

## OUTBREAKS AND NATURAL VIRAL EPIZOOTICS OF THE SATIN MOTH *LEUCOMA SALICIS* L. (LEPIDOPTERA: LYMANTRIIDAE)

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**Abstract:** Long standing systematic observations on *Leucoma salicis* populations revealed numerous occurrences of outbreaks and natural viral epizootics. Number of insects appearing in outbreaks at peak density ranged from 450 to 3250 on 10 examined poplar trees (up to 2 m height). Abundance of virus within population of such a high density increased along with an increase of insect population. Populations with high density and high level of nucleopolyhedrovirus (LesaMNPV) and cypovirus did not last long and collapsed suddenly.

Outbreaks of the satin moth were favored by warm and humid conditions while warm and dry spring, summer months were conducive to viral epizootic. Most outbreaks happened in the years with mean temperatures of spring and summer months above 15°C and 50–60% RH while, most epizootics were recorded at similar temperature conditions but lower RH, i.e. 40–50%.

**Key words:** *Leucoma salicis* L., outbreaks, epizootics, nucleopolyhedrovirus, cypovirus, bacteria, fungi, parasitoids

### INTRODUCTION

The satin moth, *Leucoma salicis* L. is a destructive pest of willow trees (*Salicaceae*) causing severe damage in forest stands not only in several European countries but in some parts of Asia and both Americas as well. *L. salicis* is one of six pests from *Lymantriidae* family of economic importance (Grijpma 1989; Schoenherr 1989; Lipa and Kolk 1995; Lipa 1996). *L. salicis* outbreaks were observed on poplar trees in Belgium (Nef 1975), Italy (Arru 1975), Yugoslavia (Sidor 1976), Switzerland (Maksymov 1978), the Netherlands (Doom 1979), Bulgaria (Zakharieva 1983a), Romania (Teodorescu 1980),

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Spain (Huertos and Templado 1958; Ortiz and Templado 1973), Turkey (Cobanoglu 1992), and in Hungary (Abraham 1996). Large outbreaks were recorded in Siberia on European aspen (*Populus tremula*) (Kolomiec 1971; Dondikov 1974; Nikiforov 1979; Gromova 1980). In Kazakhstan the satin moth caused rigorous leaf damage leaving only main nerve untouched on willow trees (*Salix caspica*) (Marikovskij 1977) and in Japan on poplar trees (*P. italica*) and willows (*S. babylonica*) (Sirota *et. al.* 1976). In the 1920s the insects were accidentally introduced to America and established in hardwood forest stands (Furniss 1939; Wallner 1988; Schaefer 1989). In Central Europe the insects appear in one generation while in Southern Europe it is possible to see two or more generations throughout the year (Serafimovski 1972; Ortiz and Templado 1973; Cobanoglu 1992; Lipa and Głowacka 1996).

The satin moth is a common pest of poplar trees in Poland in all regions except for mountain areas. In the years 1953–1956 Schnaiderowa (1959) observed severe defoliation of the poplar species such as *P. robusta* and *P. marylandica* in central and eastern Poland. According to the author the poplar trees were more attractive food source than willows. At present the satin moth is mostly observed on *P. nigra*, *P. balsamifera* and *P. italica* (Ziemnicka 1976a, 1981). Based on the conducted survey *P. nigra* seemed to be the most luring food for the satin moth, also providing the best survival conditions. Feeding on other tree species, particularly on *P. alba* trees inhibited the development of the insects and increased their sensitivity to bacterial infection (Ziemnicka 1981; Avtziš 1990).

Annual defoliation of poplar trees resulting from the satin moth feeding does not present particular threat to poplar stands. The trees are capable to regenerate the assimilation system within several weeks. However, multiple-outbreaks of the insects present a serious threat because the tree ability of regeneration is rapidly decreased and it results in smaller annual growth and lower resistance to harsh climatic conditions, particularly severe frost. Weaker trees become more susceptible to other infections and pests as well. The dieback of the trees increases in intensity and at the end the trees die (Schnaiderowa 1959; Lejeune and Silver 1961; Clarke and Pardy 1971; Kolomiec 1971). The survey conducted in the Netherlands (Luitjes 1973) showed that annual damage caused by the satin moth intensive feeding decreased the annual tree growth by 34–80%. Based on a calculated threshold it might be concluded that loss of foliage over 40% and presence of 16 caterpillars per 1 m<sup>3</sup> of leaves are danger for a tree condition (Chen *et al.* 1990).

The causes of mass occurrence of the satin moth have not been well recognized yet. Some authors (Wagner and Leonard 1979) concluded that there is a relation between the pest density and food, and climatic conditions conducive to the insect development. The causes of a sudden decrease of the pest population have been fairly well determined. Harsh winters with temperatures below –20°C, parasitoids and pathogens (Reeks and Smith 1956; Schnaiderowa 1959; Lejeune and Silver 1961; Kailidis 1964; Jahn and Sinreich 1965; Clarke and Pardy 1971; Kolomiec 1971; Kuševska 1972; Wagner and Leonard 1980; Ziemnicka 1981) are considered the major factors affecting the insect populations.

