Flight Pattern of *Archips podana* (*Lep.*: *Tortricidae*) Based on Data from Pheromone Traps

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Abstract

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In 9 years of the period 1993–1999 and 2001–2003 the flight activity of *Archips podana* was investigated by pheromone traps placed in four apple orchards in Central and East Bohemia. The cumulative catches of *A. podana* males were plotted against time of the catch expressed in sum of degree-days (DD) above 10°C and approximated by Richards' function. Common parameters of Richards' function could be found for the overwintering generation of *A. podana* from all localities. The beginning, peak and end of flight activity of the overwintering generation of the *A. podana* population in Central and East Bohemia can be predicted by use of DD. *Archips podana* is usually bivoltine in the Czech Republic, rarely univoltine in cold years or cold localities. Construct the flight pattern of the summer generation could of *A. podana* not be constructed, because the course of flight of this generation in dependence on DD differed significantly in particular years and localities.

Keywords: *Archips podana*; fruit tree tortrix moth; apple orchards; flight activity; monitoring; pheromone traps; flight pattern; degree-days

The fruit tree tortrix moth, *Archips podana* (Scopoli, 1763), is a polyphagous species and widely distributed in Europe. It occurs also in North America, probably as an introduced species (Alford 1991). According to Alford (1991) larvae of *A. podana* may attack apple (*Malus*), plum (*Prunus*), pear (*Pyrus*), birch (*Betula*), hawthorn (*Crataegus*) and other trees and shrubs.

The larva overwinters in the third or second instar. After overwintering, larvae attack buds and young leaves, which they web together and shelter between them. Larvae pupate within freshly spun leaves. Adults occur from June to September, with maximum activity in July (Alford 1991). Eggs are deposited on the leaves in batches. The larvae feed on the foliage or fruits. The latter damage often leads to downgrading of the produce. *A. podana* has one generation in northern and Central Europe, only in favourable climatic conditions a partial second generation may occur. In southern areas the species is bivoltine (Van der Geest & Evenhuis 1991).

In conventional plant protection in orchards, *A. podana* was reduced by broad-spectrum insecticides used to also control *Cydia pomonella* (Linnaeus, 1758) and other pests. The importance and abundance of *A. podana* increased after a change of pest control strategy. The moth is considered a major pest in Italy, in the United Kingdom and in the Netherlands (De Reede *et al*. 1985; Audemard 1986; Cross 1996). Currently in the Czech Republic, *A. podana* causes economically important damages only exceptionally. However, its importance will probably increase with the use of selective insecticides and expanded IPM in orchards.

In this paper we present the results of 9 year monitoring by pheromone traps of male flight activity of *A. podana* which revealed phenology and relative abundance of this species in apple orchards of

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Central and East Bohemia. We expressed the course of the flight activity of this species in relation to calendar dates and biological time (degree-days) and determined the effects of pest control strategies and weather on total catches.

MATERIALS AND METHODS

Adult male flight activity of *A. podana* was monitored from 1993 to 2003 (except of 2000 and 2001) in apple orchards with different pest control strategies. The orchards were at four localities and were maintained using different technologies of fruit growing and plant protection: (1) Horoměřice (50°08′N, 14°21′E, 315 m a.s.l.) – intensive apple orchard, for a long time treated by pyrethroids and organophosphorous insecticides, experimental area 2 ha, cultivar Idared; (2) Ruzyně (50°06′N, 14°15′E, 364 m a.s.l.) – experimental apple orchard of the Research Institute of Crop Production, Prague-Ruzyně, without chemical treatment, experimental area 1 ha, different cultivars; (3) Slaný (50°14′N, 14°05′E, 160 m a.s.l.) – intensive apple orchard with IPM regime, experimental area 1 ha, cultivar Idared; (4) Holovousy (50°37′N, 15°58′E, 321 m a.s.l.) – experimental apple orchard without chemical treatment, experimental area 1 ha, different cultivars. The flight activity was monitored at Horoměřice from 1993 to 1996, at Ruzyně from 1993 to 2003 (except of 2000 and 2001), at Slaný from 1995 to 1996 and at Holovousy from 1995 to 1998. Cardboard delta traps with sticky inserts and pheromone dispensers were used. The pheromone dispensers for *A. podana* contained (Z)-11-tetradecenyl acetate + (E)-11-tetradecenyl acetate. The traps were suspended 160 cm above the ground, at one–third distance from the crown periphery. In each orchard there was one trap. The traps were run from late May until harvest (October). The catches of moths were checked in weekly intervals, when the sticky inserts were replaced. The pheromone dispensers were replaced once a season.

