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RESEARCH CARRIED OUT IN ROMANIA ON ECOLOGY AND MANAGEMENT OF THE POPLAR DEFOLIATOR *CLOSTERA (PYGAERA) ANASTOMOSIS* L. (LEPIDOPTERA: NOTODONTIDAE)

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Abstract: *Hybrid poplar cultures have been noticeably expanded in Romania, after the World War II. These artificial cultures provide the conditions for outbreaks of the different poplar specific pests. Among these, defoliator Clostera anastomosis proves to be, lately, very dangerous. First outbreak in Romania was recorded in 1971, in the Prut Floodplain, within Iași County, followed after 4 years of a new outbreak, in the Danube Floodplain, within Giurgiu County. Then, there were no records of severe attacks, but starting with 2003, attacks of high intensity are accounted, mainly in hybrid poplar cultures in the Danube Floodplain, section Oltenița-Brăila, resulting in significant defoliation, on a cumulated area varying from 220 ha, in 2006, to a maximum of 706 ha, in 2010. Poor knowledge on biology and ecology of this species couldn't provide the basis for assessing the critical threshold values, required for developing prognosis of the population and damage trends, from a generation to another. Consequently, decision for control action was taken depending on the intensity of the current attack, and if the economic threshold was exceeded (loss of > 50 % of the foliage), aerial or ground spraying were applied, using chemical and biological insecticides. The largest area (620 ha) was sprayed in 2004. For the future, an intensification of the attacks is predicted, so that further research is required for an in deep insight of the ecology and biology of this species, in order to support the developing of an adequate prognosis, as well as an efficient pest management.*

Key words: *Clostera anastomosis, hybrid poplar, outbreaks, pest management, Romania.*

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1. Introduction

The increasing world timber demand, especially after World War II, led to a massive expansion of hybrid poplar plantations in the Northern Hemisphere (North America, Europe, partially in Asia [5-6, 12, 27], as well in regions at Southern latitudes (Australia, Brazil, Chile, New Zeeland, South Africa) [23]. Romania is not an exception, first experimental plots were installed after 1915 [8]. Subsequently, these plantations were significantly expanded, from an area of approx. 12000 ha in 1960 to a maximum of approx. 80500 ha in 1984 (66000 ha compact areas and 14500 ha alignments) [8]. Recently, in 2015, there were recorded, at national scale, approx. 70000 ha plantations with different species/clones [7].

In the world, a large area of hybrid poplar plantations consists in intensive crops, oriented for varied biomass production (from biofuels to wood for industrial applications). These are even-aged poplar plantations, generally consisting of one clone selected for increased capacity of biomass accumulation [5, 24]. Often, these plantations become the object for specific or polyphagous pest outbreaks, due to the absence or low action of natural control mechanisms [9]. The hybrid poplar crops in Romania are not an exception, a lot of insect species, mainly defoliators, developing severe outbreaks [16, 28, 30, 32-33, 36]. Among poplar defoliators, during the last years, it is noticeable the species *Clostera* (*Pygaera*) *anastomosis* Linaeus, 1758 (Lepidoptera: Notodontidae), which caused important losses especially in Euromerican poplar plantations in the Danube Floodplain or interior river floodplains [38].

2. Geographic Distribution

C. anastomosis is a common lepidopteran species in Palearctic region, native in whole Europe as in Asia (Russia, Mongolia, China, Japan, Turkey, Kazakhstan) [26]. It lives mainly on poplar and willow species, so the local area of the defoliator is restricted to the presence of the host plants.

In Romania, the first faunistic record of this species dates since 1892 in the North-Eastern part of the country, near Rădăuți (47.8463 N; 25.9399 E) [21], and shortly after there were added new records from different locations all over the country [20]. At the moment, *C. anastomosis* is distributed almost in the entire country where species of *Salix* and *Populus* are present, up to elevations of 1400-1500 m a.s.l. [25, 31] (Figure 1).

3. Life History

In Romania, first observations of the activity and development of *C. anastomosis* were carried out at the end of 19th century – the beginning of the 20th century, when it is mentioned that the species has two generations per year in North [20-21], two complete generations and the third incomplete, in Transylvania [20], three complete generations and the fourth incomplete in South [22].

Adults of the overwintering generation start flying on the second half of May until the end of June, earlier in South comparing to Northern region. The flight of the first generation occurs in July – August, and of the second generation in

September [2, 36, 38]. During the warmer years, in South, adults of the third generation might fly to the end of September, the former generations' flight occurring earlier.

