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Chapter 5

Research on Seasonal Dynamics of 14 Different Insects Pests in Slovenia Using Pheromone Traps

Žiga Laznik and Stanislav Trdan

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/53186

1. Introduction

With increasing public concern about the use of toxic pesticides to control insects and other pestiferous organisms, resource managers are turning toward other techniques of integrated pest management. Some of these techniques are common-sense approaches, such as completing sanitation or clean-up activities before the season when the damaging stages of an insect pest are present. Other tools are more "hi-tech", such as the use of odors called semiochemicals, and in particular, pheromones, to manipulate the behavior of insect pests. With these non-toxic and biodegradable chemicals, insects can be lured into traps or foiled into wasting energy that they normally need for locating food and mates. Semiochemicals are chemical signals that are produced by a plant or animal and are detected by a second plant or animal and cause a response in the second organism. Many species depend on these chemical signals for survival.

Pheromones are a class of semiochemicals that insects and other animals release to communicate with other individuals of the same species (Witzgall, 2001). The key to all of these behavioral chemicals is that they leave the body of the first organism, pass through the air (or water) and reach the second organism, where they are detected by the receiver. In insects, these pheromones are detected by the antennae on the head. The signals can be effective in attracting faraway mates, and in some cases, can be very persistent, remaining in place and active for days (Witzgall, 2001). Long-lasting pheromones allow marking of territorial boundaries or food sources. Other signals are very short-lived, and are intended to provide an immediate message, such as a short-term warning of danger or a brief period of reproductive readiness. Pheromones can be of many different chemical types, to serve different functions. As such, pheromones can range from small hydrophobic molecules to water-soluble peptides. Over the last 40 years, scientists have

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identified pheromones from over 1,500 different species of insects. With insects, though, pheromones have found wide application in the fields of agriculture, forestry, and urban pest management, and there are companies that specialize in the discovery, manufacturing, and sales of pheromone-related products (Thomson, 1997).

There are three main uses of pheromones in the integrated pest management of insects (Witzgall, 2001). The most important application is in monitoring a population of insects to determine if they are present or absent in an area or to determine if enough insects are present to warrant a costly treatment. This monitoring function is the keystone of integrated pest management. Monitoring is used extensively in urban pest control of cockroaches, in the management of stored grain pests in warehouses or distribution centers, and to track the nationwide spread of certain major pests (Thomson, 1997).

A second major use of pheromones is to mass trap insects to remove large numbers of insects from the breeding and feeding population. Massive reductions in the population density of pest insects ultimately help to protect resources such as food or fiber for human use. Mass trapping has been used successfully against the codling moth, a serious pest of apples and pears.

A third major application of pheromones is in the disruption of mating in populations of insects. This has been most effectively used with agriculturally important moth pests (Waldner, 1997). In this scenario, synthetic pheromone is dispersed into crops and the false odor plumes attract males away from females that are waiting to mate. This causes a reduction of mating, and thus reduces the population density of the pests. In some cases, the effect has been so great that the pests have been locally eradicated (Thomson, 1997).

In summary, pheromones are species-specific chemicals that affect insect behavior, but are not toxic to insects. They are active (e.g. attractive) in extremely low doses (one millionth of an ounce) and are used to bait traps or confuse a mating population of insects. Pheromones can play an important role in integrated pest management for structural, landscape, agricultural, or forest pest problems (Witzgall, 2001).

The aim of our research was to study the seasonal dynamics of different insect pests in Slovenia to acquire the informations which are important for improving the control strategy of the pests based on environmentally friendly friendly concepts.

2. Materials and methods

In this chapter we present the results of monitoring of 14 different insect pests in Slovenia (Table 1, Figure 1) with the use of pheromone traps in the period 2004-2010. The majority of the results was performed within the framework of pedagogical work – graduation theses and master thesis – and scientific work at the Dept. of Agronomy, Biotechnical Faculy, University of Ljubljana (Slovenia) under the supervison of Prof. Stanislav Trdan.

http://dx.doi.org/10.5772/53186

Species	Host plant	Monitoring		
		Location (Coordinates and elevation)	Year	Reference(s)
Agrotis segetum	maize	Veliki Slatnik (1): 45°47′41″N, 15°13′39″E, 208 m	2007	Srebernjak (2009)
Agrotis segetum	fodder beet	Podobeno (2): 46°8′40″N, 14°11′6″E, 431 m	2010	Dolenec (2012)
Agrotis segetum	maize	Pungert (3): 46°9′23.52″N, 14°20′13.08″E, 340 m	2008	Kalan (2010)
Agrotis segetum	sugarbeet	Cvetkovci (4): 46°24′44″N, 16°3′50″E, 202 m Rakičan (5): 46°39′4″N, 16°11′53″E, 186 m Kranj (6): 46°14′37″N, 14°21′21″E, 388 m	2004	Zalokar (2006)
Anagasta kuehniella	stored cereals and their products	Želimlje (7): 45°55′0″N, 14°34′14″E, 336 m Obrije (8): 46°03′N 14°30′E, 298 m Lipovci (9): 46°37′33″N, 16°13′43″E, 180 m Jable (10): 46°9′45 ″N, 14°34′5″E, 316 m	2004	Selišnik (2007)
Anagasta kuehniella	stored cereals and their products	Želimlje (7)* Obrije (8)* Jable (10)*	2004-2005	Trdan et al. (2010)
Clysia ambiguella	grapevine	Gaberje pri Ajdovščini (11): 45°50′20″N, 13°53′10″E, 191 m	2007	Florijančič (2010)
Contarinia nasturtii	cabbage	Gobovce (12): 46°16′30″N, 14°19′4″E, 374 m	2006	Bohinc (2008)
Contarinia nasturtii	cabbage	Ljubljana (13): 46°03′N 14°30′E, 298 m Rakitnica (14): 45°41′35″N, 14°45′29″E, 490 m Zakl near Braslovče (15): 46°15′45″N, 15°3′14″E, 284 m Škocjan near Koper (16): 45°31′52″N, 13°46′30″E, 48 m	2004	Trdan et al. (2005a)
Contarinia nasturtii	cabbage	Ljubljana (13)* Rakitnica (14)* Zakl near Braslovče (15)*	2004	Walland (2007)
Contarinia nasturtii	cabbage	Ljubljana (13)*	2006	Trdan and Bobnar (2007) Trdan et al. (2008)
Cossus cossus	apricot	Pišece (17): 46°0′12″N, 15°38′53″E, 232 m	2005-2006	Trdan and Jeršič (2008)Jeršič (2009)
Cydia pomonella	apple	Prigorica (18): 45°42′47″N, 14°44′38″E, 485 m	2010	Bartol (2011)
Grapholita funebrana	plum	Dolenja vas (19): 45°42′24″N, 14°45′12″E, 493 m	2007	Pogorelc (2008)
Grapholita funebrana	plum	Gabrnik (20): 46°28′17″N, 15°57′19″E, 221 m Latkova vas (21): 46°14′48″N, 15°5′46″E, 270 m Dol pri Hrastniku (22): 46°8′33″N, 15°7′1″E, 331 m	2004-2005	Humski et al. (2005) Humski (2007)

Species	Host plant	Monitoring		
		Location (Coordinates and elevation)	Year	Reference(s)
		Rakitnica (14)* Želimlje (7)* Dobrovnik (23): 46°39′6″N, 16°20′53″E, 172 m Koper (24): 45°32′47″N, 13°43′46″E, 10 m Kromberk near Nova Gorica (25): 45°57′33″N, 13°40′7″E, 135 m		
Lobesia botrana	grapevine	Gaberje pri Ajdovščini (11)*	2007	Florijančič (2010)
Phyllotreta spp.	cabbage	Ljubljana (13)*	2006	Trdan and Bobnar (2007) Kržišnik (2009)
Plodia interpunctella	stored cereals and their products	Želimlje (7)* Obrije (8)* Lipovci (9)* Jable (10)*	2004	Selišnik (2007)
Plodia interpunctella	stored cereals and their products	Želimlje (7)* Obrije (8)* Jable (10)*	2004-2005	Trdan et al. (2010)
Plutella xylostella	cabbage	Ljubljana (13)*	2006	Trdan and Bobnar (2007) Rešetič (2008)
Scrobipalpa ocellatella	fodder beet	Podobeno (2)*	2010	Dolenec (2012)
Scrobipalpa ocellatella	sugarbeet	Cvetkovci (4)* Rakičan (5)* Gornji Lenart near Brežice (26): 45°55′48″N, 15°34′22″E, 151 m Kranj (6)*	2004	Valič et al. (2005) Čepin (2006)
Sitotroga cerealella	stored cereals and their products	Obrije (8)*	2004-2005	Zalokar (2009)Trdan et al. (2010)
Synanthedon myopaeformis	apple	Bojsno (27): 45°58′13″N, 15°40′15″E, 242 m	2009	Hriberšek (2012)
Synanthedon myopaeformis	apple	Roginska Gorca (28): 46°10′48″N, 15°34′30″E, 208 m	2008	Gradič (2009)

* Coordinates and elevation already mentioned in upper cell

The numbers within parenthesis behind all locations are designed for easier visibility of Figure 1.

Table 1. Insect species monitored with pheromone traps in Slovenia in the period 2004-2010.

