FAO INTERNATIONAL WORKSHOP
" IMPROVE THE CONTRIBUTION OF POPLARS AND WILLOWS
IN MEETING SUSTAINABLE LIVELIHOODS AND LAND-USE
IN SELECTED MEDITERRANEAN AND CENTRAL ASIAN COUNTRIES"

Izmit, Turkey, 27-31 July 2009

*DISEASES OF POPLARS AND WILLOWS**

by N. Anselmi

Plant Protection Department
University of Tuscia, Viterbo, Italy
anselmi@unitus.it

INTRODUCTION

Willow and, above all, poplar plantations represent an important economical goal for many countries. They are especially aimed at the production of high quality wood principally for plywood, lumber, packing and pulp; CO_2 stockage, bioenergy and environmental improvement represent other positive aspects of these cultivations.
Poplar cultivation in Europe and America consists mainly of *P. deltoides*, *P. nigra, P. trichocarpa* and, above all, their hybrids, *Populus x canadensis* (*P. nigra x P. deltoides*) and *Populus* x *generosa* (*P. deltoides* x *P. trichocarpa*), which are able to assure the required high quality. The main species of *Salix* used for wood plantations are *S. alba*, *S. fragilis*, *S. babylonica*, *S. humboldtiana* and various hybrids among them. Other species of *Salicaceae* are used in short-rotations for bio-energy production, bio-remediation or ornamental purposes.
Production requires obviously proper forest management, due to the fact that high wood quality is the major objective of the cultivation. The forest is therefore mostly represented by coetaneous, monoclonal plantations, which may be more easily subjected to attacks by parasites. These parasites become dangerous since all the plants are in the same development phase at the same moment, and moreover they are all genetically sensitive to an equal extent. In these plantations devoted to the production of wood for more profitable uses. e.g. plywood, the incidence of damages caused by different adversities must be kept well below that of natural forests. Bark cankers, that can highly decrease the plant value by making it unsuitable for the most profitable uses, are a typical example.
In this paper we briefly describe the most serious diseases affecting poplar and willow plantations (mainly for wood production) and their most important control strategies (Anonymous, 1981; Cellerino *et al.*,1987; Cellerino, 1999). The evolution of pathological problems (Cellerino, 1986; Anselmi, 1991) and the impact of genetic improvement in Italian poplar plantations are also presented.

MAIN DISEASES

Tables 1 and 2 report viral, bacterial and fungal pathogens, having a certain interest for their potential to cause losses in poplar and willow plantations. Abiotic diseases such as damages by cold, wind and drought stresses are also reported. Some diseases are strictly specific (e.g. attack by leaf pathogens, damages by cold), others interest several species or clones, often both of poplars and willows. Many of these last diseases (root rots, bark necrosis) are caused by opportunistic parasites, usually named "weakness pathogens", that attack only

----

(*) From Anselmi, Mazzaglia and Giorcelli, 2006, modified.

plants under stress or damaged by other adversities and therefore already showing a reduced vitality.

VIRUS

Only one virus is really dangerous on Salicaceae: the poplar mosaic virus (PMV) that attacks poplar, especially in temperate regions. Mainly *P. deltoides* type clones (‘Lux’, ‘Harvard’, ‘Onda’, ‘San Martino’, “Marguette”, AFO 058, Peoria 5, etc.) are susceptible and therefore PMV limits their distribution. It has been reported that all the plants of these clones are infected even when symptomless (Castellani, 1964; Anselmi et al., 1987).

BACTERIA

Bacterial cankers by *Xanthomonas populi*, are particularly dangerous in Central Europe and in North America (Ridé, 1993). *Erwinia salicis* attacks willow particularly in the Countries of Central Europe (Kam, 1984). Less damages are caused by *Pseudomonas*, *Xanthomonas campestris* (Giorcelli *et al*., 1992) and by *Agrobacterium tumefaciens*.

FUNGI

Root Rots and wood decay. Root rots caused by *Rosellinia*, particularly *R. necatrix*, are usually endemic in most of the Countries and attack both poplar and willow. About 8 ‰ of the poplar wood production is lost due to their attacks (Anselmi and Giorcelli, 1990). In the last years, this pathogen has increased because the trees were predisposed to dieback by drought. *Armillaria* attacks, mainly by *A. mellea*, are sometime present in clay soils and/or on the oldest trees. On old poplar and willow trees, particularly in the shaded plantations, root decay by *Ganoderma* spp. is also frequent. Affected plants may also be damaged by trunk wood decays (i.e. by *Phellinus*, *Stereum*, *Trametes*, etc.), particularly in urban plantations due to severe pruning. The incidence of root decays may increase in short rotation plantations due to the wide and repeated cuts at the collar of the plants (Anselmi and Cellerino, 1984).

Bark cankers and necrosis. Bark necrosis by *Discosporium populeum* (=*Dothichiza populea,* anamorph of *Cryptodiaporthe populea*) on poplar, by *Discella carbonacea* on willow, by *Cytospora* spp. and *Phomopsis* spp. both on poplar and willow are frequent after transplanting, particularly if the young plant suffered by dehydration or bad planting techniques. On mature plantations, during the last years, both bark necrosis by *Discosporium populeum* and brown spot of the trunk (trunk scab), of uncertain origin, increased considerably in several European (Anselmi, 1979a) and American Countries, including Argentina(Anselmi *et al*., 1996). The above-mentioned dieback of poplars induced by drought has caused considerable increase of bark necrosis. As a consequence, clones such as ‘Luisa Avanzo’, ‘Cima’, ‘Bellini’ and ‘Guardi’, very resistant against other diseases and with excellent growth and wood quality, are disappearing in Europe due to their susceptibility to the disease. Also clones considered resistant to trunk scab, such as ‘1-214’, now show severe symptoms of bark necrosis. Trunk scab was detected also in willow plantations.