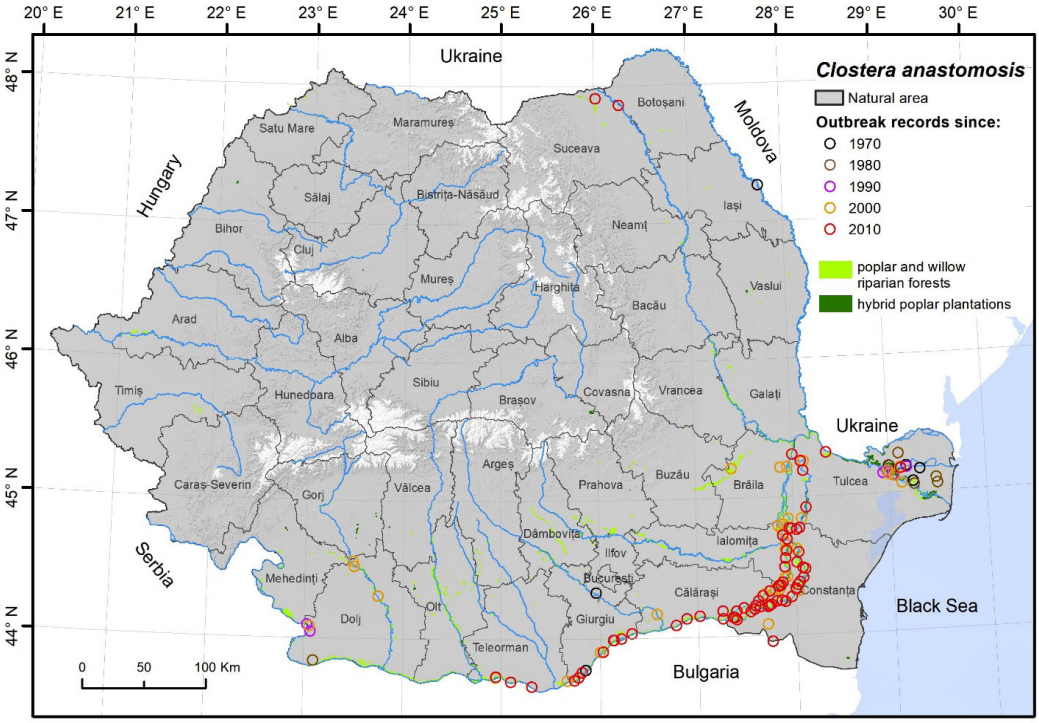


Fig. 1. *Clostera anastomosis* in Romania: distribution area and outbreak records

The flight activity is mainly nocturnal, and during the day the adults are resting on poplar leaves. Females are heavier so, the most part of the time, they shelter on branches or leaves. Males are more active, looking for females in fast and short flights [1, 36]. Adults are able to mate two – three days after emerging [40]. The copulation lasts 8-15 hours, but can be prolonged to 48 hours [1].

In three – four days after mating, females are laying in average 700-800 eggs, on the lower part of the leaves, in batches, on different leaves [36]. The embryonal development lasts for 5-8 days [2], and the eggs are changing the colour from yellow – green to reddish, finally they become grey – blackish, easily pearly [20, 38].

Neonate and second instar larvae feed gregarious, skeletonizing the leaves. Starting with the third instar they spread in the crown, eating the entire leaf, excepting the main vein [2, 20, 36].

The pupation occurs after the larvae go through five instars, and prepare by weaving a white – greyish cocoon, in a rolled leaf. In approximately two weeks, first come up the male butterflies, then the females [2].

The complete development lasts 40 – 45 days for summer generations [36] and up to 5-6 months for overwintering generation [36].

The insect overwinters as larva (second or third instar) most common in small silk nests in crevices of the bark on the lower section of the colonized tree stems [2, 36]. There are accounts of the insect overwintering as egg [21] or pupa [31].

The larvae are resuming their activity in spring when average air temperature during the day exceeds the threshold of 13,5^{o}C [2].

4. Natural Enemies

Like numerous other lepidopterans, *C. anastomosis* has a lot of natural enemies, from viruses causing diseases, to insects and vertebrates. Most often, defoliator outbreak (with specific consequences as overpopulation and larvae starvation) triggers the natural action of specific diseases (cytoplasmic polyhedrosis) caused by *Baculovirus* sp. These diseases may cause mortality to up to 90 % of larval populations [36].

