of the second generation were influenced by abundant precipitation (more than 10 mm daily for the period between June 14–24) (Fig. 1c). The second generation showed two maxima for the numbers of the adult cabbage armyworm males. The absolute maximum was the first peak between July 26 and August 4 (0.67 ± 0.15 males/trap/day), while the second increase was recorded between August 24 and September 1 (0.63 ± 0.06 males/trap/day). The last specimens were caught in the period September 1–9 (0.28 ± 0.01 males/trap/day) with the average temperature of 15°C (SET = 1,312.3°C). Again, the end of flying was influenced by precipitation (average of more than 10 mm daily for this period).

Monitoring of bright-line brown-eyes moth males in Ljubljana during 2008–2010

During 2008, only two specimens were trapped: the first in the period May 26 to June 2 and the second between August 4–11. More bright-line brown-eyes moth males were trapped in 2009 compared with 2008. The first specimen was caught on the pheromone trap in the period between April 28 and May 5. The second generation began between July 27 and August 5 (0.03 ± 0.01 males/trap/day). The last male moths, the peak of the second generation, were caught during the period August 5–12 (0.04 ± 0.005 males/trap/day).

During the last year of the field trial (2010), the first generation appeared at the end of May (0.13 ± 0.02 males/trap/day) and the second generation in the second half of July (0.03 ± 0.01 males/trap/day). Similar to 2009, the specimens of the second generation were caught until September 9. During the period of the second generation, the max. catch of the pest occurred in the period from August 16–24 (0.16 ± 0.09 males/trap/day). The abundant precipitation during this summer postponed the occurrence of the second generation; the end of flying of this generation also had an influence on the interruption of their flying period.

Monitoring of cabbage armyworm and the bright-line brown-eyes moth in the Nova Gorica region

In the Nova Gorica region, no adult bright-line brown-eyes moth specimens were recorded in the 2008 and 2009 periods. The results for the cabbage armyworm monitoring (SET for the occurrence, peak and ending of the generations) are given in Table 2.

In 2008, the results of males caught in the Nova Gorica region were significantly different from those obtained in the Ljubljana region (on the trial field of the Biotechnical Faculty). The first specimens appeared in the period between May 23–30, their number increased with the increase in average daily temperatures. The peak of the population occurred between July 11 and 18 at an average temperature of 21°C (SET = 1,033°C). The peak of the second generation was observed during the period September 13–19 (the average temperature was 14°C) (SET = 1,564.8°C). After the period October 4–10 (0.13 ± 0.02 males/trap/day), no male moths were found in the pheromone traps (Fig. 2a).

The precipitation was less abundant during the period of the occurrence of the second generation (no period had more than 5 mm average daily rainfall) compared with the occurrence of the first generation; the rain had no influence on the time when the flying of the males ended.

In 2009, due to the flooded field in Miren, the trial was carried out in two locations: the first and third part near Orehovlje, and the second part near Miren. Compared with the previous year (2008), the specimens appeared earlier. The beginning of the first generation was observed in the period from April 11–19 (0.06 ± 0.00 males/trap/day) at an average temperature of 14°C (SET = 86.6°C). The peak of the first generation occurred at an average temperature of 18°C (SET = 249.1°C) in the period from May 10–17 (0.14 ± 0.00 males/trap/day). At the end of May, the crop of the early cabbage hybrid varieties in Orehovlje was collected; therefore, the traps were moved to the location near Miren where the seasonal dynamics of the pest were studied in 2008. In 2009, the first generation ended between June 14–21 (0.04 ± 0.02 males/trap/day) with an average temperature of 22°C. The first males of the second generation were detected between July 19–26 (0.04 ± 0.02 males/trap/day) at the average temperature of 23°C (SET = 1,031.7°C). The peak of the second generation was recorded during the next period (from July 26 until August 2) (0.14 ± 0.01 males/

Table 2. Occurrence of cabbage armyworm in the Nova Gorica region (Miren and Orehovlje) in 2008–2009

Year		First generation			Second generation		
		occurrence	peak	end	occurrence	peak	end
2008	date	May 23–30	July 11–18	July 25–August 1	August 1–7	September 13–19	October 4–10
	SET (°C)	285.4	856.5	1,033	1,126.3	1,564.8	1,633.9
2009	date	April 11–19	May 10–17	June 14–21	July 19–26	July 26–August 2	August 23–30
	SET (°C)	86.6	249.1	628.6	1,031.7	1,136.4	1,526.4

Table 3. Regression equations, Pearson's coefficients (r) and significance levels (P) for the correlation of the mean number of cabbage armyworm adults per trap during the peaks of both generations in Ljubljana during the period 2009–2010

Intervals before adult peaks (days)	Regression equation (Y)	Mean temperature		Mean precipitation	
		r	P	r	P
5	$Y = -26.79 + 1.55x$ (temperature) $Y = 7.24 - 1.16x$ (precipitation)	0.5996	0.4003	–0.24	0.7591
10	$Y = -32.17 \pm 1.89x$ (temperature) $Y = 9.42 - 0.98x$ (precipitation)	0.6013	0.2131	–0.15	0.1265

mean air temperature and mean precipitation in the last 5 and 10 time intervals prior to both peaks

trap/day) with an average temperature of 25°C. After that date, the number of the male moths caught declined until the end of August when the last specimens were detected in the traps (Fig. 2b). After the collection of the cabbage crops in Miren in the beginning of September, the traps were moved to Orehovlje (on September 12) where some late cultivars of cabbage were grown, but no males of cabbage armyworm were caught at this location. The intense precipitation (14 mm/day) in the period July 5–12 may have influenced the later occurrence of the first males of the second generation; both peaks were recorded in periods with little rain.