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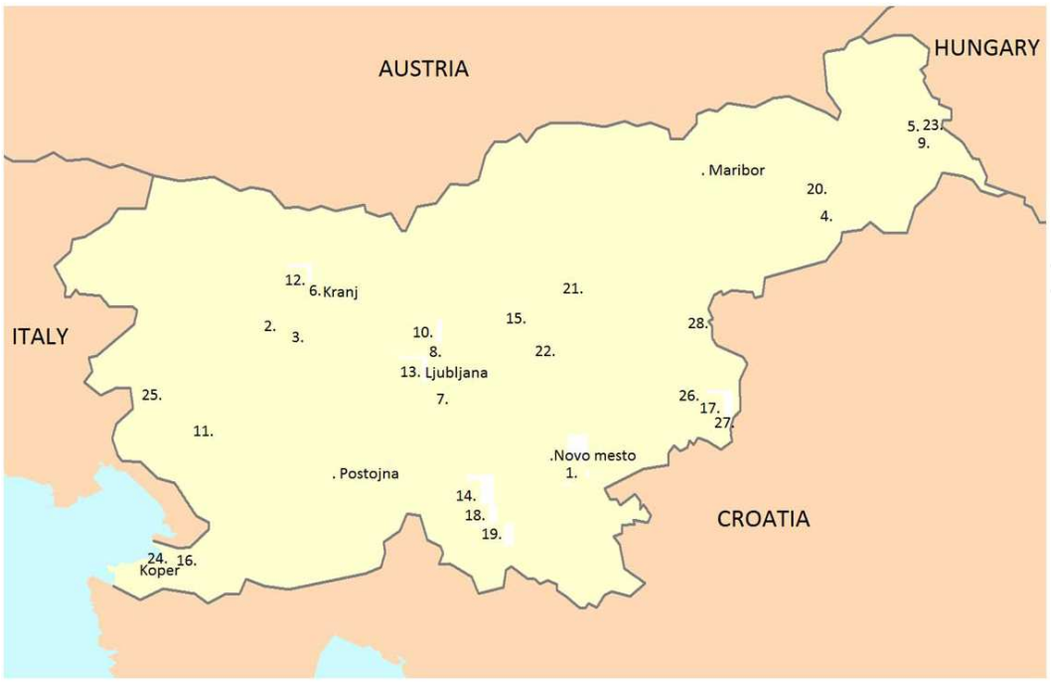


Figure 1. Locations of monitoring 14 different insect pests in 26 locations in Slovenia. Each number means specific location where the monitoring took place (seeTable 1).

Studied insect species:

a. Stored product pests

The Indian meal moth (*Plodia interpunctella* [Hübner]; Lepidoptera, Pyralidae)

Mediterranean Flour Moth (*Angusta kuehniella* [Zeller]; Lepidoptera, Pyralidae)

The Angoumois Grain Moth (*Sitotroga cerealella* [Olivier]; Lepidoptera, Gelechiidae)

2. Vegetable pests

Swede midge (*Contarinia nasturtii* [Kieffer]; Diptera, Cecidomyiidae)

The diamondback moth (*Plutella xylostella* [L.]; Lepidoptera, Plutellidae)

Flea beetle (*Phyllotreta* spp.; Coleoptera, Chrysomelidae)

2. Field crop pests

Beet moth (*Scrobipalpa ocellatella* Boyd; Lepidoptera, Gelechiidae)

The turnip moth (*Agrotis segetum* [Denis & Schiffermüller]; Lepidoptera, Noctuidae)

2. Fruit tree and grapevine pests

The Plum Fruit Moth (*Grapholita funebrana* [Treitschke]; Lepidoptera, Tortricidae)

The Codling moth (*Cydia pomonella* [L.]); Lepidoptera, Tortricidae)

The Red-belted Clearwing (*Synanthedon myopaeformis* [Borkhausen]; Lepidoptera, Sesiidae)

The Goat Moth (*Cossus cossus* [L.]; Lepidoptera, Cossidae)

The European grape berry moth (*Clysia ambiguella* [Hübner]; Lepidoptera, Tortricidae)

The European Grapevine Moth (*Lobesia botrana* [Denis & Schiffermüller]; Lepidoptera, Tortricidae)

3. Stored product pests

3.1. The Indian meal moth (*Plodia interpunctella* [Hübner]; Lepidoptera, Pyralidae)

The Indian meal moth is a serious and widespread pest of many stored food commodities (Sedlacek et al., 1996). The larval stage causes the injury. Larvae feed on flour and meal products, dried fruits, nuts, bird food, and dried pet foods. More unusual recorded foods include chocolate and cocoa beans, coffee substitute, cookies, flour, dried mangelwurzel, and even the toxic seeds of Jimsonweed (*Datura stramonium*). As the larva feeds it spins a web, leaving behind a silken thread wherever it crawls. Small particles of food often adhere loosely to the thread, making it conspicuous. Many times an infestation is noticed when moths are seen flying around the home in the evening. They are attracted to lights and often appear in front of the television screen (Sedlacek et al., 1996).

The Indian meal moth has a wingspan of about 18-20 mm. The color of the outer two-thirds of the wings is bronze to reddish brown, while the part of the wings closer to the body is grayish white. The larvae (caterpillars) are about 12-13 mm long when mature. They are a dirty white color, sometimes exhibiting pink or green hues. The pupa (resting stage) is in a loose silken cocoon spun by the larva, and is a light brown color (Hinton, 1943).

A female Indian meal moth can lay from 100 to 300 eggs during her lifetime. Eggs are laid singly or in groups on the food materials. Within a few days the tiny whitish caterpillars emerge. These larvae feed for a few weeks, and when they are mature they often crawl up the walls to where wall and ceiling meet, or crawl to the top of the cupboard, to spin the silken cocoon in which they pupate and from which the adult moth emerges. Mating occurs and the life cycle repeats itself. In warm weather the cycle may take only 6 to 8 weeks (Hinton, 1943).

Female *P. interpunctella* and females of other stored product moths of the subfamiliy Phycitinae produce Z-9, E-12-tetradecandienyl acetate as a component of their sex pheromone blends (Brady et al., 1971). Traps baited with synthetic pheromone are effective and widely used to monitor male stored-product moths (Vick et al., 1986; Chambers, 1990). Pheromone-baited traps have proven successful in detecting low level infestations of these moths (Vick et al., 1986).

In 2004-2005, pheromone traps (VARL+ type, (Csal♀m♂N® Budapest, Hungary) were used to monitor the occurrence of Indianmeal moth in Slovenia. The pheromone traps were set from March to December. Indianmeal moth was monitored during 2004 and 2005 in Želimlje and Jable and during 2004-2006 in Obrije. In Želimlje, the lepidopterian pests were monitored using two traps hung under the ceiling of a corn open air storage (part of a barn). It was used for storage of corn (corncobs) from harvest (the end of Sep-

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tember) till the end of July. In the lower part (under this corn open air storage) corn that was ground into flour was kept. In Obrije, an organic farm was monitored using four traps, three in the storage room and one in the mill. In Jable, the traps were placed in the Agricultural Centre, with one trap in the grain storage, a second one in the mill, and two outside the building (in front of the storage). At none of these locations were treatments against stored pests performed. Following the manufacturer's instructions, the pheromone lures were changed monthly. They were checked in 7 day intervals (Želimlje) or 14 day intervals (Obrije and Jable). The trapped males were stored in the lab at room temperature until identification. The determination was carried out using a Olympus SZ30 (manufacturer: Olympus Europa Gmbh, Hamburg, Germany) stereomicroscope (magnification about 10 times). The number of the trapped moths/day was calculated as the intervals were not the same for all the locations (Trdan et al., 2010).

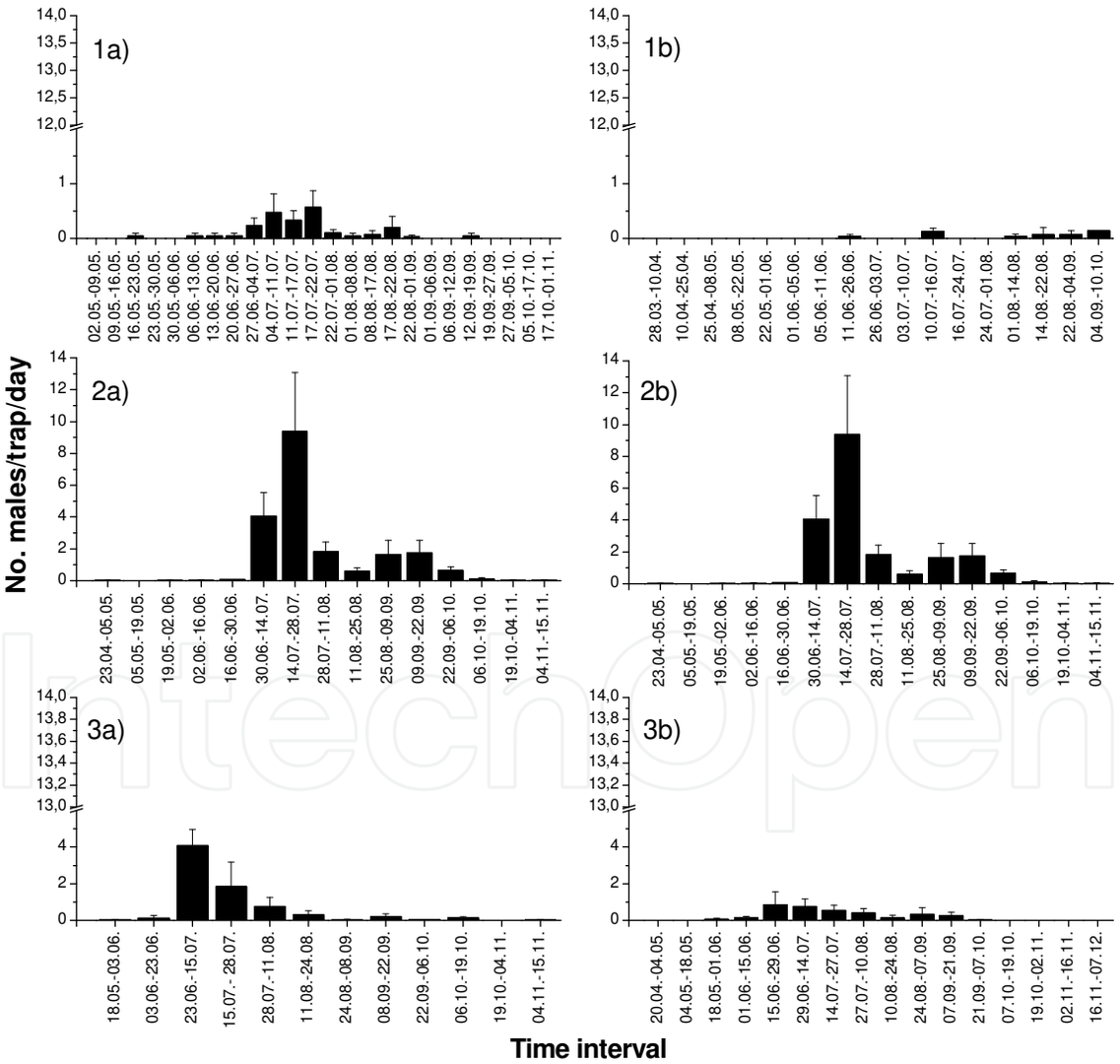


Figure 2. Number of *Plodia interpunctella* males caught by pheromone traps in Želimlje (1), Obrije (2) and Jable (3) in 2004 (a) and 2005 (b).