*Hymenoptera* and *Diptera* play the important role among parasitoids as they can infect eggs, larvae and pupae. *Telenomus nitidulus* (Hymenoptera: *Scelionidae*) is the most effective egg parasite of the satin moth (Kolomiec 1971; Dondikov 1974; Nef

1976; Grijpma *et al.* 1986; Zakharijeva-Pentcheva and Georgijev 1997) while *Apanteles rubipres* and *Rogas peluscens* are larva parasites (Obozov 1968).

The satin moth might be infected with protozoans (Lipa and Ziemnicka 1996), the nematode *Hexameris albicans* (Drea *et al.* 1977; Sidor *et al.* 1978), spiroplasma (Lipa *et al.* 1988; Lipa and Ziemnicka 1996), entomopathogenic fungi and viruses. Fungi and viruses occur frequently in the satin moth population. The fungus species *Beauveria bassiana* has been often associated with the viral epizootics but very rarely recognized as a main casual agent (Ziemnicka and Sosnowska 1996).

Nucleopolyhedrovirus (*Baculoviridae*) and cytovirus (=cytoplasmic polyhedrosis virus) CPV (*Reoviridae*) are the most important epizootic factors in the satin moth outbreaks. They both produce the polyhedral-shaped inclusion bodies inside a host body and the diseases caused by these viruses are called nucleopolyhedrosis.

Nucleopolyhedrovirus LesaMNPV is the most common pathogen and the main cause of collapses in outbreaks of the satin moth in natural populations (Orlovskaya 1968; Ziemnicka 1981; Chen 1984; Skatula 1985). Cypovirus despite its frequent occurrences in the satin moth populations is not a cause of epizootics. The epizootic caused by CPV was recorded only once in Austria in 1963 (Jahn and Sinreich 1965).

The objective of this research was to learn more about the cycles of outbreaks occurring in natural populations of the satin moth and identify the causes of their regular breaks down, and importance of environment with particular focus on climatic conditions.

## MATERIALS AND METHODS

### Collection of insects

Larvae of the satin moth (stage L<sub>2</sub>-L<sub>4</sub>) were collected at the end of May and beginning of June while the insects began feeding on lower parts of the trees. The individuals were captured from each of 10 selected trees up to 2m height of a trunk, then counted and moved to laboratory in plastic containers. At first the larvae were reared in laboratory in glass vessels (10 l each) covered with cheese clothes and fed with poplar leaves for 10 days. Food was supplemented daily.

### Health check of insects

Health of the insects was checked with light microscope at magnification 400x and 1000x. Each dead insect was removed during that period. That quarantine allowed to recognize the insect with viral infections and other natural enemies of the satin moth.

After 10 days the remaining healthy insects were treated with ether and chloroform. All individuals were identified if there were less than 100 in a group; otherwise a sample of 100 was selected for further study.

Viruses were defined using wet mount, permanent tissue slides stained with carbol fuchsin (Ěvlachova and Švecova 1964) and identified with a microscope (Ziemnicka 1981).

Presence of entomopathogenic fungi was checked microscopically using wet mount slides of insect tissues. If any were present the slides were placed on moisten filter paper in a Petri dish for several days at 20–25°C until sporulation occurred. The fungal species were identified based on macro and micro features of mycelium growing on Sabouraud medium (Gams 1971; De Hoog 1972; Samson 1974).

Identification of entomopathogenic bacteria was done based on Gram staining and morphology of vegetative cells and endospores after incubation on a solid nutritional agar (Harrigan and McCance 1966).

The protozoans were recognized using wet mount slides stained with 0.2% Giemsa stain (Lipa 1967).

Macro and micro identification techniques were applied to characterized nematodes from the family *Mermithidae*. The species were distinguished based on the morphological features (Poinar 1975).

### Meteorological date

Meteorological data were obtained from the Institute of Meteorology and Water Management in Warsaw.

## RESULTS

Development of the satin moth was monitored from mid-May until the end of August. The larvae at stage  $L_2$  left their overwintering shelters at the end of May, which is typical of climatic conditions in Poland. The most active were the larvae at stage  $L_4$ , they represented the greatest threat to the trees. At the end of June and beginning of July the larvae at stage  $L_6$  were getting ready to enter the pupal stage.

The insects developed at different rate despite the outbreak site. Simultaneously there were present larvae feeding on leaves or entering the pupal stage, mature pupae and on occasion single butterflies.

Most butterflies were recorded in mid-July. Larvae hatching were observed for two weeks starting at the beginning of August. The young larvae ( $L_1$ ) searching for food moved toward top of trees and stayed there for few days, and ate voraciously. They were able to defoliate trees of all leaves after which they turned into stage  $L_2$ . As far as a development of the satin moth is considered under Polish climatic conditions, the larvae at stages  $L_3$ – $L_6$  are called the spring-summer generation and at stage  $L_2$  the overwintering one.

Three centers were selected from all examined satin moth outbreak sites in Poland; Wielkopolska region (Kórnik), Łódź region (Kutno) and Śląsk region (Katowice). The pests were destroying the trees of *P. nigra* and *P. italica* growing on roadsides- population "Kórnik", near train tracks-population "Kutno" and in downtown-population "Katowice". The outbreak sites and epizootic centers were evaluated based on a model threshold describing number of pests and percent of infected insects. Values above the thresholds indicated an increase of either population density or higher viral disease incidence within the insect population. The thresholds were following 5 larvae/trunk up to 2m and 5% infected insects.