Entoleuca mammata (=*Hypoxylon mammatum*) attacks, in Europe (Manion and Griffin, 1986; Pinon, 1986; Falk *et al*., 1989), the native species *Populus tremula* (especially its mountain race) and, in North America (Anderson *et al.,* 1979) , *P. tremuloides*, which has also been introduced into Europe as such and in hybrid form. *P. grandidentata* is less affected. The main species at risk in Europe is the commercially exploited *P. tremuloides* (*P. tremula* mainly grows as a wild species, especially in mountain areas).

Schizopara corneolutea is an important canker disease of *Salix nigra* in Argentina(Delta region).

Diseases of stem and leaves. Most of them are caused by *Mycosphaerella populorum* on poplar (Ostry, 1987). This pathogen is spread in North America and in Argentina. It can infect all US native species of *Populus*, although there are large variations in susceptibility to the fungus. It is most important for exotic poplars and for their hybrids with *P. balsamifera*, *P. deltoides*, *P. nigra* and *P. trichocarpa*. Resistance has been reported in *P. alba*, *P. canescens* and *P. nigra* var. *italica*.

Tab. 1. Main poplar diseases, economic importance and control.

PART OF TREE	DISEASE				CONTROL		
	DISEASE	PATHOGENS	GEOGRAPHIC RANGE	ECONOMIC IMPORTANCE	GENETIC	CHEMICAL	SELVICOLTURAL
ROOTS	**Root rots**	***Armillaria mellea***	Ubiquitous	-			+ + +
		Rosellinia necatrix	Ubiquitous	+		-	+ + +
STEM AND BRANCHES	**Trunk scab**	**Uncertain**	Europe, America	+	+		+ + +
	Bark necroses	***Discosporium populeum***	Eur., America, Asia	+	+		+ + +
		Cytospora chrysosperma	South Eur., Asia	-	-		+ + +
		***Phomopsis* spp.**	Africa, North Amer.	-	-		+ + +
	Aspen canker	***Entoleuca mammata***	Eur., Asia	-	+ +		+ +
	Septoriosis	***Septoria musiva***	America	+ +	+ + +		+
	Bacterial canker	***Xanthomonas populi***	Centr. Eur.	+	+ + +		+
LEAVES AND SHOOTS	**Leaf spots**	***Marssonnina brunnea***	Eur., Asia, New Zealand	++ +	+ + +	+ +	+
		***Marssonina* spp.**	widespread	+	+ + +	-	+
	Rust	***Melampsora medusae***	France, Spain, Amer., Austr.	+ +	+ + +	+	-
		Mel. larici-populina	Eur., Amer., Austr., South Afr.	+	+ + +	+	-
		Mel. Allii-populina	South Europe, Asia Minor, East Asia	-	+++	+	-
		***Melampsora* spp.**	widespread	-	+ + +	-	-
	Spring defoliation	***Venturia populina***	Eur., Asia, North Amer.	+	+ + +		
		Venturia tremulae	Eur., Asia, North Amer.	-	+ + +		
VARIOUS	**Virus diseases**	**Poplar Mosaic Virus**	Eur., North Amer.	-	+ + +		+
	Cold			-	+++		+
	Wind			-	+++		+
	Drought			+	++		+++

Tab. 2. Main willow diseases, economic importance and control.

PART OF TREE	DISEASE				CONTROL		
	DISEASE	PATHOGENS	GEOGRAPHIC RANGE	ECONOMIC IMPORTANCE	GENETIC	CHEMICAL	SELVICOLTURAL
ROOTS	**Root rots**	***Armillaria mellea***	Ubiquitous	-			+ + +
		***Rosellinia* spp.**	Ubiquitous	+		-	+ + +
STEM AND BRANCHES	**Trunk scab**	**Uncertain**	South Europe	+ +	+		+ + +
	Bark necroses	***Discella carbonacea***	Eur., America, Asia	+	+	?	+ + +
		Cytospora , Phomopsis	Eur., America, Asia	+			+ + +
	Black canker	***Glomerella miyabeana***	Europe, North America, Asia	+	+		+
	Water mark	***Erwinia salicis***	Central Europe	+	+		+
	Wilt disease	***Pseudomonas* spp.**	North America	-	+		-
	Willow scab	***Venturia chlorospora***	Europe, North America	+	+ +		+
	Trunk canker	***Schizopara corneolutea***	Argentina	+	+++		+
LEAVES AND SHOOTS	**Leaf spots**	***Marssonnina salicicola***	Africa, Eur., South Am.,	+ +	+ + +		+
		MarssoninaKriegeriana	Oceania	+	+ +		+
		Sphaceloma murrayae	Europe, America	-	+		+
		Gloeosporium salicis	Europe, America, Oceania	+ +	+ + +	+	+
	Tar spots	***Rhytisma salicinum***	Europe, America, Oceania	- -	+		
	Powdery mildew	***Uncinula salicis***	Europe, Asia, America	-	+		
	Rusts	***Melampsora* spp.**	Europe, Asia, America widespread	+	+ + +	+	-
VARIOUS	**Cold**			--	+++		+
	Wind			-	+++		++
	Drought			+	++		+++

In North America, *M. populorum* causes only leaf spot symptoms on native species with no damege on the wood production. However, it causes severe cankering and dieback on exotics and hybrids and has resulted in extensive losses in hybrid *Populus* plantings. Although trees of all ages are susceptible, the canker stage is restricted to the bark on younger stems and branches. Serious damages are reported in Argentina (e.i. on clone "I – 214").