Maximum (t_{max}) and minimum (t_{min}) temperatures were obtained from the meteorology stations at Prague-Ruzyně (used for the localities in Central Bohemia: Horoměřice, Ruzyně and Slaný) and Holovousy (used for that locality in East Bohemia). A lower developmental threshold (LDT) of 10°C was used for calculating the sums of day-degrees (DD; accumulation of daily effective temperatures). The daily effective temperature was calculated as:

$$\frac{t_{min} + t_{max}}{2} - \text{LDT}$$

For calculating biological time, the daily effective temperatures were summed from January 1. Weekly trap catches of the overwintering generation of *A. podana* were expressed as percents of total trap catches of the overwintering generation. Richards' function was fitted into a plot of cumulative percentage of catches of males of the overwintering generation and day-degrees (DD)

$$y = \frac{100}{(1 + c_3 \times e^{-c_1(x-c_2)}) \times 1/c_3}$$

where: c_1, c_2, c_3 – parameters of the Richards' function (Fircks & Verwijst 1993)
y – cumulative percentage of captured moths
x – day-degree

The parameter c_1 means the slope of the curve, c_2 the time of 50% catch and c_3 the upper limit of the curve. The plots of Richards' function for *A. podana* catches and years we further call "flight pattern". It was impossible to construct the flight pattern of the summer generation because the course of the flight of this generation in dependence on DD differed significantly in particular years and localities. The calculations were made using STATISTICA for Windows.

RESULTS

Pheromone trap catches

The flight curves indicated that *A. podana* is usually bivoltine in the Czech Republic. The examples of typical flight curves of *A. podana* from Horoměřice in 1993 and Ruzyně in 1997 are shown in Figure 1. The beginning and termination of the flight of the overwintering and summer generation are recorded in Table 1.

The flight activity of the overwintering generation began usually in the middle of June and ceased in late July. The earliest beginning of the flight of the overwintering generation was recorded at Ruzyně in 1993 (May 13), the latest at Horoměřice in 1994 and 1995 (June 22). Flight activity ceased between July 6 (Horoměřice in 1993) and August 14 (Slaný in 1996, Ruzyně in 2003) (Table 1).

The flight of the summer generation varied considerably between years and localities. The earliest

Table 1. Dates of the first and last occurrence of the overwintering and summer generation of *Archips podana* males in pheromone traps

Year	Location	Overwintering generation			Summer generation			DD difference
		first occurrence	DD1	last occurrence	first occurrence	DD2	last occurrence	
1993	Horoměřice	1.6.	235.5	6.7.	17.8.	758.7	4.10.	523.2
	Ruzyně	13.5.	121.8	29.7.	18.8.	765.8	25.10.	644.0
1994	Horoměřice	22.6.	253.9	21.7.	19.8.	881.7	9.9.	627.8
	Ruzyně	3.6.	166.3	22.7.	5.8.	762.0	6.10.	429.4
1995	Horoměřice	22.6.	226.1	3.8.	24.8.	805.4	26.9.	579.3
	Ruzyně	15.6.	186.1	27.7.	17.8.	729.0	13.9.	542.9
	Slaný	20.6.	212.7	31.7.	28.8.	828.5	27.9.	615.8
	Holovousy	20.6.	259.3	25.7.	8.8.	775.8	26.9.	516.5
1996	Horoměřice	20.6.	283.0	7.8.	–	–	–	–
	Ruzyně	11.6.	235.3	12.8.	–	–	–	–
	Slaný	30.5.	121.7	14.8.	–	–	–	–
	Holovousy	17.6.	328.6	6.8.	19.8.	720.9	8.10.	392.3
1997	Ruzyně	17.6.	243.6	12.8.	–	–	–	–
	Holovousy	16.6.	259.5	4.8.	25.8.	850.0	15.9.	590.5
1998	Ruzyně	11.6.	292.4	23.7.	27.8.	876.5	2.9.	584.1
	Holovousy	8.6.	292.7	13.7.	10.8.	784.1	14.9.	491.4
1999	Ruzyně	10.6.	223.6	22.7.	26.8.	824.9	16.9.	601.3
2002	Ruzyně	23.5.	157.7	25.7.	16.8.	841.7	22.8.	684.0
2003	Ruzyně	4.6.	109.9	14.8.	–	–	–	–