The males of Indianmeal moth were most numerous in Obrije during the three years of the study. The results suggest two peaks of flight activity, perhaps correlated with generations, of this moth, with the first being rather more numerous (figure 2). The first peak occurred during the second half of July (7-9 males/trap/day). In all three years, the second peak was in the middle of September, with captures of 2 males/trap/day. In Jable, the pest also showed two capture peaks as in Obrije, but captures were less numerous. This can be explained by the fact that two traps were set outside the storage, were only single specimens were captured. The first peak in captures at this location was during the second half of July, and captures were five times more numerous in 2004 (4 males/trap/day) compared to the next year. The second peak in captures was less numerous and appeared at the end of August and in September. In Želimlje captures of Indianmeal moth were the least numerous, probably because monitoring was in a non-protected open air storage, where corncobs were stored. There was never more than 1 male/trap/day caught at this location, and adults were active from the beginning of June till the end of September (both years) (Trdan et al., 2010). Part of this research was published by Selišnik in 2007. These results are opposite to reports of Campbell and Arbogast (2004), who found the greater activity of Indianmeal moth outside wheat flour meal compared to inside of them.

3.2. Mediterranean Flour Moth (*Ephestia kuehniella* [Zeller]; Lepidoptera, Pyralidae)

E. kuehniella is found worlwide but not abundant in the tropic region. The complete life-cycle of this species takes about 50 days. Mediterranean Flour Moth larvae mainly feed on wheat flour but are recorded from a wide range of commodities and from dead insects (Cox and Bell, 1991).

The surface of the newly laid eggs of *E. kuehniella* is white in colour, and shining iridescent when observed by reflected light (Garcia-Barros, 2000). Just before hatching the egg turns light yellow in color due to the development of the embryo which can be seen through the shell of the egg at this time. The egg is 500-550 μm long by 290-325 μm wide. *E. kuehniella* larvae are 0.866 mm long and 0.199 mm wide on average immediately after hatching (Garcia-Barros, 2000). The newly hatched larvae are cream coloured and sparsely covered with long hairs. *E. kuehniella* larvae have six instars (Cox and Bell, 1991). Mature larvae crawl to the surface of the material on which they have fed, and spin silk cocoons intermingled with particles of meal and flour for pupation. Pupae are pale green at the early stage and then turn to reddish brown on the dorsal side of the thoerax. On the last day of development, pupae become dark in color (Garcia-Barros, 2000). Adults are 10-14 mm long when at rest, with wingspan beiing 20-25 mm; forewings are blue-grey with transverse dark wavy bars and a row of dark spots at the tip; hindwing are dirty white with fuscous veins.

In Slovenia the pest was monitored simultaneously with *Plodia interpunctella* males (in the same pheromone lures) since the manufacturer does not offer a specific pheromone for each species. Therefore the same material and methods as it is presented for *Plodia interpunctella* (see the 5th paragraph of the chapter 1.1.) was used (Trdan et al., 2010).

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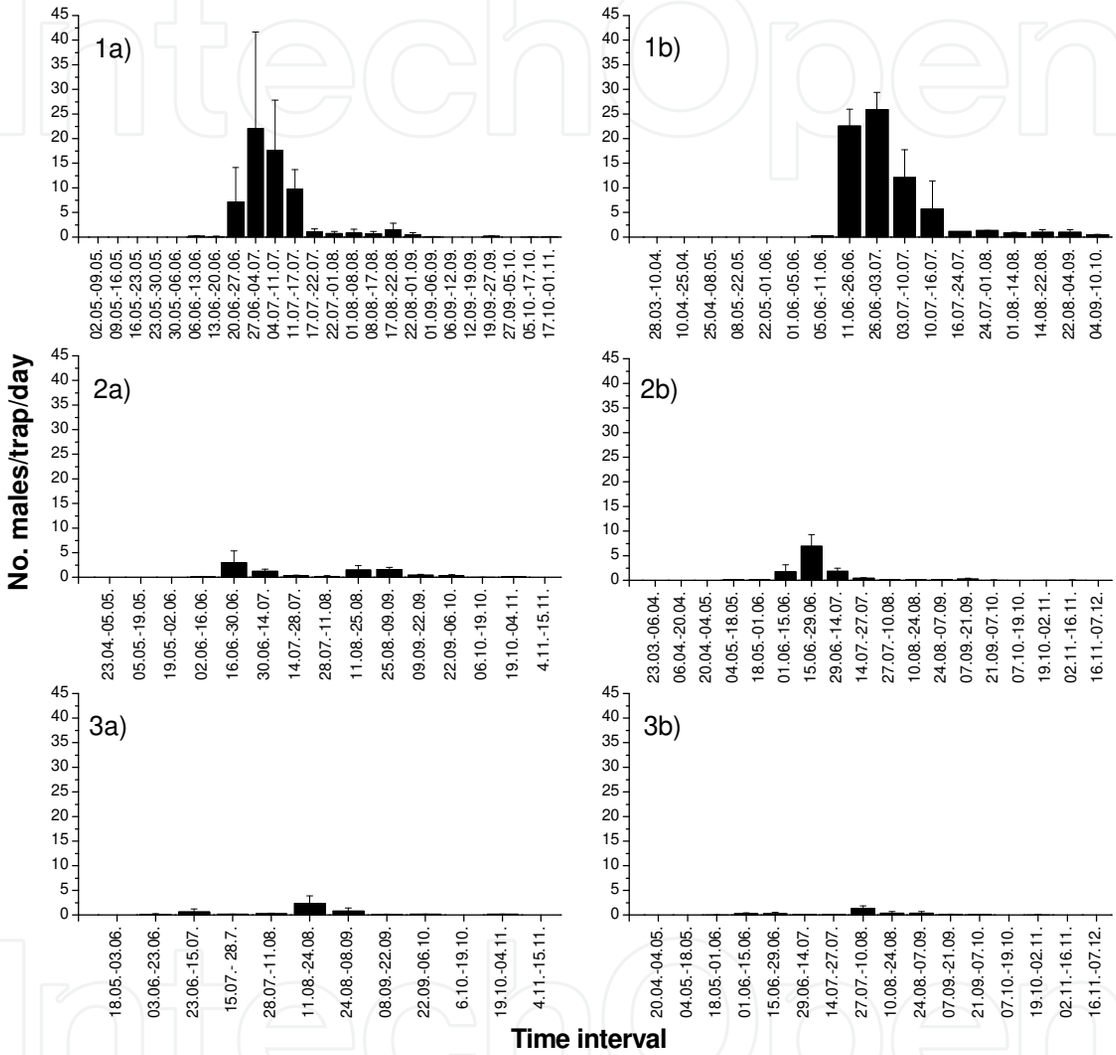


Figure 3. Number of *Ephestia kuehniella* males caught by pheromone traps in Želimlje (1), Obrije (2) and Jable (3) in 2004 (a) and 2005 (b).

Mediterranean flour moth captures in the pheromone traps were more numerous than captures of *Plodia interpunctella*. The captures of this pest, which appeared to have two peaks in capture, was most numerous in Želimlje, where the first peak was in the beginning of June (both years) – 22 to 25 males/trap/day. Later in the year the abundance of this moth de-

creased significantly, possibly also due to removal of the stored corncobs from the previous season. Single males were found in the traps till the end of the monitoring in October. In closed storage rooms, In Obrije and Jable, captures of Mediterranean flour moth were less numerous, the peak being about 7 males/trap/day in Obrije in the second half of July. The males at these locations were spotted from the beginning of June until October (Figure 3). Part of this research was published by Selišnik in 2007.

3.3. The Angoumois grain moth (*Sitotroga cerealella* [Olivier]; Lepidoptera, Gelechiidae)

Sitotroga cerealella (Olivier) is an important pest of stored grains, whose biology has been well researched (Shazali, 1990). The Angoumois grain moth overwinters as mature larvae that pupate in a silken cocoon in the grain during early spring. Larvae feed inside whole grains on the germ and endosperm, completely destroying the kernel (Arbogast and Mullen, 1987). This insect prefers damp grain to old dry grain, especially barley, corn, oats, wheat, and various seeds. This pest may infest grain, especially wheat and corn, before harvest while it is still standing in the field (Arbogast and Mullen, 1987).

Adults are small, buff or yellowish-white moths with pale yellow forewings and gray, pointed hind wings with a wingspan of 12 mm. The forewings are marked with a few darker lines, and the hind wings are notched at the apical end. The wings also have long fringe around the margins. Mature larvae are pale yellow and about 6 mm long with poorly developed prolegs on the abdomen (Arbogast and Mullen, 1987). Adults emerge in May and June and females begin laying eggs singly or in clusters on or near the grain. Eggs hatch in about a week during the summer, but may require up to four weeks to hatch when temperatures are cooler. Young larvae enter the grain immediately. Larvae mature in two to three weeks, and construct an escape tunnel in the grain through which adults can later emerge. The pupal stage lasts about two weeks (Shazali, 1990). Under favourable conditions, the life cycle may be completed in five to seven weeks. In colder climates, larvae become dormant for four to five months and the life cycle may take up to six months to complete. In unheated storage, there are two generations each year. In heated storage, there are usually four to five generations per year (Arbogast and Mullen, 1987).