Up to now, there were recorded numerous species of parasitoids which develop in eggs, larvae or pupae of *C. anastomosis*. Eggs are parasitized frequently (approx. 23-33 %) by *Trichogramma* spp. [38]. On larvae and pupae were recorded parasitoid species belonging to Family Tachinidae, as polyphagous species: *Exorista larvarum* (Linnaeus, 1758), *Blondelia nigripes* (Fallén, 1810), *Zenillia libatrix* (Panzer, 1798) [10]. In Family Braconidae was recorded the parasitoid *Apanteles congestus* (Nees 1834) [20].

Larval populations of *C. anastomosis* can be considerably affected by insectivorous bird species. In May 2017, a starling flock (*Sturnus vulgaris* Linnaeus, 1758) has eaten over 95 % of the larvae in an outbreak spot, with severe defoliation, developed in a 4 years old plantation of hybrid poplars, in Zamostea (Suceava County). The birds succeeded to naturally extinguish the outbreak [4].

5. Outbreaks in Romania

Lately, *C. anastomosis* proves to be a dangerous defoliator for artificial cultures of hybrid poplars in Romania. Complete, subsequent defoliations, occurring during outbreaks, can severely affect the stability and productivity of the infested plantations. In the case of a hybrid poplar plantation (clone AF8), age of 4, the volume increment loss during the defoliation year was of 80-90 % at complete successively defoliated trees, comparing to non-defoliated trees, and the mortality recorded in the autumn of the defoliation year among the defoliated trees can reach 28,9 % [4].

First important defoliations in Romania (most of all of heavy intensity) occurred in 1971, on approx. 200 ha, in an 8 years hybrid poplar plantation (clone Robusta), in Golăești Forest, placed in North – Eastern part of Romania, in the Prut river floodplain, within Iași County [19, 32]. Then, in 1975, it was accounted a severe infestation, in South, at hybrid poplar saplings (0.12 ha), in Malu Nursery, Giurgiu County (Danube Floodplain). Large areas with low infestations were recorded in 1976 (1298 ha) and 1977 (215 ha) in poplar plantations in the Danube Delta. Until 1980, were accounted spots with low infestations, cumulating up to 21 ha [32] (Figure 1 and Table 1).

During 1981-1990 and 1991-2000, most of the infestations produced by *C. anastomosis* were of low intensity, summing up between 5 ha (1981-1985) and 600 ha (1987). Most of the infestation

spots were placed in the Danube Delta and the Danube Floodplain, in Dolj County.

In 1989, for instance, were recorded 100 ha of poplar plantations moderately infested, at Segarcea Forest District, in Dolj County [30] (Figure 1 and Table 1).

The cumulated area of the infested cultures strongly increased during 2001 – 2010, reaching a maximum of 5452 ha in 2010. Most of the cultures were low infested (from 5 ha in 2001 to 4736 ha in 2010), but there were accounted areas with severe infestation as well (620 ha in 2004, 572 ha in 2005, 220 ha in 2006 and 706 ha in 2010). Moderate infestations were recorded on areas from 4.5 ha in 2003 and 1412 ha in 2006. Affected areas were placed mainly in the Danube Floodplain and Delta, as in floodplains of several interior rivers (Ialomița Floodplain). Severe attacks were accounted mainly in poplar plantations in the Danube Floodplain, on sections Călărași, Fetești, Brăila, where, in this period, were recorded outbreaks of this defoliator for the first time [28, 38] (Figure 1 and Table 1).

Since 2011, a decrease of the infested areas was noted, from 2153 ha (2012) and 1452 ha (2011), to 508 ha in 2016. The extent of the cumulated areas with severe attacks of *C. anastomosis* exceeds the one recorded in the previous decade, for instance in 2013, only, the areas with severe attacks summed up approx. 69 % of the affected areas. In 2011 and 2012 were recorded large areas with moderate attacks: 360 ha, respectively 638 ha. Most of the infestation spots were placed in the Danube Delta and Floodplain. The severe infestations were placed in the Danube Floodplain, on section Oltenița – Brăila (Nețoiu, unpublished data). Since 2013 new infestation spots were recorded in North Eastern Romania, in Rădăuți Depression, Suceava County, where on approx. 50 ha were recorded severe defoliations [2] (Figure 1 and Table 1).