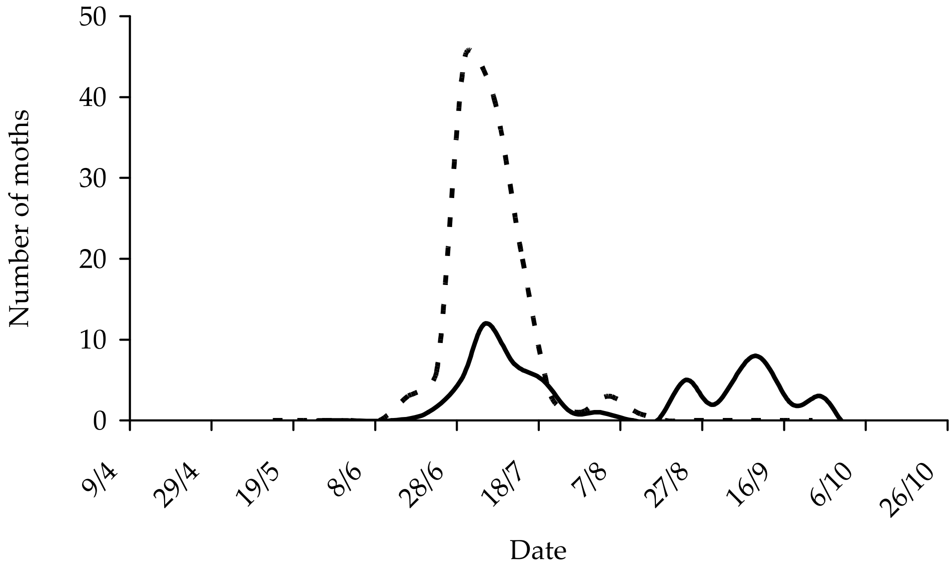

Figure 1. Examples of different course of flight curves of *Archips podana*, Horoměřice 1993 (solid line), Ruzyně 1997 (dotted line)

Table 2. Total catches of the overwintering and summer generation of *Archips podana* males in pheromone traps

Year	Horoměřice			Ruzyně			Slaný			Holovousy		
	over-wintering	summer	total	over-wintering	summer	total	over-wintering	summer	total	over-wintering	summer	total
1993	54	12	66	187	7	194	–	–	–	–	–	
1994	23	7	30	136	33	169	–	–	–	–	–	
1995	32	20	52	185	39	224	195	20	215	53	50	103
1996	21	0	21	256	0	256	139	–	139	74	10	84
1997	–	–	–	122	0	122	–	–	–	75	12	87
1998	–	–	–	92	1	93	–	–	–	69	9	78
1999	–	–	–	101	11	112	–	–	–	–	–	–
2002	–	–	–	11	6	17	–	–	–	–	–	–
2003	–	–	–	161	0	161	–	–	–	–	–	–
Average	–	–	42.3	–	–	149.8	–	–	177.0	–	–	88.0

beginning was recorded at Ruzyně in 1994 (August 5), the latest at Slaný in 1996 (September 26). Flight activity of this generation ceased between August 22 (Ruzyně in 2002) and October 25 (Ruzyně in 1993). The summer generation was absent in 1996 (Ruzyně, Horoměřice, Slaný), in 1997 (Ruzyně) and in 2003 (Ruzyně) (Table 1).