The results of investigation in Slovenia (for material and methods see the 5th paragraph of chapter 1.1.), which was performed in Obrije in the period 2005-2006, showing a typical two peaks in flight activity, allow the conclusion, that, on the average, the species under investigation develop two generations under the conditions in Central Slovenia (Figure 4). The results of our research showed that in 2005, the first males of Angoumois grain moth were caught in the first half of June, while more substantial numbers (more than 2 males/trap/day) were observed in Obrije in the first half of July. This period may correspond with the peak of first generation of the year. As the study went on, a second peak was observed in the midst of September (6 males/trap/day), which could indicate a second generation. The adults were active till the first half of November. In 2006, the pest was less numerous and the first specimens were found in the traps during the second half of June. As in 2005, two peaks in trap capture were observed, the peaks being 1 male/trap/day at the beginning of July and in the midst of September (Trdan et al., 2010; Zalokar, 2010).

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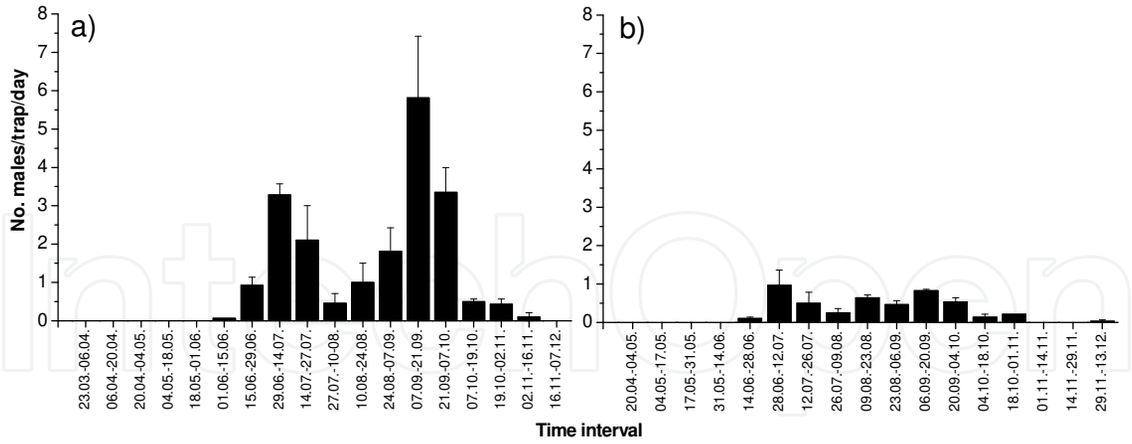


Figure 4. Number of *Sitotroga cerealella* males caught by pheromone traps in Obrije in 2005 (a) and 2006 (b).

4. Vegetable pests

4.1. Swede midge (*Contarinia nasturtii* [Kieffer]; Diptera, Cecidomyiidae)

The Swede midge is a pest of most cultivated Brassicaceae such as broccoli, canola, cauliflower, cabbage, and Brussels sprouts. The species primarily has a Palaearctic distribution and occurs throughout Europe and southwestern Asia to the Caucasus (Olfert *et al*., 2006). Plant damage is caused by larval feeding; symptoms include misshapen plants and the formation of galls on leaves and flowers (Bardner et al., 1971). The larval stage overwinters in the soil, adults emerge in May and females lay eggs, in clusters of 2–50, on the surface of actively growing plants. Larvae feed on actively growing stems, leaves, and flowers, then drop to the soil to pupate. During the growing season, adults can emerge within 2 weeks or larvae enter diapause in autumn. Depending on temperature and soil moisture, *C. nasturtii* may have 2–5 generations (Hallett and Heal, 2001). Temperature and moisture have been identified to be the two most important factors responsible for population distribution, growth, and control. Population growth was greatest in warm, moist seasons and reduced in cool or dry seasons (Readshaw, 1966).

In 2004, the occurrence of Swede midge on four locations in Slovenia (Ljubljana, Rakitnica, Zakl near Braslovče, Škocjan near Koper) was investigated (Figure 5). Pheromone traps of the Swiss producer (Agroscope FAW, Wädenswill) were set in fields with Brassica plants. The aim of the research was to determine a population dynamics of the pest in vegetation period, to establish the number of generations it develops per year in geographically and climatically different regions. Understanding of the pest bionomics would help to set a strategy for control of Swede midge in Brassica plants. The results of the monitoring indicate that the species has 4 generations per year, also in the continental part of the country. In all four locations a generation was also established in September (Trdan et al., 2005a). Part of this research was published by Walland in 2007.

In similar research, which lasted from the beginning of April to the beginning of November 2006, a seasonal dynamics of Swede midge was investigated at the Laboratory Field of the Biotechnical Faculty in Ljubljana (Trdan and Bobnar, 2007; Trdan *et al*., 2008). The males of Swede midge were trapped with already mentioned traps of Swiss producer The pheromone capsules were changed in 4-week intervals, while the males were counted on about every 7th day. The first massive occurrence of Swede midge (0.4 males/trap/day) was established in the 2nd decade of May, while the highest number of males (8/trap/day) were caught in the 2nd decade of July. In the 3rd decade of October, the last adults were found in the traps. Based on the results of monitoring we ascertained that in the central Slovenia the Swede midge has 3-4 generations.

In a related research, which was performed in 2006 (Bohinc, 2008), it was confirmed, that the use of synthetic insecticides and fungicides have an influence on a population dynamics of the above mentioned pest.

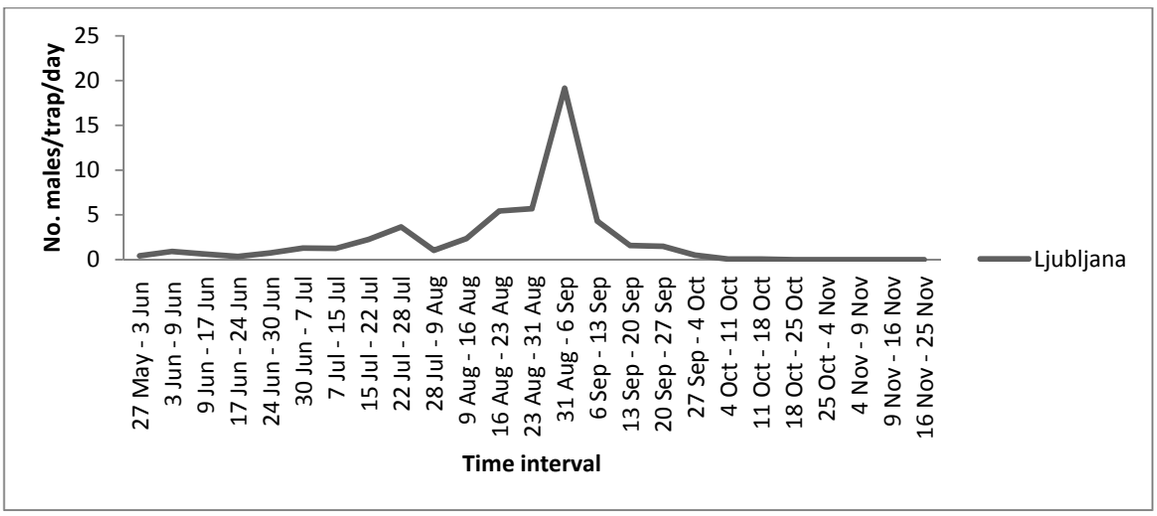


Figure 5. Population dynamics of *Contarinia nasturtii* males in Ljubljana in 2004.

4.2. The diamondback moth (*Plutella xylostella* [L.]; Lepidoptera, Plutellidae)

The diamondback moth is a cosmopolitan species that probably originated in the Mediterranean region (Hardy, 1938). Host plants include both cultivated and wild-growing plants of the family Cruciferae, as well as several ornamentals, such as wallflower, candytuft, stocks, and alyssum. Cultivated crops that are attacked include broccoli, Brussels sprouts, cabbage, cauliflower, Chinese broccoli, Chinese cabbage, flowering white cabbage, head cabbage, mustard cabbage and watercress. Weed hosts, such as mustard and radish, are important reservoir hosts for the species.

The first instars sometimes feed in the spongy plant tissue beneath the leaf surface forming shallow mines that appear as numerous white marks. These mines are usually not longer than the length of the body. The larvae are surface feeders in all subsequent stages. These

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larvae feed on the lower leaf surface 62-78 % of the time, chewing irregular patches in the leaves (Harcourt, 1957). All the leaf tissues are consumed except the veins. On some leaves, the larvae feed on all but the upper epidermis creating a "windowing" effect. The last stage larva is a voracious feeder; it causes more injury than the first three larval instars. Total development time from the egg to pupal stage averages 25 to 30 days, depending on weather, with a range of about 17 to 51 days. The number of generations varies from four in cold climates to eight to 12 in the south. Overwintering survival is positively correlated with the abundance of snowfall in northern climates (Eigenbrode and Shelton, 1990).

From the beginning of April to the beginning of November 2006, a seasonal dynamics of diamondback moth was investigated at the Laboratory Field of the Biotechnical Faculty in Ljubljana. The males were trapped with the Hungarian traps type RAG (Plant Protection Institute, Hungarian Academy of Sciences). The pheromone capsules were changed in 4-week intervals, while the males were counted on about every 7th day. The first massive occurrence of diamondback moth (1.6 males/trap/day) was established in the 2nd decade of April, and the pest remained active until the 2nd decade of September (figure 6). The adults were the most numerous in the period between the end of May to the middle of June, but even then their number did not exceed three males caught per day. Based on the results of monitoring we ascertained that in the central Slovenia the diamondback moth has 4 generations (Trdan and Bobnar, 2007; Rešetič, 2008).