Diseases of shoot and leaves. Spring defoliation by *Venturia* species and, specifically on willow, anthracnose by *Marssonina salicicola* and *M. kriegerian* are the most important diseases of this group. On susceptible clones, *Venturia* causes severe damages both on poplar, mainly *V. Populina,* teleomorph of *Pollaccia elegans* (Giorcelli and Vietto, 1990), and, in lesser extent, *V. tremulae*, and on willow (*V. Saliciperda,* teleomorph of *Fusicladium saliciperdum*). It causes withering of the leaves and shoots in early spring, often with complete defoliation. *Marssonina salicicola* causes anthracnose on *Salix* and it is widespread in Europe and America, including Argentina. Little spots on leaves and small cankers on the youngest branches, causing early defoliation, withering of the shoots and weakening of the tree, are the specific symptoms . The fungus attacks particularly *S. Babylonica*. Some clones of *S. alba* and *S. fragilis* and their hybrids with *S. Babylonica*, interesting for their wood production, are also susceptible (Anselmi, 1979b).

Leaf diseases. The most important are caused by *Marssonina* (*M. brunnea*, *M. populi-nigrae* and *M. castagnei*) on poplar (Cellerino, 1979), *Gloeosporium salicis* on willow, and by *Melampsora* spp. on both hosts. *Marssonina brunnea* (anamorph of *Drepanopeziza* *punctiformis)*, causes serious damage on poplar cultivations in Europe, North America and in Australia in spite of the great reduction of susceptible clones. The early defoliation induced by the pathogen predisposes the plant to attacks of weakness parasites and trunk scab, with very high economical losses. Chemical treatments, very frequent in Italy before 1980, are rare today because of costs and environmental considerations (Boccone *et al*., 1984).

Damages similar to those of *M. brunnea* are caused by *Gloeosporium salicis* on willow, in Europe and America. *Salix babylonica* and its hybrids, *S. nigra* and *S. humboldtiana* are particularly susceptible, whilst the Asiatic species (e.g. *S. dolicostyla*, *S. koreensis*, *S. tetrasperma*, *S. jessoensis*, etc.) show high resistance. In the *S. alba* clones a great variability is reported (Anselmi, 1977).

On susceptible clones, *Melampsora* spp. induces severe damage causing defoliation and, as a consequence, significant dieback occurs, followed by attacks of weakness parasites (Giorcelli and Vietto, 1995) that occasionally lead to the death of trees.

The most important *Melampsora* species on cultivated poplar are *M. larici populina*, *M. allii-populina* and *M. medusae*. *M. medusae* is indigenous to North America and has spread from there to other continents, including South America (Cortizo, 2003; May de Mio *et al.*, 2004).

However, its behaviour in Europe (Belgium, France, Portugal and Spain) is obscure. *M. larici-populina* is present in Europe, East Asia, America and Australia, while *M. allii-populina* is reported in South Europe, Asia Minor and East Asia. After 1980, in Europe (Pinon, 1992; Cellerino, 1999; Uluer *et al.*, 2004), new races *of M. larici-populina* (E1, E2, E3 and E4) caused severe damages on several poplar clones. In nurseries Giorcelli and Vietto (1995) showed that the early defoliation induced by the pathogen predisposes the plant to attacks of *D. Populeum* (weakness parasites), with high economical losses. Numerous other *Melampsora* of lesser economic importance are reported on poplar (Anselmi and Cellerino, 1978a; Anselmi, 1996; Spiers, 1998), for example *M. magnusiana, M. pinitorqua* and *M. rostrupii* on *Populus alba*, wood species with increasing interest for biomass, and *M. ciliata* on *Populus ciliata* (Pandey and Khan,1992; Vannini *et al*.,1995) particularly widespread in Asia.

Among *Melampsora* species on willow, the most important are *M. salicis albae* and *M. allii-fragilis*, spreading in Europe (Bennett *et* al., 2004; Anselmi and Cellerino, 1978a-b), and Asia, and, moreover, *M. epitea*, present also in America. Leaf necrosis by *Alternaria alternata* in Argentina (Merlo *et al*., 1992) and in Cina and by *Rhizoctonia solani* in India (Mehrotra, 1992) are two examples of minor poplar diseases.

ABIOTIC DISEASES

Several kinds of damages are caused by abiotic factors, mainly cold, wind and drought stresses.

Frost damages. Cold injuries are dangerous particularly on poplars cultivated out of their ecological area. Frost damages are frequent, for example, on clones of *Populus deltoides* originating from 33° and 36° parallel of United States when cultivated out the 43°-45° parallel (Cellerino, 1976).

Wind. Mainly some *P. deltoids* from southern origin (e.g. clone 'Lux', 'Harward', 'Onda', etc.) suffer from this disease.

Drought. The prolonged drought that characterized several years of the last decade (probably connected to the climatic Global Change) in the Mediterranean regions induced dangerous, early defoliation, often interacting with attacks of *Marssonina* and *Melampsora*. As a consequence, a dramatic weakening of the trees occurred with dieback which predisposed them to the attack of root rot and above all bark necrosis agents. Many of these latter fungal agents show a long endophytic phase in healthy tissues (Nasini *et al*., 2004). They often result in the death of the trees (Anselmi and Giorcelli, 1987; Anselmi, 1990). This decline involved mainly mature poplar plantations of *P. x euramericana*. The *P. deltoides* clones proved to be more resistant. In any case, dead knots, bark necrosis, breaking of trees by the wind, and fungal decay lead to heavy economical damages due to qualitative degradation of the wood (Anselmi, 1990).