We attempted to identify the relationships between the mean number of cabbage armyworm adults during the peaks of both generations, the mean air temperature and mean precipitation in the last 5 of the 7-day time intervals before both peaks in Ljubljana in the period 2009–2010; however, we did not confirm the significance of the correlations either between the number of adults and temperature ($P = 0.4003$) nor between the number of adults and precipitation ($P = 0.7591$). The same statistically confirmed result was found for the relationships in the last 10 of the 7-day intervals: the levels of the correlations between the adults and temperature were 0.2131 and between the adults and precipitation it was 0.1265 (Table 3). Correlations were not calculated for the bright-line brown-eyes moth because their numbers were very low in both years and at both locations.

In the field experiments, which were conducted from 2008 to 2010 in the regions of Ljubljana and Nova Gorica, the seasonal dynamics of cabbage armyworm and bright-line brown-eyes moth were studied. In the region of Ljubljana, the pheromone traps were placed at the same location during the entire experiment, while in the region of Nova Gorica, they were temporarily moved from the field near Miren to a field near Orehovlje at the beginning of 2009 due to the flooding of the Vipava river. The average daily temperatures and the quantities of rainfall influenced the seasonal dynamics of both pests. Temperature was identified as an important factor for the development of other Noctuidae species. Dochkova (1975) and Mironidis and Savopoulou-Soultani (2012) report that the temperature threshold for eggs of the bright-line brown-eyes moth is 9.7°C and the sum of effective daily temperatures (SET) is 65°C, for larvae 12.2°C (SET = 358.5°C) and for pupae 11.4°C (SET = 287.8°C). For the cabbage armyworm, Kwon et al. (2005) reported the following values: for eggs, 7.9°C (SET = 69.4°C); for larvae, 4.8°C (SET = 434.8°C); and for pupae, 6.7°C (SET = 344.8°C). For the cabbage armyworm in particular, the number of specimens caught in the pheromone traps was significantly lower in the periods with considerable rainfall. The influence of precipitation on the seasonal dynamics was also studied by Vajgand et al. (2008).

For cabbage armyworm, two generations per year were determined for both locations, which is consistent with the results of other studies on the seasonal dynamics of this pest in the region of central Europe (Čamprag, Jovanić 2005). The same conclusion was drawn in Spain (Cartea et al. 2009). In contrast, in Norway, Johansen (1996) reports only one generation per year. The correlation between the number of generations and temperature was also observed by Oku and Kobayashi (1974), who showed that this pest can have up to three generations in Japan. Three generations per year were also found by Setokuchi and Tanaka (1980). Our study did not observe a correlation between the number of males caught and temperatures.

Monitoring of the bright-line brown-eyes moth confirmed that it is found in lower numbers compared with the cabbage armyworm. The same result was obtained by Cartea et al. (2009), who observed that cabbage armyworm constitutes approximately 48.5% of insects of the order Lepidoptera caught in field experiments in Spain.

In the region of Nova Gorica, not a single specimen of the bright-line brown-eyes moth was trapped in the pheromone traps during the two-year period.

The first specimen of adult males of cabbage armyworm appeared in Ljubljana at the end of April (from April 16–22 in 2009 and from April 28–May 5 in 2010). In 2009, the adult males of this pest were less numerous compared with 2010. In 2008, in the Nova Gorica region, the first specimens of cabbage armyworm were observed later (May 23–30, SET = 285.4°C) compared with the Ljubljana region. In 2009, the first generation appeared nearly a month earlier (April 11–19, SET = 86.6°C). Additionally, in 2008, the adults of the second generation appeared later, with the peak occurring between September 13 and 19, while the peak of the second generation in 2009 was observed between July 26 and August 2. Saninno and Espinosa (1999) reported that in the South of Italy, the population of this pest exhibited two peaks (in May and in September). In 2008, our field trial lasted until October at SET = 1,633.9°C, which was the highest SET value during the three-year period for both locations. In 2008 and in 2009, the second generation in the Nova Gorica region appeared at the end of July or in the beginning of August, which is consistent with the data of Vanparys (1994) for Belgium.

Our study demonstrates that, compared with the bright-line brown-eyes moth, the cabbage armyworm is a much more abundant insect pest in Slovenia and that both moth species develop two generations.

There was no correlation detected between the mean number of cabbage armyworm adults during the peaks of both generations and the mean air temperature 35 and 70 days before both peaks or between the mean number of cabbage armyworm adults during the peaks of both generations and the mean precipitation 35 and 70 days before both peaks.

In years of high occurrence, the peak of the first generation of cabbage armyworm occurs between the SET of 250°C to 375°C, while the peak of the second generation occurs between the SET of 986°C to 1,290°C.

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