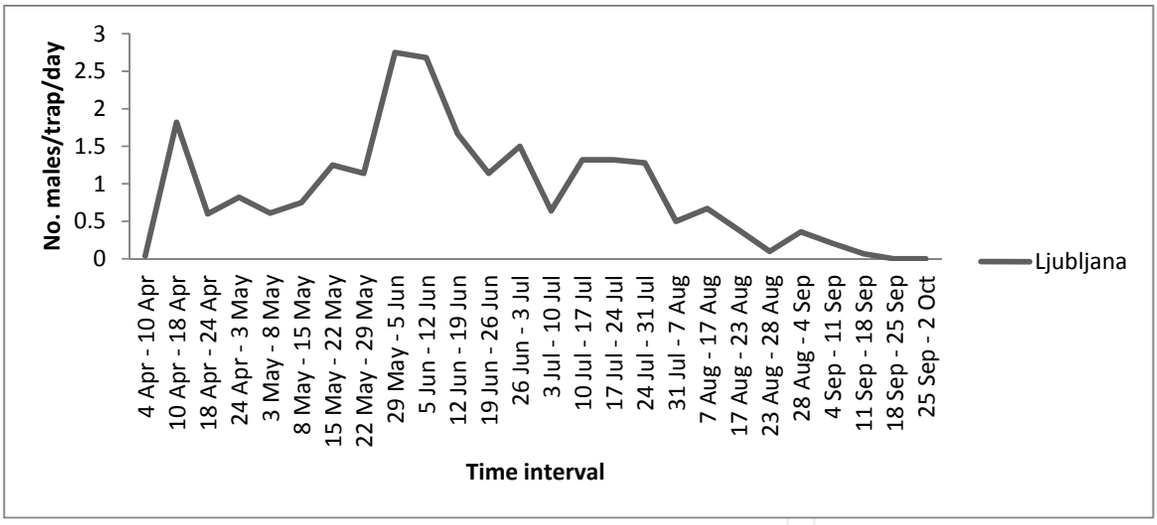


Figure 6. Population dynamics of *Plutella xylostella* males in Ljubljana in 2006.

4.3. Flea beetles (*Phyllotreta* spp.; Coleoptera, Chrysomelidae)

Flea beetles (Coleoptera: Chrysomelidae) inhabit a wide range of environments where cruciferous plants grow, including fields, gardens, and uncultivated areas. Although flea beetles colonize crops every year, their population densities vary widely between years (Andersen et al., 2005). Flea beetles are univoltine. They overwinter as adults, usually out-

side fields, in margins, in hedgerows, and beneath shrubs, although some find shelter within fields in leaf litter, in stubble, or in grassy areas (Andersen et al., 2005). Physical conditions at their overwintering sites may fluctuate daily, seasonally, and between years. Various species of flea beetle feed on the leaves of Brassica plants throughout the entire growing season (Vig, 2002; Trdan et al., 2005b; Bohinc et al., 2012). The beetles usually cause most problems on young plants, as these are small and hence, can tolerate only small amounts of damage.

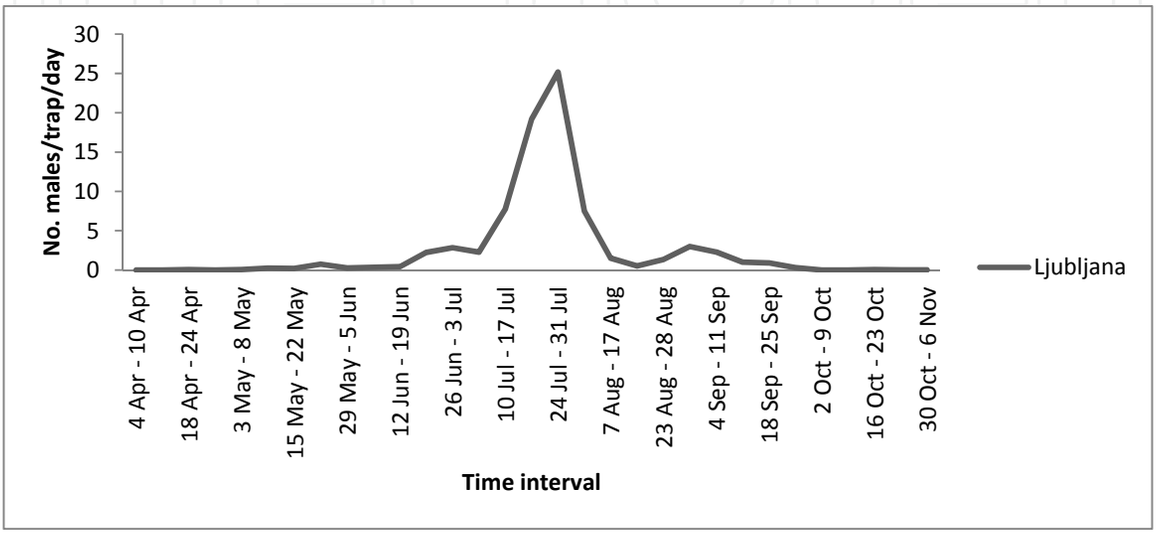


Figure 7. Population dynamics of *Phyllotreta* spp. males in Ljubljana in 2006.

From the beginning of April until the beginning of November 2006, a seasonal dynamics of flea beetles was investigated in Ljubljana (Trdan and Bobnar, 2007; Kržišnik, 2009). The number of males was monitored with pheromone traps (type KLP+) of Hungarian producer. Pheromone baits were changed once per month, and the males which were caught in the traps were counted once per week. The beetles were the most numerous in the second and third ten-days period of July, while the last flea beetle was found in the beginning of November. Weather conditions in the growth period of cabbage, above all the rainfall and air temperature, had important influence on the number of the beetles. Based on the results of flea beetles monitoring we can conclude that in Central Slovenia the pest under our investigation has 1-2 generation (firure 7).

5. Field crop pests

5.1. Beet moth (*Scrobipalpa ocellatella* Boyd; Lepidoptera, Gelechiidae)

Beet moth is a dangerous pest of sugar beet especially in southern Europe (Robert and Blaisinger, 1978). Caterpillars can also feed on other plants of the family Chenopodiaceae (pigweed, seablite, saltwort etc.). The caterpillars skeletonize leaves, braiding them with silk

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threads. In spring and in the beginning of summer, they mine leaves, usually along main veins, also piercing holes in petioles. The damaged leaves roll and blacken. A black clump of rotten leaves fastened with silk threads is formed instead of the central rosette. In hot and dry years, such damage frequently causes the whole plant to die since the outer leaves die off quickly and new ones are not formed because of the central rosette loss. Caterpillars of the following generations penetrate into roots. In the upper part of the roots they gnaw out narrow, twisting grooves or holes under thin skin, sometimes boring to a depth of 5 cm. These holes under skin also injure lateral parts of roots. The damaged roots become languid and rotten. In parent beet plants, the caterpillars injure flower buds, unripe seeds, and tips of growing floriferous stalks, piercing holes; as a result, the stalks are bent, and yield of seeds sharply falls (Robert and Blaisinger, 1978). The economic damage threshold is exceeded when 4-5 larvae are found on 70% of plants (Valič et al., 2005).

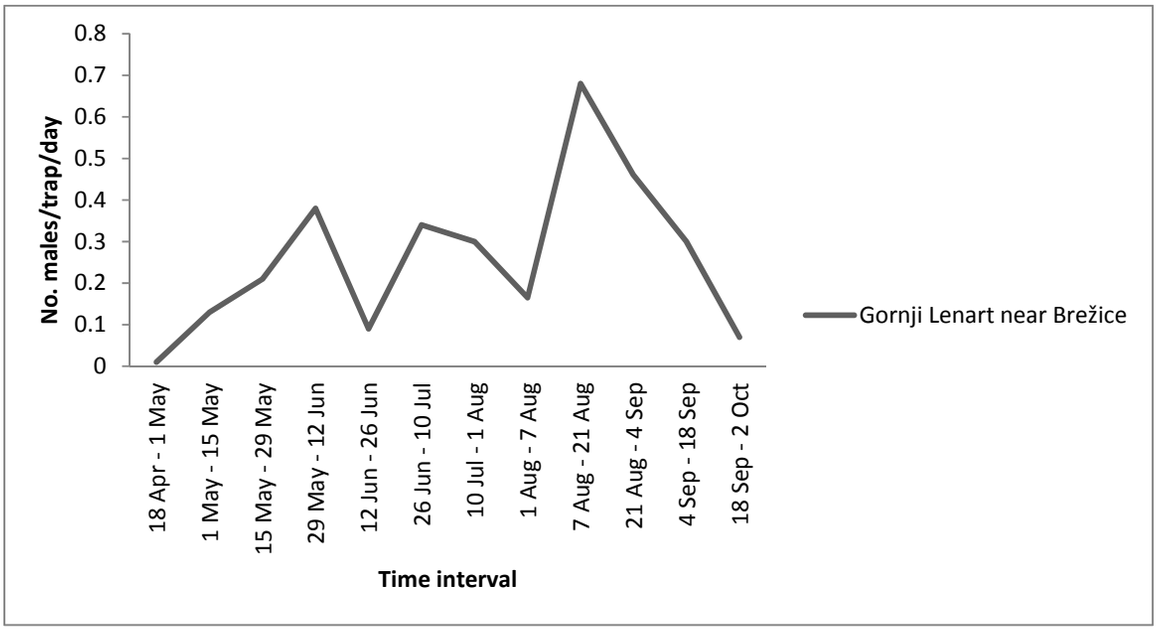


Figure 8. Population dynamics of *Scrobipalpa ocellatella* males in Gornji Lenart near Brežice in 2004.

