

University of West-Hungary

Phd Thesis

**HERBIVORE ASSOCIATION OF DIFFERENT POPLAR SPECIES  
AND CLONES WITH PARTICULAR EMPHASIS  
ON *POPULUS NIGRA* PROVENANCES**

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**Sopron  
2012**

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## 1. Introduction

The *Populus* genus includes key species with both the ecological and economic importance. Nowadays they play an important role in natural ecosystems and biomass production, as well.

The dramatic increase in energy consumption forces us to expand the scope of available resources and to further increase the efficiency of production and utilisation. This demand is unlikely to be covered from natural forests due to environmental and climatic reasons. Fast-growing tree species such as poplars managed in short-rotation energy plantations may provide a remarkable alternative to timber extracted from natural forests. These systems also play an important environmental role by sequestering large amounts of carbon thus slowing the accumulation of greenhouse gases (Dickmann, 2006). In order to make this system operate as efficiently as possible, it is essential to know the properties of fast-growing tree species and understand their relationships with abiotic and biotic systems, in particular with arthropod associations. Short-rotation plantations are expected to maximize profits, so the clones and varieties are selected based on timber yields with minimal consideration for adaptive abilities. This fact, along with the specific age and cultivation methods of these plantations contribute to higher instability and less resistance to damages and diseases. The knowledge and understanding of the dominant species of a particular habitat and its relationship with associated communities play an important role in preserving genetic diversity (Crutsinger *et al.*, 2006; Reusch *et al.*, 2005; Wimp *et al.*, 2004). These dominant species and genotypes with complex community-level interactions and possess such characteristics that allow them to stabilize communities that are associated with them. These so-called founder species require more attention with regards to their role in conservation, reforestation and the ecological aspects of rehabilitation. Poplars are the key characteristic species of riparian communities. Whithman *et al.* (1994) regard poplars as the most productive members of floodplain communities in the northern hemisphere.

In their natural habitat, thanks to their large size, longer life span and ecological dominance white and especially black poplars develop tighter and looser interactions with a wide range of arthropods. Poplars are pioneer species

that spread quickly and easily both vegetatively and generatively and occur in early successional communities. They show a high degree of tolerance to a broad range of environmental conditions. Some species and clones can tolerate major air pollution while others can endure extreme soil conditions. They show high vigour and their oxygen-producing capacity is good due to their large foliage.

Although there have been several research results published in the domestic and foreign literature, a systematic approach is still somewhat of a novelty. This study provides new knowledge on the composition, relationships, interactions and complex mechanisms of arthropod associations.

## **2. Aimes**

The identification of the key elements that define arthropod associations, and the knowledge of those associations that develop on poplar clones and varieties of different origin may help in understanding how the plant genotype affects, through phenotypic properties, the formation, stabilisation and development of herbivore communities. The objectives of this study are:

- I. To identify the key elements that define arthropod associations developing on the same poplar genotype,
- II. To determine the factors that influence arthropod associations developing on poplar species, clones and hybrids, and
- III. To compare arthropod associations developing on non-native and indigenous *Populus nigra* clones and to expand the knowledge on the adaptation processes of insect communities.

Accordingly, my hypotheses were as follows:

1. The immediate environment in correlation with the time factor (changes within and between growing seasons) plays a definite role considering to herbivore communities of poplars.
2. *Pemphigus* species on poplars have different life-history strategies.

3. The age of poplar trees greatly influence the characteristics of arthropod associations developing on them.
4. The genotype in correlation with the time factor (changes within and between growing seasons) play an important role with regards to herbivore communities of poplars.
5. The diversity on a given poplar clone correlates with the level of chewer and skeletoniser damage, and with the number of miners, leaf rollers, gall makers and aphids.
6. Host plants with similar genetic background promote the development of similar herbivore communities.
7. The sedentation, stabilisation and development of arthropod associations of different functional groups are influenced to a varying degree by the genotype of poplars, partly through phenotypic properties such as bud-burst and leaf size.
8. Individuals of distant populations of the same poplar species living in a new habitat form arthropod associations that are more or less different from the local population. These associations adapt to the new habitat at varying rates.