## DYNAMICS AND HEALTHINESS OF INSECTS IN "KÓRNIK" POPULATION

Continuous monitoring of population dynamics of the satin moth in Kórnik area was conducted for nineteen years (1972–1990) from May 18<sup>th</sup> to 31<sup>st</sup> (Fig. 1) on the poplar trees (*P. nigra*) growing on roadsides. Results from observations conducted during first year showed a decline of the insect population density (depression phase;

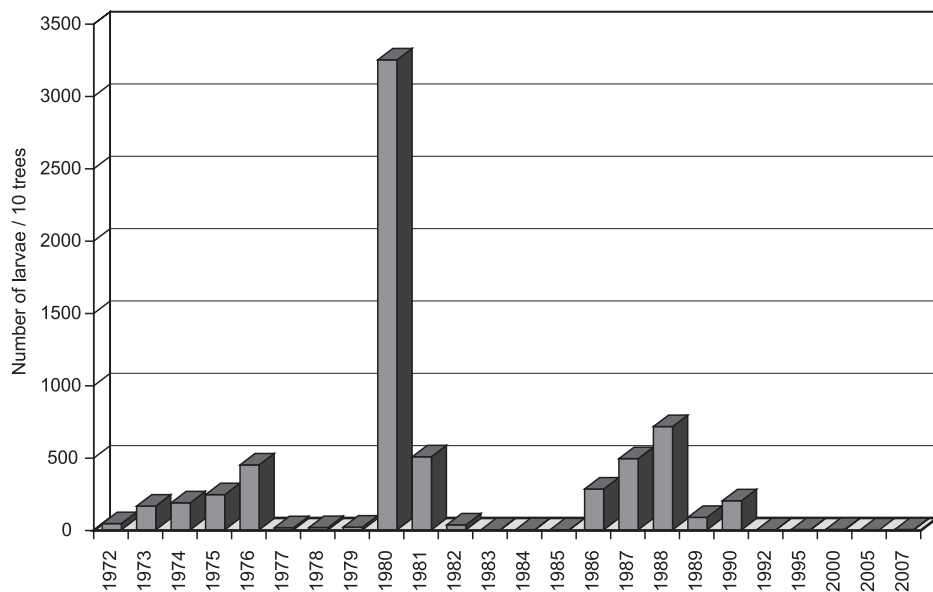


Fig. 1. Population dynamic of the satin moth (*L. salicis*) – "Kórník"

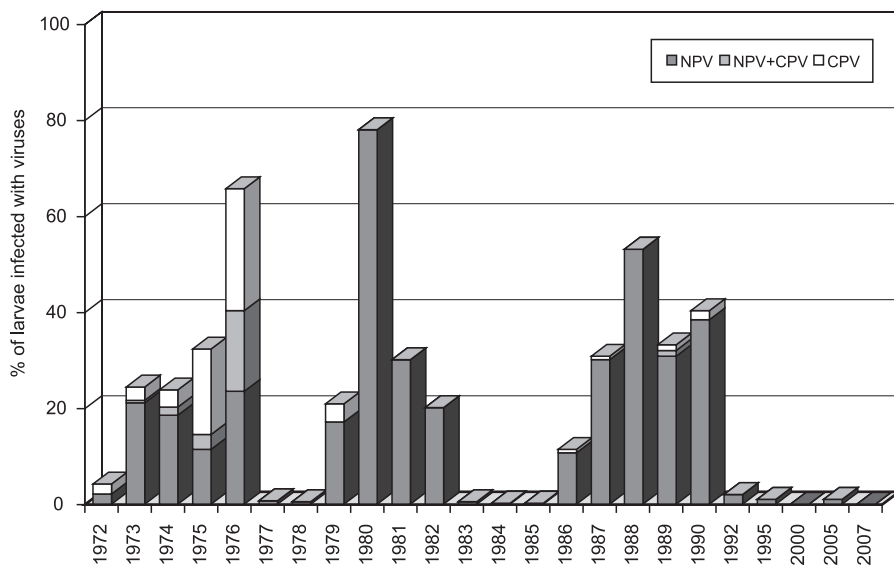


Fig. 2. Healthiness of the satin moth population (*L. salicis*) – "Kórník"  
 NPV – nucleopolyhedrovirus; CPV – cypovirus

48 larvae on 10 trees). In the following years, 1973, 1974 until 1976 the population gradually increased until it reached 450 individuals; this was considered an outbreak stage (**outbreak I**). Records from the subsequent years revealed a decrease in number of the satin moth; the final count was 25–30 larvae. The next three years with low population density passed and a sudden outbreak of insects was observed in 1980 (3250 larvae) (**outbreak II**). This outbreak of the satin moth ended in 1981. However, the number of insects was only partially reduced and the population density was still high at the end (506 larvae). After four years of population decline the population density started growing again and in 1986 and 1987 there were 285 and 493 larvae. In 1988 the number of larvae was 715 (**outbreak III**). In two consequent years the density dropped again. In the years 1991–2007 occasional monitors showed low number of the satin moth insects (3–9 larvae on 10 trees).

Several collapses of the outbreaks in the satin moth population resulted from activity of different pathogens. They infected sensitive insects and consequently raised mortality rate within the population (Fig. 2).