DAMAGES

The importance of damages induced by different diseases obviously changes according to the purpose of the poplar and willow cultivations **(Tab. 3).** In the case of wood production,

particularly when high quality is required, economic losses are mainly induced by root rots or epidemic leaf diseases, causing a decrease in production quantity, and by bark cankers, decreasing the wood quality.
Leaf and root pathogens also induce high damages on plantations destined to phyto-remediation or bio-energy. Short-term rotation plantations are subjected also to root rots and stump decays since the trees are predisposed to these diseases by repeated cuts at their collars. In this kind of cultivations also the sooty mould attacks (and those of the predisposing phyllomyzous insects: *Tingidae, Aphididae*) could increase due to a greater foliage development that generate shade and limit air circulation in the crown (Anselmi *et al*., 2002).
Finally, the most important damages on the ornamental plantations are caused by leaf diseases, because of the aesthetic alterations of the crown, by root rots inducing the death of the plants, and by wood decays (predisposed by trunk wounds or big cuts from severe pruning), causing dangerous breaking of branches or sudden falls of the trees.
The prolonged drought of the last decades increased weakness diseases resulting in root (*Rosellinia, Armillaria*) or bark (trunk scab, necrosis by *Discosporium, Cytospora*, *Phomopsis*, *Discella*) attacks, but, on the other side, it reduced the incidence of those pathogens characterised by rain spreading of their inoculum, such as *Marssonina*, *Gloeosporium*, etc.

Tab. 3. Damages by various diseases on poplar and willow plantations related to the different cultivation aims.

DISEASE	DAMAGES			
	WOOD PRODUCTION	SHORT-ROTATION FOR BIO-ENERGY	BIO-REMEDIATION	ORNAMENTAL TREES
Epidemic leaf diseases **Sooty moulds**	+ + + - -	+ + + +	+ + +	+ + - -
Bark necrosis **Trunk scab**	+ + + + +	+ - -	+ - -	+ -
Root rots by *Rosellinia* **Root rots by *Armillaria*** **Root rots by *Ganoderma***	+ - - - -	+ + + - -	+ + + - -	- + + + +
Trunk wood decay **Stump wood decay**	- -	- +	- ?	+ + +

CONTROL STRATEGY

The control of the above mentioned diseases is based on: research and use of resistant species, varieties or clones; use of healthy propagation material; phytosanitary selection during the growing period in the nursery; suitable cultivation practices; biological control and, sometimes, chemical treatments (Tabb. 1 and 2).
The use of certificate healthy material is of fundamental importance to obtain plants free from various pathogens. This practice is particularly important when exchanging internationally vegetative material (seed, cuttings, etc.) and involves, first of all, quarantine strategies to prevent the risk of introduction of undesired pathogens in different countries. In the Mediterranean basin, the introduction of the following pathogens is to be particularly feared: *Septoria musiva* and *Melampsora medusae*,

dangerous parasites of poplar, which are both absent in the old continent, and *Erwinia* on willow.
These precautions also help reducing the passive spreading of existing parasites, particularly those that dwell in cortical tissues or in buds such as *Xanthomonas populi*, *Erwinia salicis* and some *Marssoninae* or *Venturiae*.
Frequent inspections help to eradicate diseased plants without considerable negative economical effects.
All the cultural practices which contribute, directly or indirectly, in reducing transplantation crises and allow a good growth of plants in the following development period can hinder the attacks by both cortical and root facultative fungi.
Attacks by *Discosporium populeum* can be controlled by the utilization of well lignified nursery material of tolerant clones with high rooting capacity, and by planting them in a well drained soil, with an adequate water supply.
Appropriate soil cultivation may contribute: (a) to improve soil aeration increasing the reaction of the root system against rotting agents (*Rosellinia*, *Armillaria*); (b) to enhance the resistance of plants to attacks by several weakness-parasites (*Discosporium*, *Cytospora*, *Phomopsis*); (c) to reduce the inoculum of the different leaf diseases, by burying infected leaves (*Marssoninae*. *Venturiae*) and to eliminate possible hosts of heteroecious fungi (*Melampsora*); (d) to restrain weed spreading and, consequently, their competition against young plants.
Sufficiently wide spacing, with larger soil volume available for the trees, reduces possible nutritional deficiencies and lowers the risks connected with trunk scab and cortical necrosis; moreover, by modifying the microclimate, it reduces the probability of attacks by some fungus parasites, in particular *Melampsora*, *Marssonina* and *Gloeosporium salicis*.
The natural biological protection from diseases, unfortunately, is scarcely important and gives aleatory results. Nevertheless, attempts to control poplar rusts have been made by spraying the poplar leaves with conidial suspension of *Sphaerellopsis filum, Ramularia uredinis*, and *Cladosporium* species (Cellerino, 1999; Nischwitz and Newcombe, 2004; Moricca *et al*., 2005).
Root rot agents are particularly important in the development phases following fast growing stand establishment. Soil cultural practices act in a similar way against *Rosellinia*, as indicated against several other pathogens in nurseries, especially as far as the drainage improvement is concerned. In cases of limited attacks the removal, or at least the isolation of healthy plants with ditches may be taken into consideration.
The epiphytic phase can be kept at a low level by waiting for 2 or 3 years between the felling of a stand and the establishment of a new one, as well as by keeping the new plantations at an adequate distance from susceptible arboreous crops.
A timely elimination of plants or of portions of plants to get rid of particularly dangerous diseases of infective etiology as is in the case of *Septoria*, *Entoleuca* and bacterial cankers on poplar, *Erwinia* bacteriosis on Salix, and other diseases of unknown origin, as in the case of "do Rio Roce" disease, may be recommended.
Finally, chemical control may be sometimes necessary to protect the production of particularly profitable forests as in the case of certain European poplar growing. Until the availability of resistant clones, a direct intervention, at least against *Marssonina*, will be required.
The above mentioned agronomic and biologic procedures reduce but do not eliminate the effects of adverse causes which may lead to negative consequences also during the following growth in the plantation stand. So, in order to keep the attacks below dangerous limits which, in some cases, must be extremely low, these procedures must be integrated with chemical control as, for example, on poplar in Europe against *Marssonina brunnea* and, with minor results, against *Gloeosporium salicis* on willow.