Total catches of the overwintering and summer generation of *A. podana* in particular years and localities are shown in Table 2. Total catches varied mainly between localities, but did not differ significantly between years at any one locality. *A. podana* was caught in moderate to high numbers in all four orchards, irrespective of insecticide management. The lowest average catches were recorded in the chemically treated orchard at Horoměřice (mean catch 42.3), the highest average catches in the chemically treated orchard at Slaný (mean catch 177.0) (Table 2). Total average catches in the untreated orchards Ruzyně and Holovousy were 149.8 and 88.0, respectively (Table 2).

The portion of the summer generation (if it occurred) in the total catch fluctuated between years and localities from 1.1% (Ruzyně 1998) to 48.5% (Holovousy 1995) (Table 3). On average, the catches of the summer generation varied from 9.3% (Slaný) to 26.7% (Horoměřice) of the total catch.

Table 3. Portion of the summer generation (in %) of *Archips podana* of the total catch per season

Year	Horoměřice	Ruzyně	Slaný	Holovousy
1993	18.2	3.6	–	–
1994	23.3	19.5	–	–
1995	38.5	17.4	9.3	48.5
1996	0	0	0	11.9
1997	–	0	–	13.8
1998	–	1.1	–	11.5
1999	–	9.8	–	–
2002	–	35.3	–	–
2003	–	0	–	–
Average	26.7	14.5	9.3	21.4