### **3. Material and method**

*Populus nigra* 'Italica', as trees with the same genotype were examined in their natural habitat from 2009 to 2010. These trees were older than 30 years, which presume that they already adapted the local biotic and abiotic environmental conditions. The *Populus* species clones and hybrids were examined in a common-garden experiment in Bajti from 2009 to 2011. In both trials the evaluation method was similar. The number of selected leaves and the sampling density were different because the size of trees and the local environmental conditions were different between the two age-groups. Fifty leaves were randomly selected on each *Populus nigra* 'Italica' tree up to 2.5 m height to assess the percentage of the damage leaf surface and presence of the diffe-

rent functional groups. The evaluations were done in every two weeks from the middle of April until the end of October. Every month from May until October in every month 15 leaves were examined on different *Populus* taxa. The damage caused by the insects was categorized in six groups: chewers, skeletonisers, leaf miners, suckers and sap feeders, gall makers and leaf rollers. The missing leaf surface was evaluated in percentage for chewers and skeletonisers. The mines, galls and rolls were counted, while aphid presence was recorded.

Basic statistical methods were used to compare the extent of damage and number of species and abundance. Parametric, non-parametric tests and cluster analysis were also applied.

#### **4. Results**

The arthropods functional groups were influenced by survey sites, the growing season, years examined on the poplars with same genotype. These factors affected the insects in different rate and way. The chewers and skeletonisers responded more sensible to the effects of years and survey sites than the other four function groups. Considering the mature Lombardy black poplar, there were some species which could be found only on the narrow range of survey sites.

The genotype of the trees, the provenance, the growing season, the years had a serious effect on the insects association of the *Poplar* taxa living on the same habitat. The type and extent of pest damage is significantly influenced by the genotype during the first three-quarter of the growing season, and it is less important beyond that. Poplar trees having the same genotype but originating from different habitats facilitate more or less different arthropod associations. The effect of the years on the younger trees was similar as to the mature tree.

During the examination of different clones there was only one species which jointed to one genotype. It was an aphid. At the same time there were more species which fed and lived on more clones of a species. For example the *Pemphigus* species, the *Parathecabius lysimachiae*, *Aulagromyza populi* and the *A. populicola* occurred on black poplars, even more in a narrower range of the clones.

Arthropod associations developing on mature *Populus nigra* 'Italica' were very different from those on younger trees. There were differences in species

composition, abundance and damage correlations of the functional groups. Insect communities with higher species richness were related to mature trees. Arthropod communities with higher richness raised the interspecific competition level. It seemed that this situation drove very complex insects association with negative or positive correlations and different extent of correlations. The younger trees were characterized by more strength correlation. One of the causes of this relationship that the herbivore insects could become dominant species on these trees in part of the growing season. On the other hand the different stages of these species lived and fed on same poplar species, and they can significantly increase the damages.

## 5. Thesis

### **1. During the two years examination the year over year (YOY) variance in the number of individuals of species and groups in more protected environments (gallmaker, leaf rollers and miners) is the minimal and the number is less influenced by habitat (gallmaker and miners).**

The YOY variance in the number of individuals was significant for the miners, while the effect of site were not significant. The number of gall makers and leaf rollers were not influenced by year or site factors. However, the extent of chewing damage was significantly different by site, while YOY variance was barely significant. Skeletoniser damage was highly significant for both site and year.

### **2.1. The life-history strategy of the different *Pemphigus* species is include the position of the gall, gall opening, the number of aphids in the galls, and the morphologically different fundatrigeniae types in the galls.**

The successful life-history strategy seems to consist of multiple elements, with success being achieved in different ways. On the petiole-placed galls, a small gap on the gall, a long but tightly closed gap, or a completely closed gall type with at least a moderate number of individuals in the gall, morphological and functional different morphs mean in every case an advantage for any *Pemphigus* species. A long and looser gap, the midrib-placed galls, a low number of aphids, the lack of the morphological and

functional different morphs mean a disadvantage from the perspective of vulnerability to predators.