The use of chemical control varies according to the local conditions, to the resistance or susceptibility of single clones, and to the ecologic impact, as already well docuented for the widespread insect chemical control. The chemical products should be chosen among those which have low toxicity and persistence.

The resistance remains anyway the most important control strategy (Thielgs, 1985).

The production and use of material resistant to adverse causes, both biotic ones is of considerable importance, with special regards to fungi and bacteria, some aphides and mites (e.g. *Phloeomyzus passerinii* on poplar, *Gipsomonia salicis* on willow, etc.) and abiotic origin.

Resistant clones to some obligate parasites of Salicaceae have been already obtained from breeding. For example:

- the plant breeders have utilized the resistance characters of some *Populus deltoides* Bartr. to *Marssonina*, *Venturia*, *Melampsora populina, M. Larici- populina*, of some balsam poplars to PMV, *M. medusae*, and of some *Populus nigra* to PMV and to *Xanthomonas populi* (Tab.3). Moreover, where poplars of the Leuce Section are largely cultivated, breeders have exploited the resistance factors of some *P. alba* to *Venturiae* and to *Hypoxylon mammatum* and those of *P. tremulae* and *P. tremuloides* to *M. castagnei*;
- the resistance to both *Marssonina salicicola* of *Salix nigra*, *Salix* x *argentinensis* and of some East Asian species (*S. dolichostyla*, *S. jessoensis*, *S. lasiandra*, *S. matsudana*, *S. sachalinensis*), and to *Gloeosporium salicis* of several clones of *Salix alba*, *S. alba* ss. *Calva, S. alba* ss. *pyramidalis*, *S. alba* x *fragilis*, as well as of the above mentioned East Asian species, may also be used.

Screening of the resistance toward *Marssonina* and *Melampsora* according to the geographic origin of the population have been carried out for *P. deltoides* (Cellerino and Anselmi, 1982), *P.nigra* (Cellerino *et al*., 1986); *P. alba* (Avanzo *et al*., 1992).

Moreover breeding can influence the acquisition of a general tolerance towards facultative pathogens inhabiting branches, trunk and roots. Such tolerance, available for some cortical necrosis (e.g. *D. populeum* on poplar, *Cytospora* ssp. on poplar and willow, etc.) can be obtained also with respect to some damping off and root rotting agents which are dangerous in the juvenile development phase of the plantation.

Resistance to root and heart rot of plants in over-mature forests is almost unobtainable.

The combined susceptibility towards low temperatures in winter and the wind during the vegetative season of the Southern *P. deltoides*, which was introduced in Europe for its resistance to *Marssonina* and to other foliar diseases, may be considerably overcome by crossing it with local *P. nigra*.

In any case, it is important to emphasize that it is not necessary to find poplars that are absolutely resistant to the different diseases. On the contrary, it is necessary to search for clones with horizontal resistance, not completely resistant but tolerating the most important diseases and, consequently, more tough.

Therefore the new European clones are selected with the goal of improving a general tolerance to the most important abiotic factors and fungal diseases, which should allow suitable levels of production and low damage even in presence of significant pathological outbreaks. This strategy is presently preferred rather than pursue a resistance focused on a specific pathogen, not preventing a further pathogenic evolution of the same agent or the exposure to the possible occurrence of other impairing factors. Such phenomenon had occurred in last years with the rust pathogens, which are also dangerous in a perspective of improving biomass cultivations. In this connection a high tolerance should give rise to moderate attacks without significant leaf fall and consequently without significant reduction of the stump viability.

In a perspective of a feared climatic change, with possible long periods of drought, physio-pathological diseases (mainly brown spots of the stem) and weakness parasites (mainly *Discosporium populeum*) may increase their incidence. So, clonal selection should also consider the environmental fitness of the lines selected by the aforesaid criteria.
Recently, genetic engineering and other biotechnological approaches have been employed as a mean of circumventing some of the problems associated with genetic improvement in poplars. Micropropagation, selection of somatoclonal and gametoclonal variants, and protoplast fusion play an important role in these programs. Many of our espectations are deposited on this advanced technology!
A complete control of the various adverse causes is obviously impossible, even in man-made forests of fast growing species. Nevertheless, more positive results may come from integrated control strategies, improved biological and epidemiologic knowledge of parasites, deeper knowledge of climate conditions affecting the species of interest and, of course, of resistance factors.