There are two to five generations a year depending on the climate. Moth flight after wintering begins in April, during shooting of beet in spring. One generation develops 40-65 days. The pest numbers increase in every following generation, reaching maximum by the end of summer. This species overwinters as a pupa or partly-grown larva (Robert and Blaisinger, 1978).

In the beginning of this century, the sugarbeet moth was a new pest of sugarbeet in Slovenia. The first noticeable occurrence of the pest was recorded in 2003, which was distinctively drier and warmer than an average year. Such weather conditions are especially suitable for this species. In 2004, monitoring of the pest was carried out on four locations: Cvetkovci, Rakičan, Gornji Lenart near Brežice and Kranj. The occurrence of the pest was determined by means of setting pheromone traps on the margins of the sugarbeet fields. The greatest number of sugarbeet moths was caught in traps in Gornji Lenart near Brežice, where sugarbeet

was grown in close vicinity in 2003. In Kranj, there was no trace of the pest at all. Based on one-year results of the monitoring of the sugarbeet moth we came to a conclusion that in 2004 in Slovenia the pest had 2 generations (figure 8). The sugarbeet moth has caused no severe yield loss in Slovenia so far. Consequently, no insecticides have been registered for its control as yet (Valič et al., 2005; Čepin, 2006). After 2006, the production of sugarbeet has stopped in Slovenia, and that is also one of the reasons that the pest was not recorded in the fodder beet field in the vicinity of Škoflja Loka during monitoring in 2010 (Dolenec, 2012).

5.2. The turnip moth (*Agrotis segetum* [Denis & Schiffermüller]; Lepidoptera, Noctuidae)

The turnip moth is distributed across the European and the Mediterranean regions. *Agrotis segetum* is an important economic insect of turnip, lettuce, Swedes, wild-growing plants, couch grass, bindweed and plantain. Infestation also occurs in neighbouring vegetables including red beet, potato, cereals, tobacco and vine (Wood et al., 2009).

The adult has a 40 mm wingspan; dark brown fore wings with, in the middle, a uniform spot and a clearer circular spot. The hind wings are white in the male and grey in the female. The periphery of the wings bears a thin black border. Larva is 45 to 50 mm, reddish head and a greyish body with two parallel longitudinal lines in the middle region. On each segment, 2 small black spots at the front and two at the back, bearing a small bristle as well.The young caterpillar first nibbles the wild-growing plants and then attacks the neighbouring cultivated species. It feeds at night, gnawing the foliage and cutting the petioles. During the day, it conceals itself by rolling up under a lump of earth or at a slight depth in the ground (Anderson and Löfquist, 1996).

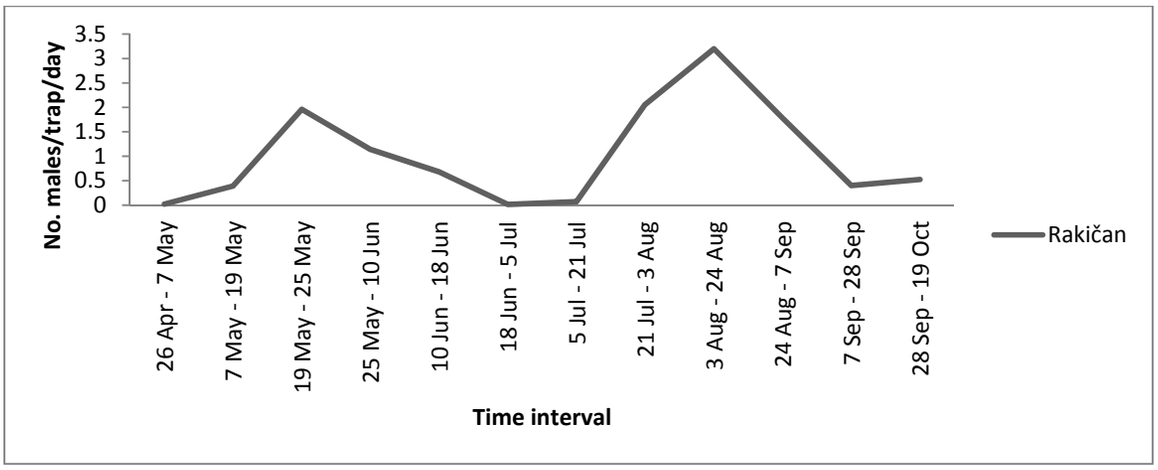


Figure 9. Population dynamics of *Agrotis segetum* males in Rakičan in 2004.

In 2004, the monitoring of turnip moth in sugarbeet (*Beta vulgaris* var. *altissima* Döll.) were performed in two locations in Slovenia: Cvetkovci near Ormož, Rakičan and Kranj (Zalokar, 2006). Pheromone traps (VARL type, Csal♀m♂N® Budapest, Hungary) were used for monitoring the pest under investigation. Four baits were set along the margins of fields (one par-

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cel on each location) where sugarbeet was sowed. Pheromone capsules were replaced once a month and the butterflies captured in them were counted in 2-3 week intervals. We ascertained that, under favourable climatic conditions, the turnip moth are able to overmultiply; that occurs when the air temperature rises above 12°C. The amount of rainfall does not influence the bionomics of the pest. In the neighbouring countries turnip moth develops two generations per year. Based on our observations in 2004 turnip moth appears in two generations also in Slovenia (figure 9). Similar conclusions were gained also in two researches, which took place in the vicinity of Škofja Loka; Kalan (2010), monitored the pest in 2008 on the corn field, and Dolenec (2012) studied the seasonal dynamics of the butterfly in 2010 on the fodder beet field. On the other side Srebernjak (2009) confirmed the occurrence of three generations of the same pest on the corn field in the vicinity of Novo mesto.

6. Fruit tree and grapevine pests

6.1. The Plum Fruit Moth (*Grapholita funebrana* [Treitschke]; Lepidoptera, Tortricidae)

A native of Europe, *Grapholita funebrana* has spread to most other fruit-growing regions of the Palaearctic. It is currently present from Europe and northern Africa across Asia Minor and Central Asia to China, Korea, and Japan (Hrdy et al., 1996). *Grapholita funebrana* is one of the most important lepidopteran pests of fruit in Europe. Larvae can cause significant damage to apricot, cherry, peach, plum, and other *Prunus* species. The Plum Fruit Moth completes 1-3 generations per year; two generations are most common over most of its range. Adults are present from late May to September (Polesny et al., 2000).

First generation females lay eggs singly on fruitlets. Second generation females lay eggs near the base of maturing fruit. Larvae tunnel into the fruit and feed inside. Last instar larvae bore out of the fruit and overwinter in a cocoon spun on tree bark or in the soil. Pupation occurs the following spring. Larvae of the second generation cause the most damage to fruits such as plum that mature in mid- to late summer (Hrdy et al., 1996).

Distribution of plum fruit moth in plum crowns and its apperance in the vicinity of the trees was investigated in 2007 in Dolenja vas near Ribnica (Pogorelc, 2008). Pheromone traps were placed in the first half of February on two trees. Experiment has lasted till the end of September. The purpose of experiment was to find out in which parts of the crowns or how far from the trees the pest appears. It was found out that pest was the most abundant at sunny exposure of crowns, on SE and SW crown parts. Inside of crowns and in northern part of crowns, the pest was less abundant. Before the flowering of plums the abundance of the plum fruit moth in plum crowns and in the vicinity of the trees was almost same numbers. During the flowering and growing season, the number of the moths was higher inside crowns. Plum fruit moth appeared also in the vicinity of the trees. On baits, 10 and 20 m away of them, quite high number of the males has been caught. Air temperature and amount of rain also influenced moth apperance. From the data of our research we can conclude that pest had two generations per year (figure 10), whose the second generation was more abundant from the first generation. In a related research Humski et al. (2005) and

Humski (2007) studied the occurence of the plum fruit moth in 2004 and 2005 on different locations in Slovenia and concluded that the plum fruit moth has 3 generations per year only in the littoral part of Slovenia (Kromberk near Nova Gorica and Koper), while in the continental part of the country it has 2 generations per year.

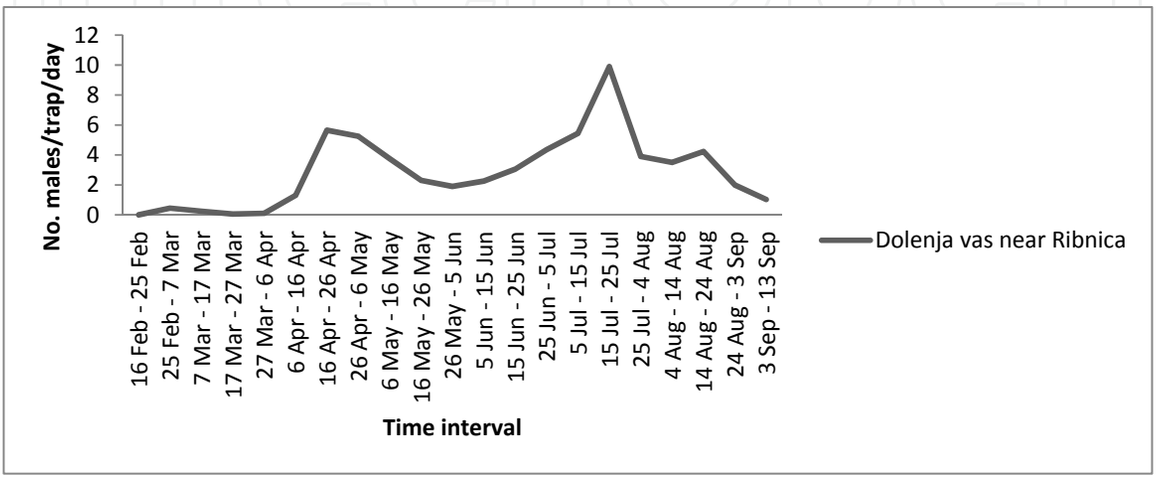


Figure 10. Population dynamics of *Grapholita funebrana* males in Dolenja vas near Ribnica in 2007.