Nucleopolyhedrovirus (LesamNPV) and *L. salicis* cypovirus (CPV) were the main pathogens causing such a high mortality among the insects (Fig. 2). Virus CPV was present in the satin moth population during first years of the survey in "Kórnik" population. In the years 1972–1976 the infection with LesamNPV and CPV turned to epizootic (**epizootic I**) and that caused a decline in population lasting three years (Fig. 1). Despite low number of insects, the viruses were present within a population. In the year 1980 another epizootic peak occurred (**epizootic II**; 78% of larvae were infected with LesamNPV) (Fig. 2). This year was also a second year of the satin moth outbreak (Fig. 1). The epizootic lasted four years. Since 1986 while the population density increased, the viral infection level raised as well. In the beginning it was fairly low; around 11% of insects were infected with NPV in 1986; then it gradually escalated. The **epizootic III** was recorded in 1988 (53% of infected insects) with a population density of 715 larvae. High incidence of NPV infection (33 and 42%) was recorded for next two years of the survey (Fig. 2). In the years 1992–2007 only single individuals with viruses were found.

The larvae collected in "Kórnik" region were also infected with bacteria from the genus *Bacillus* sp. and *Serratia marcescens*. Bacterial infections ranged from 3 to 35% of all examined insects. High occurrences of bacterioses were recorded in the years 1972–1978. Among pathogenic fungi the most common were *Aspergillus flavus* Lin. Ex Fr., *Beauveria bassiana* (Bals.) Vuill and *Fusarium* sp. Link ex Fr. Nematodes from the family *Mermithidae* (4–6% of insects infected) were other pests pathogenic to larvae at stage L<sub>5</sub>. The least frequent and rarely occurring were protozoa such as *Plistophora* sp.; 1.7% of larvae were infected.

## DYNAMICS AND HEALTHINESS OF INSECTS IN "KUTNO" POPULATION

Observations of population density in Kutno region were conducted for fourteen years (1977–1990) from May 25<sup>th</sup> to June 6<sup>th</sup> (Fig. 3). The survey was conducted on *P. italica* trees growing near a train station in Kutno. A high density of insects occurred during first two years of the survey (1000–900 larvae per 10 trees) (**outbreak I**). This abundant appearance of the satin moth ceased with a 10-fold decrease of population

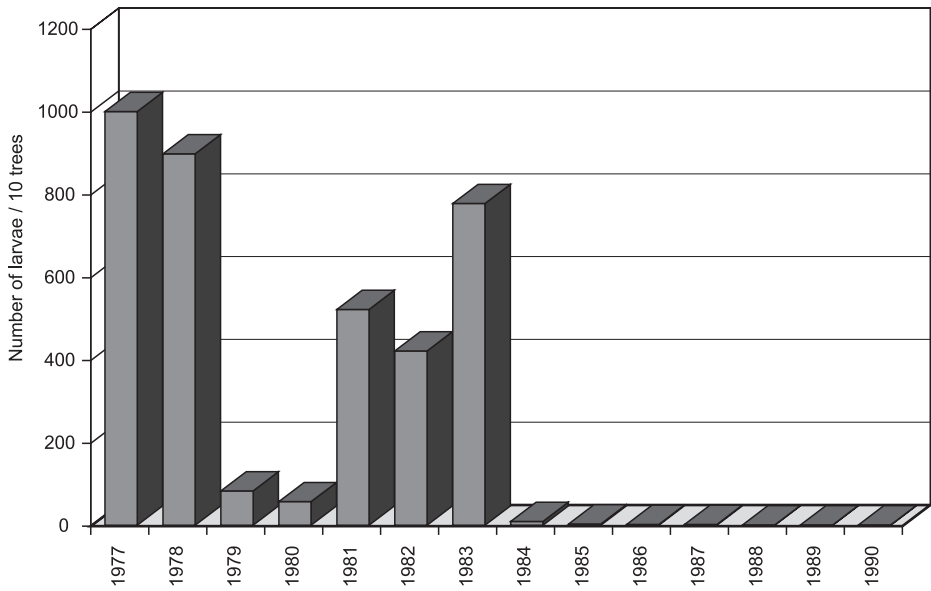


Fig. 3. Population dynamic of the satin moth (*L. salicis*) – "Kutno"