EVOLUTION OF PATHOLOGICAL PROBLEMS AND THE IMPACT OF GENETIC IMPROVEMENT: THE EXAMPLE OF THE POPLAR IN ITALY (FIG.1)

In the beginning of the 20th century, the Italian poplar cultivation – founded particularly on some hybrids of *P. x euramericana* named inappropriately "Canadian" and of unknown origin - did not suffer from serious pathological problems.
During the twenties the spreading of an epidemic disease, the "spring defoliation" was reported. It was caused by *Pollaccia elegans* and severely attacked all the "Canadian" clones. The wood production loss reached 30-35%.
This disease prompted the first study on genetic improvement of poplar, particularly by Jacometti. In the beginning, the Istituto di Sperimentazione per la Pioppicoltura di Casale Monferrato produced new, very interesting clones, such as '1-214' (famous all over the world), 'I-455', 'I-262' and 'I-488'. They were all resistant to "spring defoliation" and to other important diseases.
With the spread of these clones, particularly the first one, during the period 1940-1963, there were no serious pathological problems in poplar plantations. The poplar areas cultivated in Italy increased considerably, exceeding 100,000 ha.

- A new, very important pathological problem appeared in 1963 (Castellani and Cellerino, 1964) through the sudden epidemic spread of *Marssonina brunnea,* the causal agent of the leaf spot disease. All the above-mentioned clones were susceptible to this disease. The damage ranged between 25 to 50 % passing from susceptible ('1-214') to very susceptible ('I-262', 'I-488', 'I-154') clones (Castellani, 1971).Luckely, chemical control (Cellerino, 1966) allowed favourable cultivation of the clone '1-214', but at high costs (Castellani and Prevosto, 1970).

A new effort in genetic improvement of poplar led to the creation of the following new clones (see tab. 4).

- At the end of the sixties, some *P. deltoides* clones were selected by Sekavin from the southern regions of the U.S.A., such as 'Lux', 'Harvard', 'Onda', 'San Martino'. They were all very resistant to *Marssonina*, to *Pollaccia* and to bark necrosis. Unfortunately, they were susceptible to wind and Poplar Mosaic Virus and have some difficulties in rooting.
- During the seventies, some clones such as 'Boccalari', 'Gattoni', 'Branagesi' and 'Saffa 302' were selected from old populations of "Canadian" by poplar farmers. However, they were susceptible to "spring defoliation".
- Toward the end of the seventies, Avanzo selected several *P x euramericana* clones such as 'Luisa Avanzo', 'Cima', 'Bellini', 'Guardi', etc., which were excellent for their

growth and their resistance to leaf diseases. Unfortunately, they showed a serious susceptibility to bark necrosis, both by *Discosporium populeum* (Anselmi, 1986) and trunk scab.

So, the problems arising with *Marssonina* still remained open. They were worsened by ecological problems associated with chemical control (Cellerino *et al*., 1986). The utilization of Maneb and Mancozeb for chemical control triggered a discussion on their environmental effects. Nevertheless, during the first part of the eighties, an apparent reduction of the pathological problems caused by *M. brunnea* on poplar seemed to take place due to the replacement of many hectares of the '1-214' clone by the above-mentioned new clones. But, with the increase of plantations of the above-mentioned clones, the attacks of bark necrosis and spring defoliation increased considerably. Furthermore in 1987 another problem appeared, involving a new race of *Melampsora larici-populina*, named E3 (Giorcelli *et al*., 1990). This race very seriously attacked several cultivated clones such as 'L. Avanzo' and 'Cima'. At present, rusts are to be considered a latent threat since the 'I-214' clone (tolerant) has become more and more prevalent during the last two decades.

The increase of phytopathological knowledge has led to the intensification of studies on the genetic improvement of poplar employing both traditional breeding and advanced technology. These studies are being carried out particularly at the Istituto di Sperimentazione per la Pioppicoltura di Casale Monferrato.

The main program of traditional genetic studies is still articulated on a cross between *P. deltoides* and *P. nigra.* There is already considerable information about several different origins of *P. deltoides*, both on wood production and disease resistance levels (Giordano, 1971; Avanzo, 1975; Cellerino, 1976). With regard to *P. ni*gra, although a systematic collection of different geographical originshas already been made, the knowledge of their behavior toward the diseases is limited (Bisoffi *et al*., 1987).

The development of the genetic program on Euramericana poplar in Italy has been based on a "Reciprocal Recurrent Selection" of the above mentioned two species for the improvement of their hybrids (Avanzo *et al*., 1985; Bisoffi, 1989).

First of all, the genotypes of the two species are crossed. The information obtained from the hybrid offspring is used the select the parents for successive intraspecific crosses. The best progeny in this second generation of the two species are used for a new cycle of interspecific crosses analogous to the previous cycle.

To evaluate the parents of the two species, the following methods were used:

- for females of *P. deltoides*, the "poly-cross" method in which each mother of the *P. deltoides* is fertilized by a pollen-mix of *P. nigra* males of different origins;
- for male *P.nigra*, the "common testers" method in which the pollen of each father of *P. nigra* fertilizes an identical group of 4 to 5 females of *P. deltoides*.

Since males of *P. deltoides* and females of *P. nigra* are not sexually compatible, the evaluation is made through intraspecific crosses.

The comparison of the different series of descending genotypes will be made in the nurseries following opportune plot designs and field tests for the statistical analysis of the results.

The analysis of disease resistance concerns essentially *Marssonina, Venturia*, *Melampsora* and *Discosporium*. This analysis will be made both on the descending genotypes for inter or intraspecific crosses and also on the parental population. The method of selection for the diseases is founded on the threshold level, establishing a resistance level for each disease and for each poplar ideo-type and with the rejection of the less resistant selections.