Comparing to period 1971-2002, when the cumulated area of poplar plantations infested by *C. anastomosis* was small, reaching a maximum of approx. 1300 ha in 1976 and the average number of infestation spots didn't exceed 14 yearly, beginning with 2003 a strong increment was recorded both of the infested areas, at over 5400 ha in 2010, and of the number of infestation spots, at over 50 yearly, in 2013 or 2014.

The maximum level recorded in 2006 and 2012, for cumulated infested area as well for their number, is succeeded of much lower levels in the next years. This significant decrease is the result of the control actions conducted in areas with moderate – high infestations, as well of the natural control agents (Figure 2).

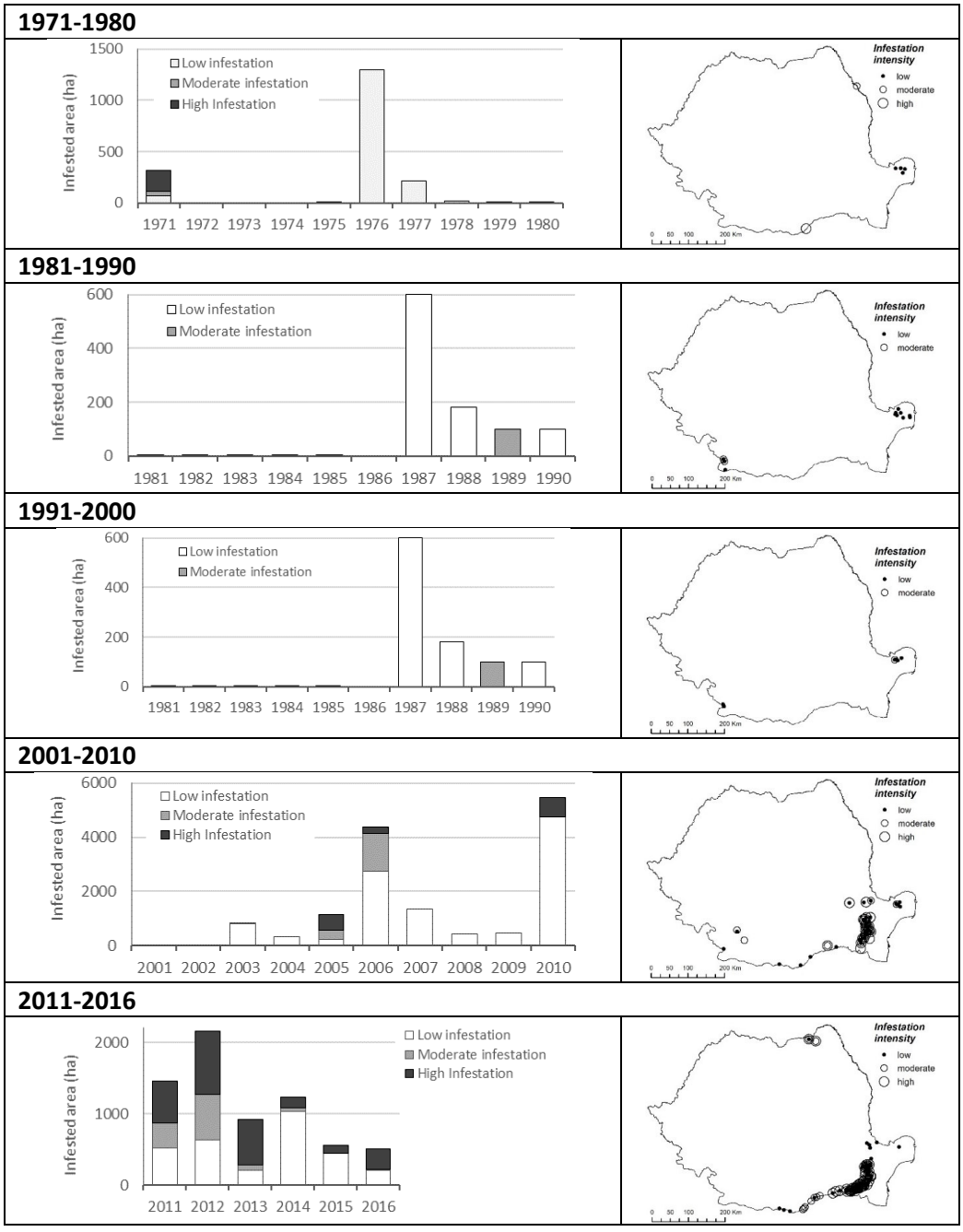
6. Management of *Clostera anastomosis*

Pest detection is done by observation and ascertainment of the presence of the insect on the poplar leaves, in different development stages (egg masses on the lower side of the leaves, larvae feeding on leaves, pupae in cocoons sheltered between leaves, or resting adults), as by checking the defoliations [2, 36].