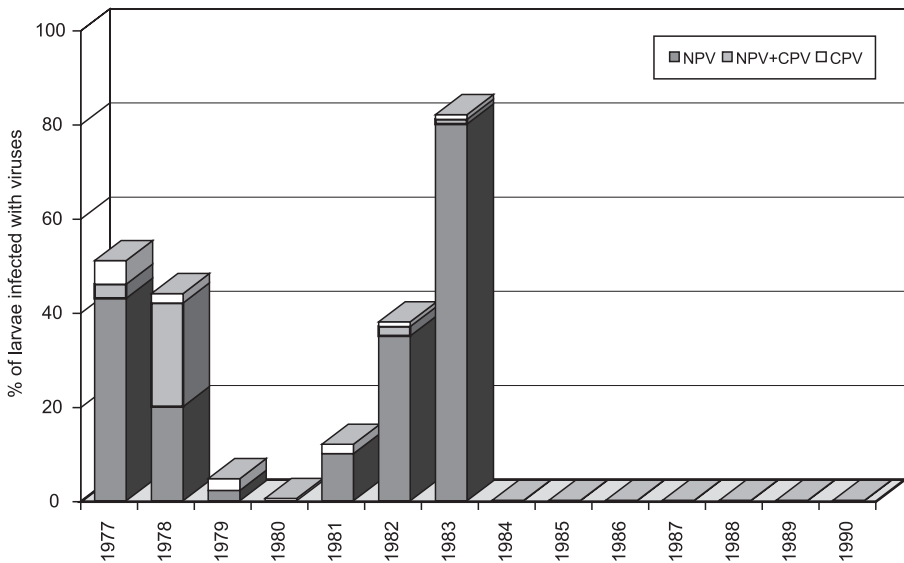


Fig. 4. Healthiness of the satin moth population (*L. salicis*) – "Kutno".  
 NPV – nucleopolyhedrovirus; CPV – cypovirus.

density in the following two years (1979–1980). The next outbreak (**outbreak II**) was recorded in the years 1981–1983 (778 larvae maximum). In 1994 the population density suddenly crashed and the insect incidence was at a level that did not represent a danger to trees. The number of insects was reduced approximately 80-fold. The insects were at a depression stage and remained at that level until the end of the survey (1990). In the following year the trees were removed.

Microscopic analyses showed that 2% of larvae were infected with bacteria from the genus *Bacillus* sp. and 2–6% with the fungus *B. bassiana*. While bacterial and fungal infections were low, a viral infection with nucleopolyhedrovirus and cypovirus appeared to be high at the time of analysis. The virus NPV was observed more frequently than CPV in 1977 (46%), (**epizootic I**) (Fig. 4).

In the following year 1978 in addition to high incidence of NPV (20%) infection with NPV + CPV (22%) was registered. Viruses present at such a high level reduced the satin moth population drastically in the years 1979–1980 until the pest reached a depression stage. Since 1981 the viral infections among insects increased (**epizootic II**). An epizootic peak was recorded in 1983 when 80% of insects living in high-populated group (778 larvae) were infected with nucleopolyhedrovirus (Fig. 4). Viral infections resulted in sudden reduction of the satin moth population the following year and this phase lasted until the end of survey (1990).

## DYNAMICS AND HEALTHINESS OF INSECTS IN "KATOWICE" POPULATION

Observations on population dynamics of the satin moth in Katowice were conducted for thirteen years (1973–1985), from May 21<sup>st</sup> to June 6<sup>th</sup>. The examined *P. nigra* trees grew in the center of town.

In the years 1973–1975 the insect population was at a progression stage (Fig. 5). Since 1976 the population started suddenly increasing in numbers and in 1977 it reached its peak (1000 larvae) (**outbreak I**). In 1978 the population collapsed, and the number of insects was four times lower. In the subsequent seven years the satin moth went through a phase of three-year recession (52–24 larvae) followed by a depression stage, and it was extremely difficult to find any individuals (0–1 larva). Further surveys couldn't be conducted due to removal of the trees.

Nucleopolyhedrovirus and cypovirus dominated in the examined populations. In the years 1973–1977 (Fig. 6) they often appeared in mixed infections. In the year 1978 at the highest level of virus occurrences, only nucleopolyhedrovirus was detected (97% larvae infected) (**epizootic I**). *L. salicis* population drastically decreased for the next seven years.

The satin moth population in "Katowice" region was infected with bacteria (3–4%), fungi (1–2%) and protozoa (1–3%). Among bacteria the genus *Bacillus* sp. dominated. *S. marcescens* was rarely identified. Mycoses were caused by *B. bassiana*. As far as protozoa were concerned, *Plistophora* sp. was a causal agent of infections. *Ichneumonidae* were the most frequent parasitoids recorded in the samples (4–6%).



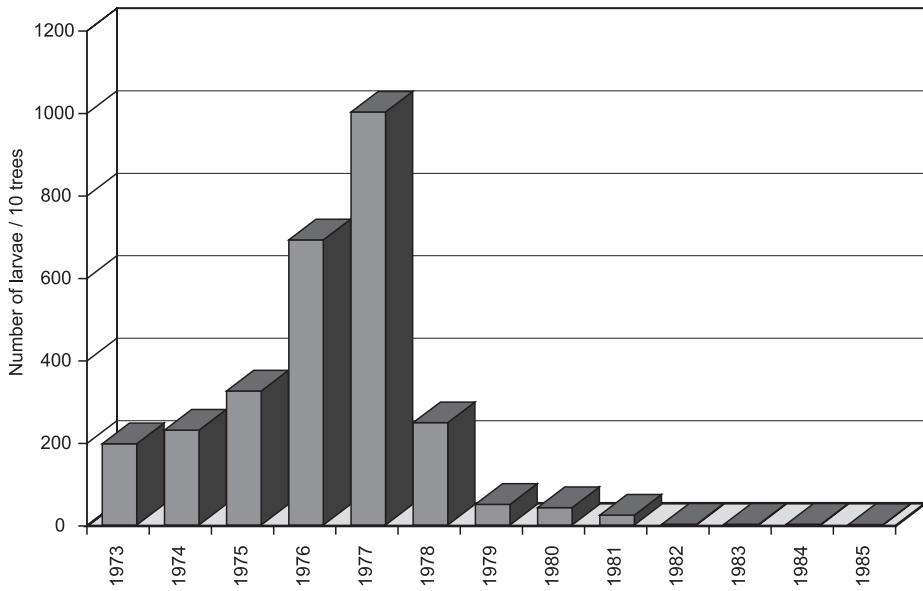


Fig. 5. Population dynamic of the satin moth (*L. salicis*) – “Katowice”