The latest group of selected clones (e.g. 'A4A', 'Brenta', 'Lambro', 'Mella', 'Soligo', 'Taro', 'Timavo', 'Patrizia Invernizzi', 'Ballottino') is the outcome of this selection trend: all the clones are tolerant to rust and are resistant to the other leaf diseases **(Tab. 4**). We have great expectations from these new numerous clones !

Tab. 4. Resistance behaviour to some adversities of European poplar clones of different genetic origin (Anselmi *et al.*,2006)

CLONE		ADVERSITY RESISTANCE							
Genetic origin	**Name**	**Drought**	**Wind**	**PMV**	***Venturia***	***Marssonina***	***Melampsora***	***Discosporium***	**Trunk scab**
P. alba	Villafranca	+	+	++	++	++	+	++	++
	Marte	+	+	++	+	+	+	++	++
	Saturno	+	+	++	+	+	+	++	++
P. nigra	Jean Pourtet	0	+	++	++	++	+	- -	- -
P. deltoides	Harvard	+	-	-	++	++	+	++	++
	Onda	+	-	- -	++	++	+	++	++
	Lux	+	-	- -	++	++	+	++	++
	Dvina	+	0	0	++	++	+	++	++
	Lena	0	-	0	++	++	+	++	++
	Alcinde	0	-	-	++	++	+	-	-
P. ×canadensis	I-262	0	0	++	++	- -	0	-	0
	I-214	0	0	++	++	- -	0	-	0
	Boccalari	0	+	+	-	-	-	-	0
	Adige	0	0	+	-	0	-	-	0
	Luisa Avanzo	-	++	++	0	+	-	-	-
	Cima	-	+	++	0	+	0	-	-
	Guardi	-	-	++	++	0	-	- -	- -
	Neva	0	-	++	- -	0	- -	0	0
	A4A	0	0	+	++	+	0	+	+
	Brenta	-	0	+	++	++	0	0	-
	Lambro	+	-	-	++	++	0	++	+
	Mella	-	+	+	++	++	0	0	-
	Soligo	+	-	-	++	++	++	++	++
	Taro	0	-	-	++	++	+	++	++
	Timavo	+	0	0	+	++	0	0	+
	Patrizia Invernizzi	0	0	+	+	+	0	0	+
	Ballottino	0	0	+	+	0	0	0	0
	Ghoy	0	+	-	++	+	+	++	++
	Koster	0	+	0	++	+	+	++	++
	Doorskamp	0	0	++	++	++	0	- -	- -
	Blanc du Poitou	0	0	+	+	-	-	-	-
P. ×generosa	Beaupré	0	-	+	++	+	-	++	++
	Hazendans	0	?	++	++	+	+	+	
	Hoogvorst	0	?	++	++	+	+	+	
	Raspalje	0	0	++	++	0	0	++	++
P. deltoides × *P. maximowiczii*	Eridano	++	- -	++	++	++	++	++	++

++ = resistant; + = poorly resistant; 0 = tolerant; - = poorly susceptible; - - = susceptible