6.2. The codling moth (*Cydia pomonella* [L.]); Lepidoptera, Tortricidae)

The Codling Moth is a cosmopolitan insect pest of deciduous fruits. It has a remarkable ability to adapt to a wide range of climatic conditions. The number of generations gradually increases toward the southern latitude in the Northern Hemisphere and towards the north in the Southern Hemisphere. In, general, the larva of codling moth have five instars (Witzgall et al., 2008). Weitzner and Whalon (1987) describes that the codling moth overwinters as either a fourth or fifth instar diapausing larvae. Codling moth overwinters as a mature larva beneath tree bark scales or at the base of the tree. Adults appear in the spring and eggs are laid singly on or near the fruit. Eggs hatch in 5 to 12 days, depending upon temperature, and the young larvae move to developing fruit within a few hours, chew through the skin, and burrow into the flesh. Subsequently, the larva burrows to the fruit core and feeds on seeds. The potential for crop loss to the codling moth makes it the most important pest of pome fruits. When uncontrolled, the codling moth is capable of annually destroying 80 % or more of an apple crop and 40-60 % of a pear crop. Besides apples, the codling moth can develop on other pome fruits such as pear and quince, on stone fruits such as apricot, plum and peaches as well as on walnuts (Witzgall et al., 2008), apricot, almond, pecan nuts and pomegranates (Weitzner and Whalon, 1987).

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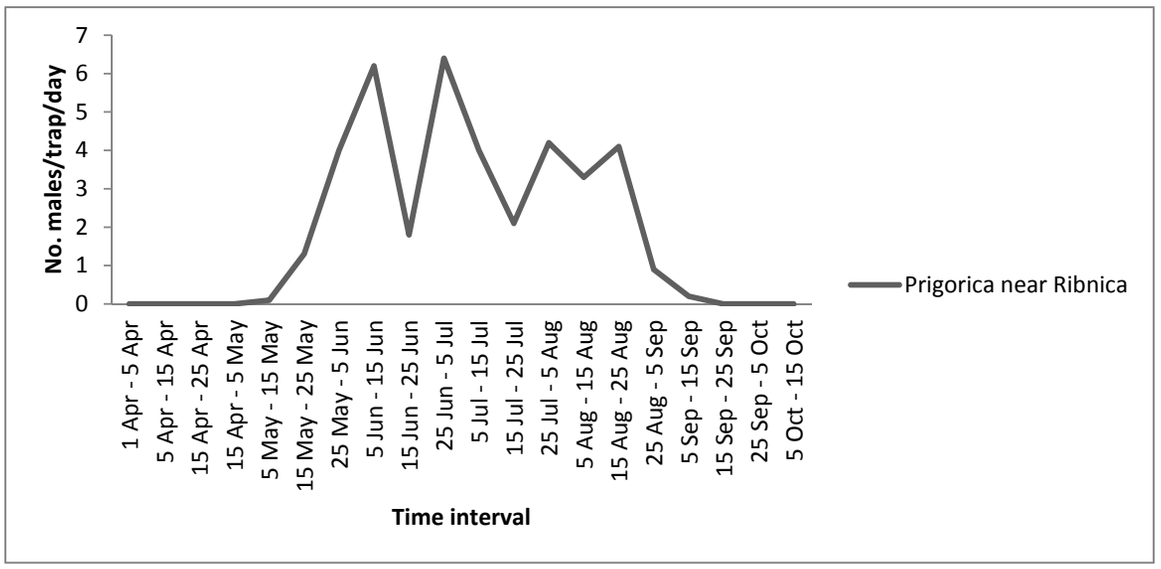


Figure 11. Population dynamics of *Cydia pomonella* males in Prigorica near Ribnica in 2010.

In 2010, a monitoring of codling moth was conducted in an extensive mixed orchard in the village Prigorica near Ribnica (Bartol, 2011). In the orchard, four insect pheromone baits (RAG type, Csal♀m♂N® Budapest, Hungary) were placed and the occurrence of the pest was monitored from early April to mid-October. The purpose of the study was to examine the presence and the numbers in which this pest occurrs, since it was assumed that they differ from that of the intensive orchards. With the research the author obtained useful informations needed to optimize control strategies of codling moth, in which a pheromone baits can also be used for mass trapping of the pest. It was found out that the pest appeared from the first decade of May until the second decade of September and during this time it developed two generations (figure 11). The first generation was larger than the second one. Both, the temperature and the rainfall affect the occurrence and the numbers of codling moth.

6.3. The Red-belted Clearwing (*Synanthedon myopaeformis* [Borkhausen]; Lepidoptera, Sesiidae)

Synanthedon myopaeformis is a xylophagous species that attacks pome and stone fruit trees (Trematerra, 1993). The larval form of this insect lives under the bark of fruit trees, especially apple (*Malus*), but sometimes pear (*Pyrus*), almond (*Prunus amygdalus* Batsch) and a few other closely related plant species (Iren and Bulut, 1981). The larvae located under the bark of tree trunk and thick branches bore deep subcortical galleries 20 to 25 mm long and cut into the phloem (Iren and Bulut 1981). The control of this pest is difficult because the adults have a long emergence period and the larvae develop inside the trunk and thick branches. Failure to prevent injury can lead to reduced tree vigor and yield (Trematerra, 1993).

In 2008 and 2009, a seasonal dynamics of apple clearwing moth (*Synanthedon myopaeformis*) was monitored in two extensive apple orchards (mowed and overgrown) in the village Bojsno in the Bizeljsko region (Hriberšek, 2012) and in Roginska Gorica in the Kozjansko region

(Gradič, 2009). Pheromone traps (RAG type, Csal♀m♂N® Budapest, Hungary), which consist of a triangular plastic casing, a pheromone capsule and a sticky plate were used for monitoring. Four traps were randomly placed in each orchard. Capsules were changed monthly and caught moths were counted in 10 day intervals. The research was conducted from the beginning of April to the beginning of September. The purpose of the research was to examine influence of temperature and quantity of precipitation to the abundance of the pest regarding usage of grassland in the orchards. The results revealed that the usage of grassland has a great influence on the abundance and as well on the appearance of the apple clearwing. The pest was more abundant in the mowed extensive orchard than in the overgrown extensive orchard. First males appeared earlier in the overgrown orchard than in the mowed orchard and they stopped appearing earlier in the overgrown than in the mowed orchard. Captured moths were detected from the end of April to the beginning of August. Moths were the most abundant from June to the beginning of July. Similar conclusions gained also Gradič (2009) in her related research (figure 12). The pest occurred in the mowed extensive orchard when the temperature increased above 15 °C and in the overgrown orchard when the temperature increased above 13, 5 °C. Abundance of the male apple clearwing moths was also increased by the quantity of precipitation from 20 to 40 mm.

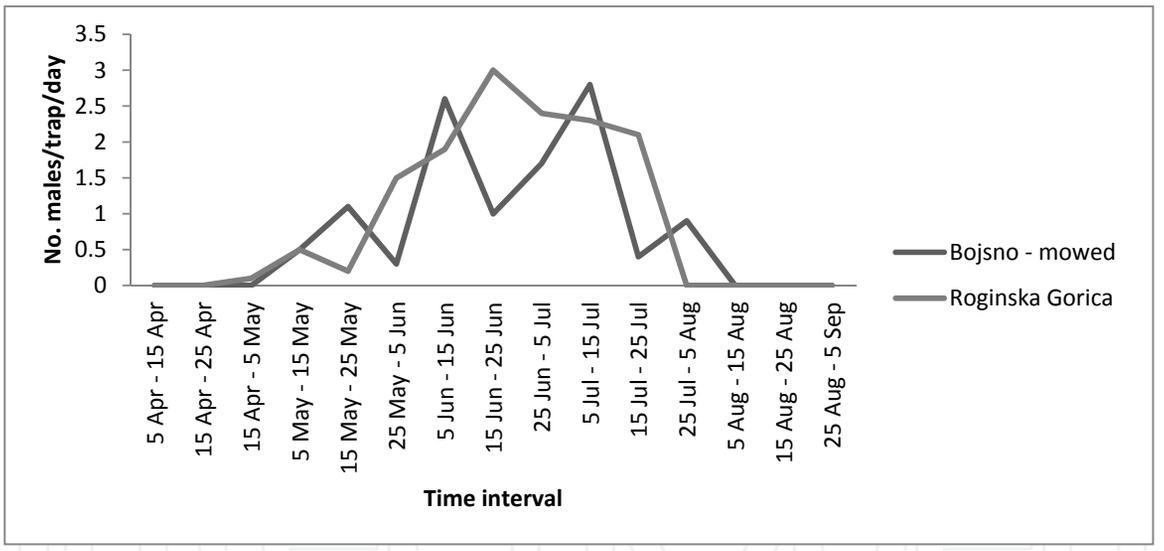


Figure 12. Population dynamics of *Synanthedon myopaeformis* males in Bojsno (2008) and in Roginska Gorica (2009).

6.4. The Goat Moth (*Cossus cossus* [L.]; Lepidoptera, Cossidae)

Goat moth is an important forest insect of Europe. It is distributed in North America, China and Siberia. Larvae cause the main damage. It bores into the heart wood causing extensive damage and finally killing the tree (Oberhauser and Peterson, 2003). In southern Europe this species has been recorded on sugar beet and Artichoke (Pasqualini and Natale, 1999). Caterpillars can also damage wood of pears, apple, plums, cherries, quince, apricot, walnut, persimmon, European olives, wild olives (*Olea oleaster*), mulberries, sea-buckthorn, willow,

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poplar, aspen, alder, ash-tree, birches, beech, oak, maple, elm (*Ulmus suberosa*), oleaster. Adults fore wings are white and the hind wing grey in colour. Head, thorax and abdomen on the adult has the similar grey colour. Antennal type is pactinate type. Larvae head is black and shiny, body yellowish white with a dorsal band of purplish red. It has special distinctive goat type smell. Larvae bore the trees from bark and take 2-4 years to complete full growth. Pupation takes place in a cocoon made with silk and wood materials (Pasqualini and Natale, 1999).