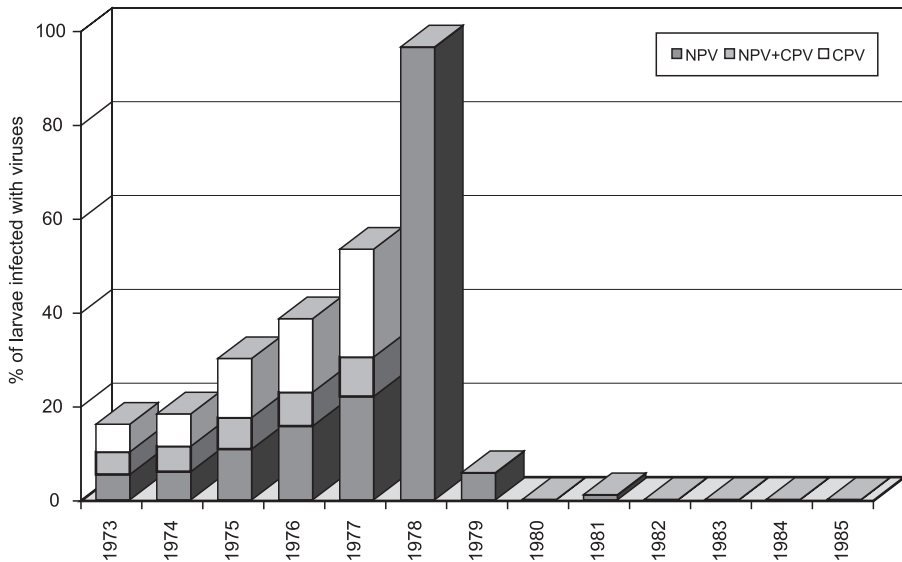


Fig. 6. Healthiness of the satin moth population (*L. salicis*) – “Katowice”  
 NPV – nucleopolyhedrovirus; CPV – cypovirus

## EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON OUTBREAK AND EPIZOOTIC OCCURRENCES OF THE SATIN MOTH

Analyses of correlation of outbreak and epizootic occurrences and mean temperatures and relative humidity for spring, summer months were conducted. The results are presented in Table 1 and indicate some of the relationships. Most outbreak peaks appeared in the years with warm spring, summer months with mean temperatures above 15°C and mean RH 50–60%. Analyses of epizootic peaks showed similar relation to temperatures but RH was lower, i.e. 40–50%.

Table 1. Years of occurrence of outbreak and epizootic peaks of the satin moth (*L. salicis*) in correlation to meteorological conditions

Population	Mean temperature V–VII			Mean relative humidity V–VII		
	13–14°C	14–15°C	above 15°C	40–50%	50–60%	above 60%
OUTBREAK						
Kórník	1980	–	1976 1988	–	1988	1980
Kutno	–	–	1977	–	1977	1976
Katowice	–	–	1977	–	1977	–
EPIZOOTIC						
Kórník	1980 <b>N</b>	–	1976 <b>NMC</b> 1988 <b>N</b>	1976 <b>NMC</b>	1988 <b>N</b>	1980 <b>N</b>
Kutno	–	–	1977 <b>NMC</b> 1983 <b>NMC</b>	–	1977 <b>NMC</b> 1983 <b>NMC</b>	–
Katowice	–	1978 <b>N</b>	–	–	1978 <b>N</b>	–

N – NPV (nucleopolyhedrovirus); C – CPV (cypovirus); M – NPV+CPV.  
Bold letters indicate pathogen dominating in the population

## DISCUSSION

Outbreaks of the satin moth and viral epizootics were observed in numerous European and other continents countries but knowledge about them is scarce. The literature refers mostly to their incidental occurrence in different environments. Long-term survey on the same population of the satin moth allowed to understand better these phenomena and a relation host-pathogen under conditions of low and high density, also at different infection severity, and various temperatures and humidity. Outbreaks and epizootics shared some similarities in examined regions. They displayed similar rhythm, orders of particular stages, and periods of their increases, peaks and declines.

Duration of particular stages differed in each monitored population. There were some concerns not only about length of outbreaks and epizootics within the same population but also effect of pollution on insects in examined areas. Some authors indicated (Price *et al.* 1974; Chłodny 1980) that pollution is usually more harmful to

predatory and parasitic insects. *Lepidoptera* and *Homoptera* insects demonstrate high tolerance to polluted environment (Villemant 1980; Migula 1984). Migula (1985) revealed that mortality of *L. salicis* and *Euproctis chrysoorrhoea* increased with toxin accumulation in the surroundings, particularly SO<sub>2</sub> and acid rain. However, direct effect of dust pollution was small. Long hairs covering larva bodies protected insects from dust contact. As far as pupae were concerned and dust pollution, the pupal bodies were protected with strong cocoon that developed during pupating. Because of better mechanism of cell regulation the satin moth demonstrated better response to environment stress than *E. chrysoorrhoea*. This behavior is typical for the insects living for many generations under high pollution pressure in particular environment (Migula 1985). High tolerance to environment conditions allows the insects to spread out easily into large areas.