**2.2. There is significant competition among *Pemphigus* species that belong to the same guild. This is shown in the size of galls and the number of gall-dwelling aphids.**

The level of competition is defined by the location of gall formation, the similarities and differences between gall maker species, as well as by the species themselves. The most common case of twin gall making is when one gall is formed on the petiole while the other gall forms on the leaf midrib. This is followed by the case where two gall makers of the same species form on the petiole, then where two different species form galls on the petiole. It is less common for one species to form a gall on the leaf midrib while another species forms a gall on the leaf surface next to the midrib. Finally, the rarest case of multiple gall making is where several different species form galls on the leaf midrib.

**2.3. *Pemphigus gairi* was identified as a new species in the Hungarian fauna. Substantial expansion was observed in the distribution of *Parathecabius lysimachiae*, *Pemphigus protospirae* and *Pemphigus populinigrae*.**

*Pemphigus gairi* was only noted in three countries according to the Hungarian and European literature. The *P. lysimachiae* was found in Nagytétény. *Pemphigus protospirae* and *Pemphigus populinigrae* were known to occur only in the eastern part of Hungary extending to the line of the Danube river.

**2.4. As a result of this study, the knowledge base of 8 *Pemphigus* species was substantially extended with regards to their life cycle and developmental stages.**

For each *Pemphigus* species, this study determined the beginning of the galling phase, the time of appearance of the 1st, 2nd, 3rd and 4th morphs and first winged aphids, the related timing of emigration, and the time of gall abandoning and gall dropping.

- 3. Arthropod associations developing until 3 meter height on mature *Populus nigra* 'Italica' are very different from those on younger trees. There are differences in species composition, abundance and pest correlations. There are also significant differences in the duration, extent and peak time of the damage caused by chewers, skeletonisers and leaf rollers.**

Between the two age-group the species composition and the abundance were different at the chewers, skeletonisers, leaf rollers and the gall makers, while the abundance was various at the leaf miners finally the species composition was different at the sap suckers. The duration and regularity of chewing and skeletonising damage show greater YOY variance on mature trees. The peak time of chewing and skeletonising damage also differs. The duration and timing of roller damage is inherently different due to the differences in species. There were no significant differences between younger and older trees in the time of appearance for miners and *Chaitophorus leucomelas*.

During this study the correlations between pests were rarely if ever significant on older trees. There was no significant correlation amongst functional groups. Moreover, positive and negative correlations varied within and between years. On the younger *Populus nigra* 'Italica' trees there was a negative correlation between chewers and skeletonisers that was also significant up until the autumn. There was a negative correlation between chewers and miners and a positive correlation between skeletonisers and miners. These correlations were more often significant on younger trees; however the timing of significance could not be associated with a particular phase during this two-year study. Chewers and rollers generally had a positive correlation that was consistently significant during the main rolling phase. Skeletonisers and rollers had a negative correlation that was not significant.

- 4. The type and extent of pest damage is significantly influenced by the genotype during the first three-quarter of the growing season, and it is less important beyond that.**

The extent of chewing was significantly influenced by the genotype of the clones and year, except during October considering the genotype of clones. Both factors were also significant for the skeletonisers, again with the exception of August and October.

These results also indicate that the strength of the relationship between insects and their food plants weakens by August with the progression of vegetation development. This could be due to the plants changing their metabolites and this process can also be concurrently enhanced by the transformation of the arthropod association. There was no significant difference between the average number of galls and rolls between the two years, but the number of galls, rolls and aphids were significantly influenced by the genotype of the clones.

**5. Poplar genotypes with less diverse insect associations promoted higher chewing and skeletonising damage than those with higher diversity.**

The lowest levels of diversity were associated with the most severe chewing and skeletonising damage. The least damage caused by chewers and skeletonisers was correlated with medium levels of diversity.

The Shannon-Weaver diversity index counted by leaf miners, rollers, gall makers and aphids showed that *Populus nigra* proveniences are the most similar group. Hybrids differed significantly each other's regarding the diversity index.

**6. Poplars with similar genetic background promoted more similar arthropod association.**

**7. The formation of functional groups was affected by different factors depending on genotype. The ratio of these factors changed; however it characterized the given functional group.**

The rate of chewing did not show a close correlation with geographic linkages. The extent of chewing reflected the genetic relations. Chewing damage showed significant correlation with budburst at spring time, and with leaf size from May to September.