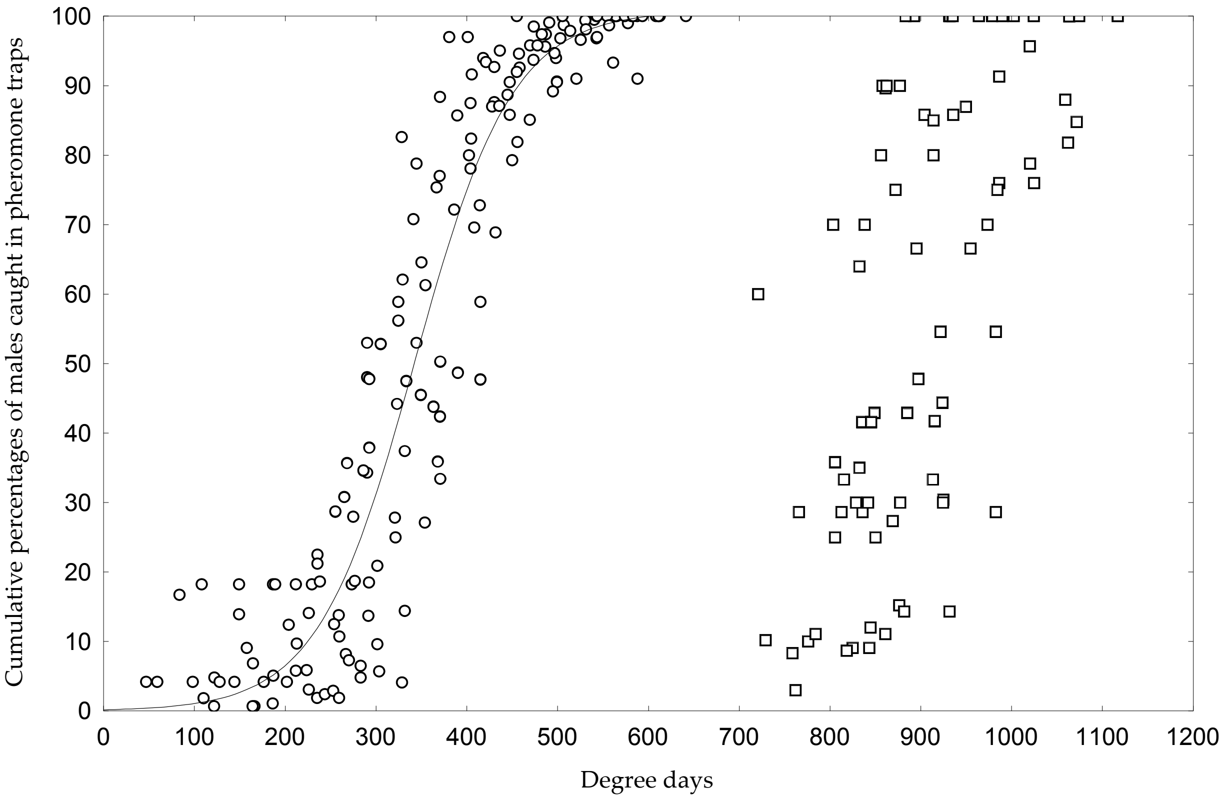

Figure 2. Flight patterns of *Archips podana* constructed by using Richards' function, Ruzyně, Horoměřice, Slaný, Holovousy, 1993–2003

Cumulative catches

The data on cumulative pheromone trap catches of the overwintering and summer generation of *A. podana* males in dependence on DD are shown in Figure 2. For the overwintering generation, the results of different years and localities were similar after calculating DD. Consequently, a generalised curve of cumulative catches could be constructed for the overwintering generation (Figure 2). The parameters of the Richards' equation for the curve construction are c_1 = 0.016335, c_2 = 322.0892 and c_3 = 1.018594 (R = 0.90811, variance explained 82.466%). The curve of the cumulative percentage of moths in dependence on DD is steep and corresponds to the quite short period of flight of the overwintering generation. The flight activity of *A. podana* started (5% catch) at 200 DD, median catch (50% catch) was at 320 DD, and the flight ceased at 420 DD (85% catch) (Figure 2).

The flight of moths of the summer generation is prolonged and differs not only according to locality but also through the conditions of a given year. It was not possible to construct any flight pattern of this generation. The moths of the summer generation fly from 720 DD to 1110 DD. The time period of flight activity differed significantly between localities and years.

The difference of the beginning of flight of the overwintering and summer generation ranged from 392 DD to 684 DD. Large differences in DD were found between localities as well as between years in one locality (Table 1). The generation time of the summer generation of *A. podana* in DD in Central Europe is variable between years. Consequently, it is difficult to determine the generation time from data of pheromone traps.

DISCUSSION

A. podana is usually bivoltine in the Czech Republic. Exceptionally, *A. podana* is univoltine in colder years or colder localities. This corrects the earlier opinion of Audemard (1986) who considered *A. podana* univoltine in Central Europe with a partial second generation only when climatic

Table 4. Average temperatures per vegetative period (IV–X), 1993–1999, 2002–2003

Year	Locality		
	Ruzyně, Horoměřice	Slaný	Holovousy
1993	13.6	–	–
1994	14.4	–	–
1995	14.0	14.9	14.7
1996	13.0	13.6	13.5
1997	13.3	–	13.7
1998	14.3	–	14.3
1999	14.7	–	–
2002	14.6	–	–
2003	15.3	–	–

conditions are favourable. Similarly, ALFORD *et al*. (1979) found two generations in most years and localities of the United Kingdom. During 9 years of monitoring of *A. podana* in the Czech Republic, it was univoltine in the coldest year 1996 (Table 4) at three localities and in 1997 at one locality. On the other hand, it was also univoltine at Ruzyně in 2003, when temperatures during the vegetation period were extremely high (Table 4), especially during June and July. This probably lowered the quality of food and led to worse conditions for development of *A. podana* larvae. In autumn, before hibernation, young larvae can cause severe skin damage to mature fruits, often leading to downgrading of the produce (VAN DER GEEST & EVENHUIS 1991). Thus, important damage on harvested fruits can be expected at localities where catches of the summer generation moths in pheromone traps increase and larvae of the overwintering generation hatch before harvest.