In "Kórnik" population there were three outbreaks over nineteen years and lasted four, two and three years. The periods between the outbreaks with low insect densities were two and three years. In "Kutno" during fourteen-year observations the outbreak lasted seven years. In "Katowice" population there was a five-year outbreak.

In the mid 1950s Schnaiderowa (1959) observed the outbreak of satin moth on poplar trees. The outbreaks lasting from two to seven years and longer were observed also in other countries. Jahn and Sinreich (1965) described two-year outbreak in Austria. Three-year outbreaks were documented in Belgium (Nef 1976) Bulgaria (Zakharieva 1983a) and Hungary (Abraham 1996). The outbreaks lasting four years were observed on poplars in western Siberia (Kolomicz 1971), in Altai region, Russia (Dondikov 1974), Tomsk region, Russia (Nikiforov 1979) and Turkey (Cobanoğlu 1992). Seven-year outbreaks were recorded in Belgium (Nef 1975). The outbreaks of satin moth in Siberia were ten-eleven years lasting (Galkin 1975). Long-term outbreaks were often caused by both low level of predators and parasitoids or lack and low level of entomopathogens within pest population. Polluted air in Katowice area did not favor development of entomophages, as we can assume low temperatures in Siberia did either.

All observed outbreaks fluctuated similarly. Outbreak rhythm was dependent upon virus type and its abundance within insect population. Abundant insect populations with high concentration of a virus collapsed rapidly. It was observed in "Kórnik" region where both virus nucleopolyhedrovirus and cypovirus reduced *L. salicis* numbers to a level of depression. Presence of both viruses NPV and CPV at the same time was conducive to development of mixed infection in the insects. The laboratory experiments showed that inoculum of NPV and CPV placed in food for larvae *L. salicis* caused synergistic effect (Ziemnicka 1981). It resulted in several times higher mortality rate. *L. salicis* cypovirus occurred less frequently than nucleopolyhedrovirus did. NPV virus domination was observed in mixed populations also in the next two outbreaks.

*L. salicis* NPV virus is very aggressive towards its hosts. Some Polish strains are several times more virulent compare to others with different origin. Higher virulence of NPV was confirmed in an assay comparing Polish strains with Yugoslavian (Lameris *et al.* 1985). Dominating role of NPV in biological control was observed in all outbreaks of the satin moth in Poland (Schnaiderowa 1959; Ziemnicka 1976a, b, 1981) and other countries as well (Weiser *et al.* 1954; Huertos and Templado 1958; Grigорова 1962; Orlovskaya 1968; Sidor *et al.* 1978; Maksymov 1978; Grijsma 1989). Similar

domination and high efficiency of NPV was also recorded in the second outbreak in "Kutno" and "Katowice".

Domination of CPV did not decrease population density of the satin moth. Sudden decline within the insect population was recorded upon appearance of NPV that reduced the number of insects to a depression level. Epizootics caused by CPV do not occur frequently. CPV epizootic in the satin moth population was observed only once in Austria in the years 1962–1963 (Jahn and Sinreich 1965). However, it doesn't prove that CPV virus does not infect the satin moth population, what was showed in the bibliographic study (Ziemnicka 1976b; Ziemnicka 1981). CPV virus belongs to the family Reoviridae, genus Cypoviruses differ with NPV virus not only in the genome and also in biological activity. Reoviridae viruses are less aggressive compared to viruses from the Baculoviridae family. CPV has a RNA genome and replicates in the cytoplasm of the infected cells while NPV has a DNA genome and replicates in the nucleus. Replication of the CPV virus is only confined to midgut epithelial cells, which have a great regeneration potential (Yamaguchi 1977).

Other natural enemies of the satin moth such as bacteria, fungi and parasitoids occurred in small quantities and did not affect outbreak and epizootic cycles in examined regions. Nonetheless, they might play an important role in other populations of that insect species. Entomopathogenic fungi *B. bassiana*, *Fusarium* sp., *Paecilomyces* sp. and *Hirsutella gigantea* (Ogarkov and Ogarkova 1979; Wagner and Leonard 1980; Ziemnicka and Sosnowska 1996) caused several-year epizootics decreasing efficiently the insect population. *Telenomus nitidulus* (Hymenoptera), an egg parasite of the satin moth played an important role in decreasing density of the stain moth population (Dondikov 1974; Nef 1976; Teodorescu 1980; Zakharieva 1983b, Grijpma and Van Lenteren 1988) as well as larval parasites *Meteorus versicolor* and *Rogas* spp. (Obozov 1968; Maksymov 1978; Grijpma 1989). Parasitoid insects do not only reduce a number of insects but also act as vectors spreading out the viruses (Ziemnicka *et al.* 1996).

Temperature and humidity are significant abiotic elements responsible for proper metabolism of insect hosts. They can also affect the antagonists of the pests. Numerous observations showed that high temperatures were recorded prior mass occurrence of the insects (Maksymov 1978). Analyses of meteorological data for the investigated regions did not show the differences in temperatures and humidity of the years before and during the outbreaks and epizootics. There was no influence of temperature and humidity on initiation and duration of the outbreaks as well. However, years of outbreak peaks showed some relationship with temperatures and humidity range. Most happened at temperatures above 15°C and 50–60% RH. It indicates that warm and humid weather favors replication of the satin moth.