Larvae defoliations are easily noticeable, so a careful check during the vegetation season, and mainly in spring, for the defoliations produced by the overwintering generation, result in a facile mean of establishing a simple and efficient pest management.

Table 1

Dynamic of poplar plantation areas attacks of different intensity of *Clostera anastomosis*[3]



[3]For this summary were used data published in forest pest statistics in Romania [28, 30, 32], as well data from scientific papers [2, 4, 19, 38], or unpublished data (Nețoiu 2018, unpublished data).

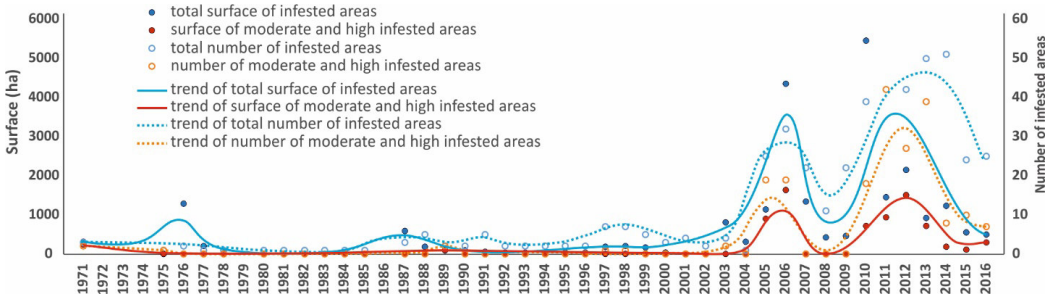


Fig. 2. Trend of cumulated infested areas and number of accounted infestation spots

In the same time, the large number of generations per year, the variations due to the geographical position, as the lack of an articulate method for damage prognosis by a generation to another, determined the introduction of the infested stands in the control area on a basis of the level of defoliation caused by the former larval generation. Thus, if real defoliation done by larval generation *n* exceeded 50%, considered the economic damage threshold [11], for the next generation (*n+1*), the affected stands were included in the control area and the control tactics were initiated only after the check of the larval population density. If it was ascertained the presence of a population large enough to produce a defoliation over 50%, chemical treatments were applied on the ground or even in the air, for mature stands. Population density was assessed by various means, recorded in literature, as control trees method [29], sprayed with chemical insecticides (aerosols) on the ground (in mature stands), or by assessing the larvae on the branches, collected by random from the crown of the young trees, and extrapolating to the whole crown [36].

Due to the large number of generations/year and, in some of the years, to the overlapping of some stages, the control of the pest become relatively difficult, the optimal moment for conducting the treatment requiring a careful monitoring of the insect phenology. Chemical and biological control efficacy depends mostly on the correlation with pest phenology [36, 40].

Starting with the first outbreaks of this insect and with the first severe defoliations recorded, in nurseries, as in poplar plantations, were conducted chemical control actions. Thus, in the case of outbreak in 1971 (Golăești – Iași) [19], were applied on the ground, with good results, chemical treatments with DDT (0.5 kg active substance/ha). Afterwards, in 1975 (Pepiniera Malu – Giurgiu), Detox 25 (active substance DDT) was administrated on approx. 0.12 ha [32]. After these two severe attacks, poplar plantations in Romania cross a calm period regarding the infestations with *C. anastomosis,* since 1975 to 2003 [16, 28, 30].

In 2004, in mature poplar stands of Răcari – Coțofeni Forest (Dolj County), because of the high density of the overwintering larval population, aerial insecticide spraying was given on approx. 620 ha, with Dimilin 48 SC (diflubenzuron), dose 80 g/ha in 3 l water. In the same forest, on approx. 85 ha of young cultures (1-2 years), insecticide ground spraying was applied, using pyrethroids [38]. Chemical spraying was applied at the end

of April, when 60 % of the larvae were in third instar, 20 %, in second instar and 10 % in fourth instar, with high efficacy (96 %), even, in some spots, severe defoliations were recorded before the application of the aerial spraying [13].