There were no differences between the size of catches of *A. podana* from untreated orchards and orchards with intensive insecticide application. This corresponds with data of CROSS (1996) who found that *A. podana* abundance did not depend on insecticide history of an orchard.

The length of the flight activity was independent of population density. Thus, during a 13 week period of 1995, only 52 males were caught at Horoměřice, while 224 of them were caught at Ruzyně. The length of the period of flight activity varied mainly with temperature conditions of a given locality and year.

Flight patterns expressed by cumulative catches of moths in dependence on DD differ significantly between tortricid species in orchards. In this study we found that the flight pattern of the overwintering generation of *A. podana* in dependence on DD was uniform for all years and localities in a region. Yet for the summer generation of *A. podana* the flight patterns differ significantly between localities as well as between years at one locality. Similarly, a uniform flight pattern of the overwintering generation was constructed for the bivoltine species *Adoxophyes orana* (Fisher von Röslerstamm, 1834) (STARÁ & KOCOUREK submitted). For the univoltine species *Spilonota ocellana* (Denis & Schiffermüller, 1775) and *Hedya nubiferana* (Haworth, 1811) it was also possible to construct an universal flight pattern in dependence on DD for populations from localities in a region that differ in their temperatures (STARÁ & KOCOUREK 2001). In contrast, the flight patterns of the overwintering generation of the partly bivoltine species *Pandemis heparana* (Denis & Schiffermüller, 1775) differed between localities of a region with different temperatures (STARÁ & KOCOUREK 2001).

The flight pattern of the overwintering generation of *A. podana*, expressed by cumulative catches of moths in dependence on DD as presented in this paper, enables to define the duration of the flight activity of *A. podana* more accurately than by calendar dates. It allows to estimate more precisely the beginning, peak and termination of flight of the overwintering generation. From a practical point of view it is possible to use this flight pattern to determine suitable terms of treatment. Since defining the peak of flight has the lowest variability, the pattern is especially useful to time the treatment by ovicide and ovo-larvicide preparations that are applied after the peak of flight of moths. In contrast, the course of flight of the summer generation cannot be predicted by DD and it is necessary to monitor the flight activity of this generation by pheromone traps. When catches of the summer generation moths are high (more than 30 males per trap), damage on harvested fruits can be important. An insecticide application should be timed according to the peak of flight of moths and adjusted to the protection period of the pesticide used before harvest.

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Souhrn

Stará J., Kocourek F. (2004): **Monitorování letové aktivity obaleče zahradního** (*Archips podana*) (*Lep*.: *Tortricidae*) **pomocí feromonových lapáků**. Plant Protect. Sci., **40**: 75–81.

Monitorování letové aktivity obaleče zahradního (*Archips podana*) pomocí feromonových lapáků probíhalo v letech 1993–1999 a 2002–2003 v jabloňových sadech na čtyřech lokalitách ve středních a východních Čechách. Na základě analýzy letových křivek byl sestaven jednotný vzor letové aktivity přezimující generace obaleče zahradního pro všechny sledované lokality. Tento vzor letové aktivity byl sestrojen s použitím Richardsovy funkce a vyjadřuje závislost mezi kumulativním procentem motýlů zachycených ve feromonových lapácích a termínem odchytu vyjádřeným v sumách efektivních teplot (SET) nad prahem vývoje 10°C. Pro přezimující generaci populace obaleče zahradního ze středních a východních Čech lze na základě SET předpovídat začátek, vrchol a konec letové aktivity. Bylo zjištěno, že *A. podana* je v ČR obvykle bivoltinní, výjimečně univoltinní v chladných letech nebo na chladných lokalitách. Vzor letové aktivity letní generace obaleče zimolezového nebylo možné sestrojit, protože období letové aktivity této generace se v SET výrazně lišilo mezi sledovanými lokalitami a roky.

Klíčová slova: *Archips podana*; obaleč zahradní; jabloňové sady; letová aktivita; monitoring; feromonové lapáky; vzor letové aktivity; suma efektivních teplot

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