There was no clear differentiation between species based on skeletonising damage, but species genetic relational linkages are well defined. The extent of skeletonising damage did not show a correlation with geographic origin.

Different *Populus* species had different miners species composition and different abundance. There was also geographic differentiation amongst the *Populus nigra* clones. The southern types were consistently and sig-

nificantly different from the other *Populus nigra* clones. This differentiation was less distinct for the northern types.

The extent of roller damage was closely related to leaf size, especially for *Byctiscus populi*. The genetic relationship among the Poplar clones played an important role in the occurrence of gall makers and aphids. The most significant genetic relations were indicated by the presence of *Thecabius affinis*.

**8.1. Poplar trees having the same genotype but originating from different habitats facilitate more or less different arthropod associations. These associations adapt to new habitats at varying rates.**

*Populus nigra* clones from the peripheral areas showed greater differentiation in arthropod associations than clones from the more central areas of the geographic range

These differences in arthropod associations could also be observed across the entire geographic range for the chewer, skeletoniser, leaf miner and gall maker functional groups. The leaf rollers showed these differentiations only in case of provenances from the more southerly regions. In this respect, clones from the more southern origin proved to be more consistent than those of northern origin.

Differences among *P. trichocarpa* provenances were found between clones from Great-Britain and from mainland first of all considering chewers, skeletonisers and leaf roller.

**8.2. Forms of pest damage that are presumably strongly influenced by secondary metabolites adapt much faster to biotic and abiotic conditions of a new environment than those forms also characterized by phenotype.**

The *Populus nigra* 4 clone from Germany did not show separation from the Hungarian clones for miners (Coleoptera, Tenthredinidae) and sap suckers. The adaptation process was slower regarding gall makers, miners (Lepidoptera) and skeletonisers. Considering the chewers and leaf rollers damage the differences among the various provenances existed for a long time. In case of these functional groups the leaf size namely phenotypic characteristics showed significant relation with level of damage. It was especially true in case of the leaf roller *Byctiscus populi*.

## **6. Possibilities of practical utilization of the results and suggestions for further research tasks**

These results may help in the practical aspects the selection of *Populus* species for breeding, and determination of the breeding lines.

Poplars as founder species has an important role in restoration conservation in this way the detailed knowledge of herbivore association on poplar trees support more effective this complex object. This work can provide useful information to elaboration of the afforestation and restoration plans on sensitive habitats.

This research is also important for plantations and agroforestry. The new observation can help to choose elaboration of the poplar species and clones for both plantation, agroforestry and short-rotation energy plantations. If they are used correctly the resistant and the resilient ability of the plantations can be strengthened. These outcomes support improvement of self-regulation at reforestation, and the creating the basis of the self-regulation at plantations.

Short-rotation energy plantations are characterised by instable association and weak immune system. The knowledge of the herbivore association can help to moderate the effects of mentioned disadvantages in this type of plantation.

Findings of this study can enlarge, the applicable knowledge in production of the propagation material and in cost-effective plant protection and increase knowledge about poplar and interactions of their insects association

Considering the breeding and climate changing is also important to understand the mutual adaptation of the non-native host plant and indigenous insect associations in detail. Different origins should be compared in common garden long-term experiments.

The control and correct description of the block age phenomena can offer more specific information to establish the shelterbelt plantations and to mend their plant health stage.

During the last quarter of vegetation the effect of the clone's genotype is less important for insect associations. It would be essential to identify the factors which play role in the development of these phenomena. It is very important in particular in many respects of the founder species but the other

woody plants that the decline of genetic influence is a universal phenomenon at the trees in temperate zone or it characterises a species.

The arthropods examined on the higher parts of the crown of mature poplar trees can provide useful information referring to vertical level of insect habitats.

Development of insects association on the poplar gets an important role the appearances of the gallmakers aphids. It can help to understand the community level processes.

Predators and parasitoids are influenced by volatiles of the *Chrysomela populi* widely researched but the role of the interspecific competition is less studied even though forest and plant protection respects are important.

## **7. The list of publications related with thesis**

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