Control actions were conducted in spots during the next years, only in young plantations, with high attack risk. For that purpose, were applied bacterial insecticide Dipel 8L, so that pyrethroids (Lamdex 5 EC 0.05% (lambda-cyhalothrin) and Faster 10 CE (cypermethrin). Solely in 2014, were applied ground insecticide sprayings with Lamdex or Faster on approx. 270 ha, in Departments Călărași (142 ha) and Constanța (128 ha), and in 2015 on approx. 134 ha (Călărași: 96 ha, Constanța: 32 ha, Ialomița: 6 ha). In 2016 control actions were conducted only in Călărași Department, on 110 ha) [39].

Trials were conducted in order to assess the efficacy of *C. anastomosis* larvae control after overwintering. The insecticide sprayings on the stems of the trees colonized with overwintering larvae led to 100% mortality of the larvae, using the pyrethroid Karate Zeon (lambda-cyhalothrin 50g/l). When insecticide Confidor was applied, the mortality reached 78-90 %. In the same trial, has been shown that after overwintering, the larvae can be caught in sticky band traps placed on the stems in order to prevent from crawling up to the crown [3].

7. Discussion

C. anastomosis is a native component of natural poplar and willow ecosystems. In artificial poplar ecosystems, this insect can produce outbreaks, causing severe defoliations to the colonized trees. In epidemic conditions, this insect is a threat for hybrid poplar cultures.

Many of the biological and ecological features of *C. anastomosis* are relatively well-known in Romanian scientific literature, excepting aspects referring to survival rate of larvae during overwintering, mortality rate in different development stages, quantity and quality of the food ingested by larval individuals, fecundity, etc.

Also, less is known on the natural mortality factors, and on the influence of the climate parameters on the insect development. On the other side, even though the composition of the natural specific pheromone is known [41], the artificial pheromone was not produced up to now.

Outbreaks of this species are more likely triggered by the abundance of the quality food for larvae, available especially in artificial monocultures, consisting in poplar clones selected mainly for their productivity. In Romania, as in many of the European countries, and not only, hybrid poplar cultures expanded after the World War II [1, 8, 19], but C. *anastomosis* acts as a pest just in spots in 1971 [32]. Attack intensity and frequency increased noticeable since 2003 (Figure 2), even the area of the hybrid poplar cultures were slightly decreasing in Romania [5-7].

Outbreaks of *C. anastomosis* recorded lately are not a unique scenario in Romanian silviculture. There are more and more frequent the records of outbreaks produced by insect species that didn’t act as pests in the past: *Pristiphora abietina* (Christ 1791) in spruce stands extended outside the natural area [18], *Cephalcia abietis* (Linnaeus 1758) in spruce stands in Eastern and Southern Carpathians [17], *Stereonychus fraxini* (De Geer, 1775)

especially in pure ash tree stands or within forests with high percentage of ash trees [16], Polyphagous species of *Orthosia* [29]. As *C. anastomosis,* some of the mentioned species developed outbreaks mainly in artificial forest monocultures established outside the natural area.

Otherwise, in Romania, during last decades, in the context of the climate changes and of establishing of more and more favourable life conditions to outbreaks, new circumstances were created for common insect pests, showing trends of time and space expansion of outbreaks. An example is the polyphagous defoliator *Lymantria dispar* (Linnaeus, 1758), which, during the last decades, showed an noticeable altitudinal and latitudinal expansion [38], and, during the outbreak in 2004-2006, was able of severe infestations in beech forests in Orșova-Băile Herculane- Moldova Nouă or in South Maramureș [14, 37].

Another example is the defoliator *Dasychira pudibunda* (Linnaeus, 1758), which, during 1992-1994, developed a severe outbreak on approx. 10 thousand ha, in Sovata region, in beech forests, causing complete defoliations on approx. 700 ha [34-35].

Managing the losses caused by *C. anastomosis* is a big challenge for Romanian foresters. In the context of the scarcity in knowledge on biology and ecology of the mentioned species, up to now there weren't assessed the critical threshold values. Therefore, a long term prognosis of the population development isn't possible at the moment. Under these circumstances, there are required researches on the parameters specific for critical thresholds: larvae food demand, natural mortality for different development stages and outbreak phases, sex ratio of adult populations in different outbreak phases, etc.

Referring to the integrated control of the pest, there are required researches in order to design a control scheme considering several strategies: a) mechanical control of larvae by sticky band traps; b) contact insecticide spraying of the stems, on rhytidome, in early spring; c) biological insecticide spraying during the vegetation season; d) favouring insectivorous bird population.

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