High temperatures were also conducive to years of epizootic peaks but humidity range was lower (40–50%). It indicates that warm and dry weather in spring and summer months is more favorable to development of viruses. These conditions affect negatively parasitoids and a host. Lack of food occurring during outbreaks and its low nutritional value increase the host sensitivity to viral infections. As it was observed mean monthly temperatures above 15°C in spring and summer favored a development of NPV and mixed infection of NPV and CPV, while below 13–14°C only NPV. Similar correlations were found in Macedonia (Kuševska 1972).

## CONCLUSIONS

1. Nucleopolyhedrovirus LesaMNPV is the most efficient biological control of the satin moth (*Leucoma salicis*) in regions of its common occurrence.
2. Natural epizootics occur in populations of high density and severe incidence of nuclear polyhedrosis viral infection.
3. Mean monthly temperatures above 15°C in spring, summer months, and relative humidity 50–60% are favorable to the occurrence of outbreak peaks.
4. Mean monthly temperatures above 15°C in spring, summer months, and relative humidity 40–50% are favorable to the occurrence of epizootic peaks.

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## POLISH SUMMARY

### GRADACJE I NATURALNE EPIZOOCJE WIRUSOWE BIAŁKI WIERZBÓWKI *LEUCOMA SALICIS* L. (LEPIDOPTERA: LYMANTRIIDAE)

Podczas wieloletnich badań populacji białki wierzbówki *Leucoma salicis* stwierdzono występowanie licznych ognisk gradacyjnych i naturalnych epizoozji wirusowych. Liczba owadów w ogniskach gradacyjnych w fazie kulminacji wyniosła od 450 do 3250 na 10 topolach doświadczalnych (do 2 m wysokości pnia). Poziom wirusów w populacjach o takim zagęszczeniu rósł wraz ze wzrostem liczebności owadów. Gwałtownemu załamaniu ulegały populacje silnie zagęszczone o wysokim poziomie nukleopoliedrowirusa i cypowirusa.

Gradacjom białki sprzyjały ciepłe i wilgotne, natomiast epizoozjom wirusowym ciepłe i suche miesiące wiosenno-letnie. Większość kulminacji gradacyjnych miała miejsce w latach o średnich temperaturach miesięcy wiosenno-letnich wyższych od 15°C i przy 50–60% średniej wilgotności względnej powietrza. Większość kulminacji epizootycznych występowało w warunkach o podobnej temperaturze lecz niższej wilgotności względnej powietrza (40–50%).

## BOOK REVIEW

**Buntin G.D., Pike K.S., Weiss M.J., Webster J.A. 2007. (Eds.). Handbook of Small Grain Insects. Published jointly by the Entomological Society of America, Lanham, MD and the American Phytopathological Society, St. Paul, MN, USA. ISBN 978-0-9776209-1-3 & ISBN 780977-602913.**

As indicated in the introductory chapter "How to use this handbook" (p. 1) this book is designed primarily for the practitioners of integrated pest management (IPM) programs in small grains, crop consultants, extension agents, agronomists and university teachers who will find very valuable information on various topics in this handbook.

The editors invited 54 specialists from the United States, Canada, Czech Republic, Morocco and Syria who provided fundamental and practical information about managing and control of insects and mites noxious to wheat, barley, oats, rye and triticale with an emphasis on wheat. Rice, millet and other grain crops are not covered in this handbook

In chapter "An introduction to small grains" (p. 2–13) several useful information on worldwide and North American production of major small grain crops are provided. In a clear table Zadok's and Feeke's wheat development scales are well explained making them useful for developing and endorsing grain plantation protection programmes.

The chapter "Small grain pest management" (p. 14–23) provides very useful information on sampling and decision making in arthropod pest management tactics (cultural control, plant resistance, biological control, chemical control) in various kinds of small grain plantations.

Particularly useful is chapter "Identification of arthropods and diagnosis of injury" (p. 24–36) in which the interested reader will find the keys designed for identifying the most common and important pest insects, and a few unusual small grain pests that often are mistaken for more serious pests of small grains.

The main part of the handbook makes chapter "Pest information" (p. 37–91) which provides information on over 60 insect and mite species in respect to the following features: (1) scientific classification, (2) origin and distribution; (3) description, (3) pest status; (4) injury, (5) life history, (6) management, and (7) selected references. In this chapter also the following arthropod species occurring on small grains outside of North America are characterized: *Eurygaster integriceps*, *Zabrus tenebrioides*, *Porphyrophora tritici*, *Mayetiola hordei*, *Delia* spp., and *Schistocerca gregaria*.

In chapter "Beneficial organisms" (p. 93–100) the readers will find interesting information on the role which entomopathogens, parasitoids and predators play in natural control and management of insect pests of small grains.

A great number of good illustrations, list of 205 references, useful glossary (p. 107–111), large list of sources of local information (p. 112–116) and good index (p. 117–119) make this book an excellent source of valuable information for plant protection specialists and academic teachers. Therefore this book should be in each agricultural library.

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