In the period 2005-2006, the monitoring of male adults of the goat moth (*Cossus cossus* L.) were performed with pheromone traps in plantation of apricots and cherries in the vicinity of Pišece (Jeršič, 2009). In the past years the caterpillars of this insect pest caused languishing state of the trees. In both years the massive occurrence of the pest was established in the period from the end of June until the end of July. In 2005, the highest number of the males (one specimen/trap/2 days) was found in the first decade of July, when the degree-day sum was 595.4 °C. In 2006, the highest number of butterflies (1.4 males/trap/day) were found in the second half of the last decade of June, when the degree-day sum was 519.0 °C (figure 13). The hypothetical lower developmental threshold was 10.0 °C. In Slovenia, no insecticides are registered for controlling the goat moth, therefore other ways of suppressing its damage should be found. One of the most promissing methods is the use of controlled-release pheromone dispensers (mating disruption method), which we suggest for implementation in the systems of the fruit production in these areas, where the goat moth is an important biotic factors for limitation of fruit production (Trdan and Jeršič, 2008).

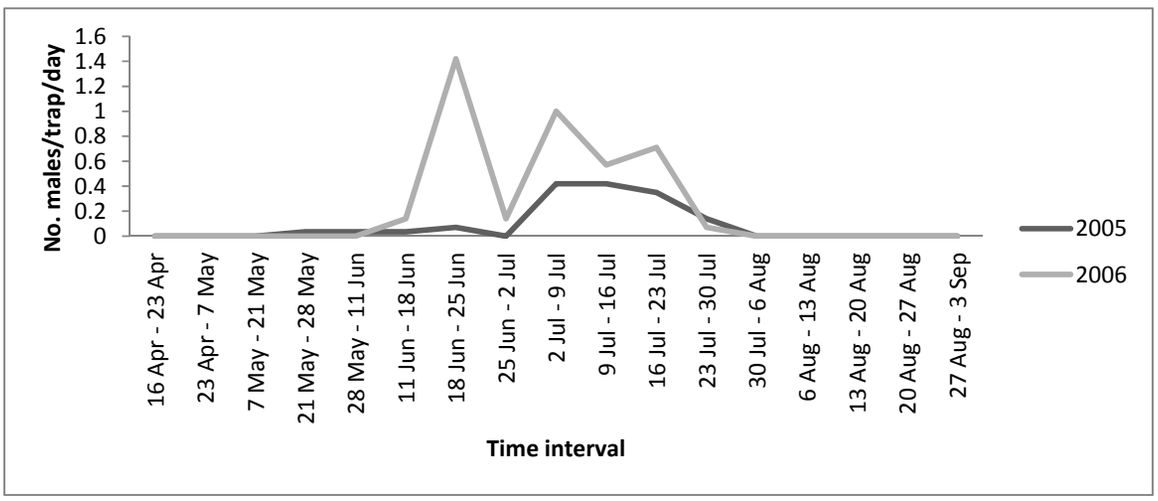


Figure 13. Population dynamics of *Cossus cossus* males in Pišece in the period 2005-2006.

6.5. The European grape berry moth (*Clysia ambiguella* [Hübner]; Lepidoptera, Tortricidae) and the European Grapevine Moth (*Lobesia botrana* [Denis & Schiffermüller]; Lepidoptera, Tortricidae)

The life cycle of *C. ambiguella* is similar to that of *L. botrana*, with the exception of two generations for *C. ambiguella* versus three or more generations for *L. botrana*. Over most of its range, adults are present in May and June for the first generation and again in August and September for the second generation (Gilligan and Epstein, 2011).

Females deposit eggs singly on buds, pedicels, and flowers during the first generation, and on grape berries during the second generation. Early instar larvae burrow into the buds or berries and feed internally; later instars web together buds or berries, and a single larva can feed on up to a dozen berries. Pupation occurs in leaves for the first generation and under bark for the second generation. Overwintering occurs as a second generation pupa. Development time is highly dependent on temperature and humidity. The optimum relative humidity level for development is 70% or higher; eggs will fail to hatch at low relative humidity levels (Gilligan and Epstein, 2011).

Economic losses on grape are caused by direct feeding damage and secondary infections. Feeding damage is similar to that of *L. botrana*. Larvae of the first generation cause minor damage by feeding on flower buds, while those of the second generation cause the most damage by feeding on grape berries. The most significant losses are due to secondary infection of feeding sites on berries and clusters by *Botrytis cinerea.* Economic thresholds vary with the type of grape and cultivar (Gilligan and Epstein, 2011).

During 2007 the occurrence of European grape berry moth (*Clysia ambiguella*) and European grapevine moth (*Lobesia botrana*) was monitored in vineyard at Gaberje village near Ajdovščina (Florijančič, 2010). We observed them on two grapevine varieties: 'Chardonnay' and 'Rebula'. Four pheromone lures (type Pherocon 1C trap, manufacturer Trécé Incorporated, Oklahoma, USA) were placed symmetrically on each variety of grapevine in the vineyard with the size of 0,35 ha. From the end of April to the first days of September, the butterflies developed two generations (figure 14). The peak of the first generation of European grape berry moth was established from 23rd April to 6th May, followed by the second generation, which peaked between 18th June and 1st July. The first generation of European grapevine moth occurred in the period between 7th and 27th of May, followed by the second generation, which established between 11th June and 22nd July. The last three specimens were caught between 27th August and 2nd September. The number of present specimens during the growing season was influenced by weather conditions, namely the air temperature, quantity of precipitations and the relative humidity. In our lures almost twice as many butterflies of European grapevine moth were collected in comparison to European grape berry moth. It is assumed that in Slovenia at least two generations of European grape berry moth and European grapevine moth appear per year. It is assumed also that the variety of grapevine has no influence on the occurrence of both species of butterflies.

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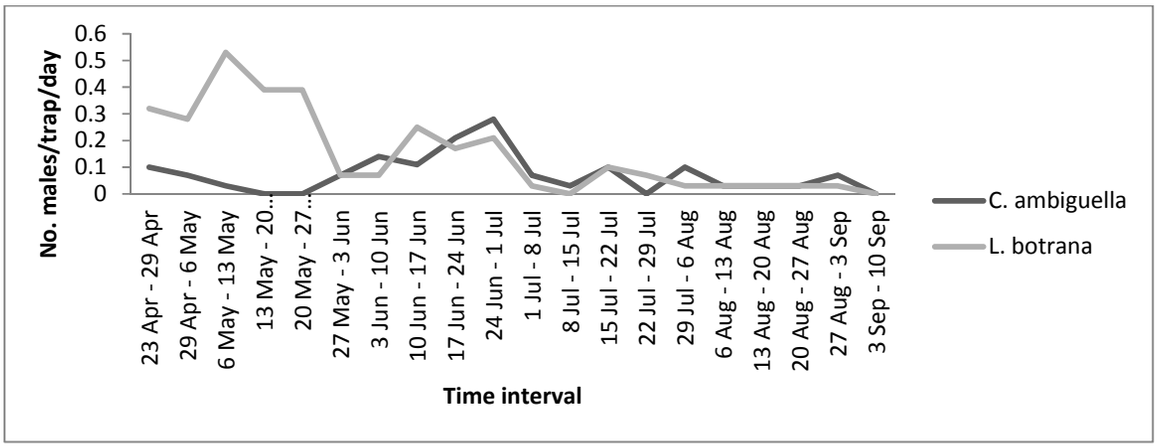


Figure 14. Population dynamics of *Clysia ambiguella* and *Lobesia botrana* males in Gaberje in 2007.

7. Conclusions

Monitoring of harmful insects is one of the basic steps of integrated food production and storing of plant products, since timely detection of the pests prevents their development, spreading and consecutive damage, as well it enables the diminishing of insecticide use. Pheromone traps belong among the most commonly used detection methods of insects, and their advantage over other methods (coloured sticky boards, light traps…) is particularly in their specificity, which is the reason for simple and reliable assessment on the number of harmful insects under investigation. With the use of pheromone traps it is possible – more effective than with other detection methods - to realize one of the fundamental principles of integrated pest management (Milevoj, 2007), i.e. the use of insecticides against insects pests only then, when they reach the damage threshold in agricultural plants and products. In this way the pheromone traps enable the insecticide use in time, which is one of the more important conditions of their satisfactory efficacy. The greater part of investigations, which are present in this chapter, are bounded with the monitoring of insect pests, which bionomics was up to now not studied in Slovenia. Therefore these resuls are important contribution to the field of applied entomology. Results of some researches only confirmed the statements from Slovenian scientific monographies (Vrabl, 1992; Vrabl, 1999), which were in many cases summarized from foreign authors. Other investigations offer less expected results, which can be influenced by climate change, changing of plant varieties, food production techniques etc. In any case this chapter presents the first comprehensive review of monitoring of many insects pests (14 species in 26 different locations) in Slovenia, which can be a good basis for further investigations of complexicity of relations between insects and environment. We hope that with the results of mentioned investigations we will be able to offer the answers for higher present economic impact of some insect pests compared with past decades and to found out if the populations of harmful insect pests can be effectivelly diminished with the use of environmentally friendly methods, in the group of which also pheromone traps have important role.

Acknowledgements

This chapter was performed under the programme Horticulture (P4-0013), funded by the Slovenian Research Agency, and under Professional tasks from the field of plant protection, funded by the Ministry of Agriculture and Environment – Phytosanitary Administration of the Republic of Slovenia.

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