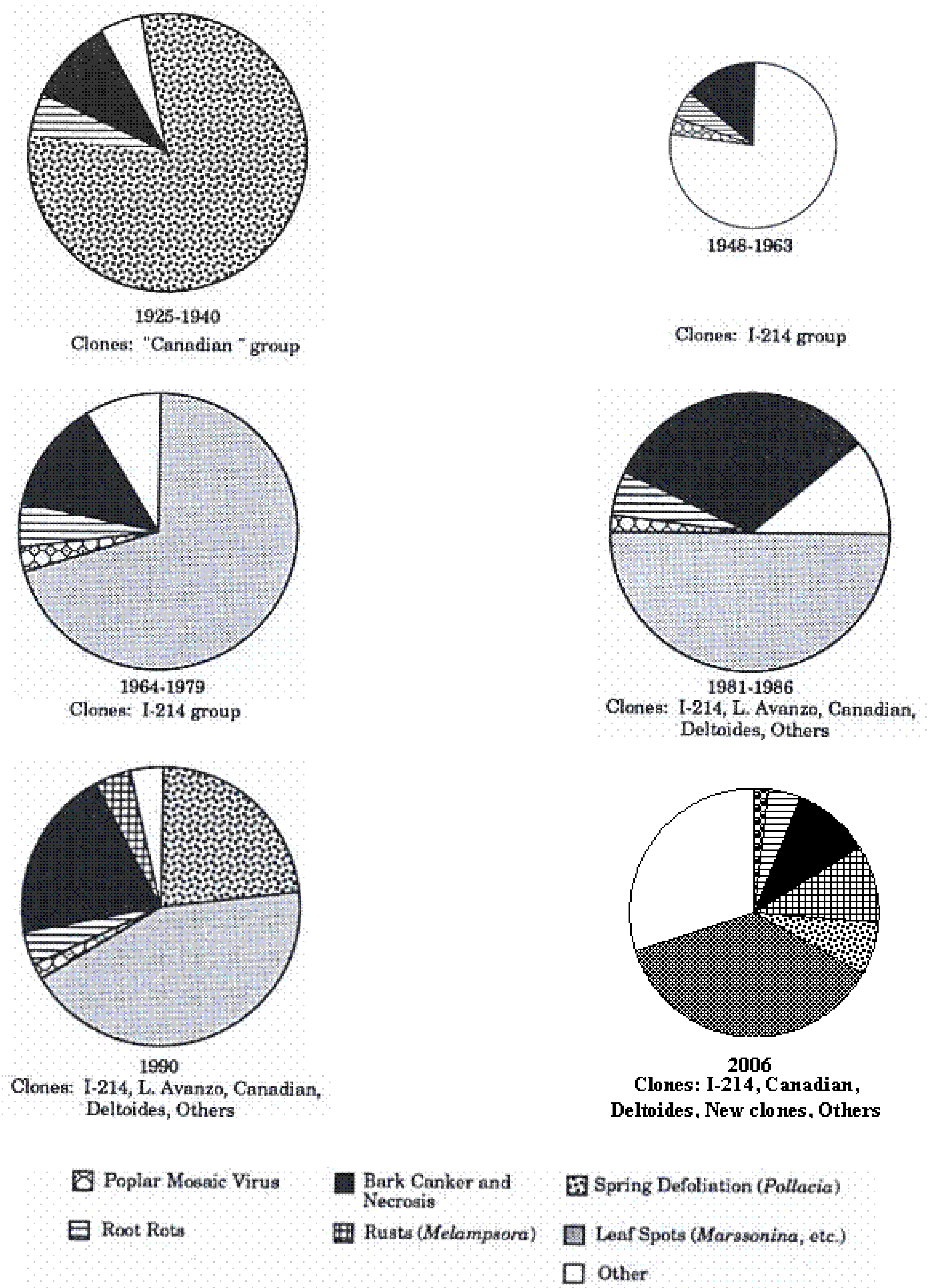

Figure 1: Importance of different diseases in poplar plantations in Italy (in proportion to 1990).

ACKNOWLEDGEMENTS
The work was sustained by the grants ex-60% from Ministero dell'Università e della Ricerca (MiUR).

REFERENCES

- Anderson N.A., Ostry M.E., Anderson G.W., 1979. Insect wounds as infection sites for *Hypoxylon mammatum* on trembling aspen. Phytopathology, 69, 476-503.
- Anonymous, 1981. Les maladies des peupliers. Groupe de Travail des Maladies de la C.I.P. Association Forët-Cellulose: Champagne sur Seine, 199 pp.
- Anselmi N., 1977. Gleosporiosi del salice. Cellulosa e Carta, 28, 6, 19-39.
- Anselmi N., 1979a. Malattia delle "macchie brune" del pioppo. Inf.tore Agr., 35, 36, 7275-7278.
- Anselmi N., 1979b. La bronzatura del Salice da *Marssonina salicicola* (Bres.) Magn. Cellulosa e Carta, 30, 3, 3-19.
- Anselmi, N. 1986. Resurgence of *Dothichiza populea* Sacc. et Briard in Italy. Eppo Bull. 16, 571-583.
- Anselmi N. 1990. Wood deterioration in poplars following decline after water stress. Eur. J. For. Path., 20, 321-328.
- Anselmi N., 1991. Pathological problems in poplar plantations in Italy. In: Proc. International Energy Agency Meetings, Ames, (USA), 22-27 August, 10-18.
- Anselmi N., 1996. Poplar diseases situation in Southern Africa. Proceed. 20th Session Intern. Poplar Commission "Environmental and Social Issues in Poplar and Willow Cultivation and Utilization". Budapest, 1-4 Ottobre, Vol. 1, 99-103.
- Anselmi N., Arreghini R., Lucero H, Calderon A., 1996. La "Mancha Parda" de alamo su precencia en Mendoza, Argentina. Revista de la Facultad de Ciencias Agrarias, U.N.Cuyo, Mendoza, Tomo 28, 2, 71-77.
- Anselmi N., Cellerino G.P., 1978a. On the main *Melampsorae* of *Salicaceae* in Italy. XX Sess. FAO/IPC/DIS/78/1-3, Vienna 28-31 August, 7 pp.
- Anselmi N., Cellerino G.P., 1978b. Malattie del Salice in Italia (Willow diseases in Italy). Cellulosa e Carta, 29, 9, 3-13.
- Anselmi N., Cellerino G.P., 1984. Influence de la conduite en taillis du peuplier sur la mycoflore de la rhizosphère. XVII Session FO:CIP, Ottawa, 30 Septembre-4 Octobre, XXIII Réunion FAO/CIP/MAL, 10 pp.
- Anselmi N., Giorcelli A., 1987. Gravi deperimenti del pioppo nell'Italia Settentrionale (Serious poplar decline in Northern Italy), In: Proceed. "Conv. Avv. bosco e spec. Arb. legno". Firenze, 369-390
- Anselmi N., Giorcelli A., 1990. Marciumi radicali del pioppo da *Rosellinia necatrix* Prill. (Root rots in poplars by *Rosellinia necatrix* Prill.). Inf. tore fitopat., 1, 45-52.
- Anselmi N., Luisoni E., Roggero P., Giorcelli A., 1987. Damages caused by Poplar Mosaic Virus (PMV) in mediterranea Countries and control strategies. Proc. VII Congres of the Mediterranean Phitopathological Union. Granata, 34-35.
- Anselmi N., Mazzaglia A., Giorcelli, 2006. Disease Of Salicaceae. *Salicaceae* Symposium, Buenos Aires, Argentina, 27-30 September, 14pp.
- Anselmi N, Mazzaglia A., Nasini M., Falessi T., Vannini A., Giorcelli A., Scarascia Mugnozza G., De Angelis P., Sabatti M., 2002. The influence of the atmospheric carbon dioxide increase on poplar pathogens attacks. Proceed. International Poplar Symposium III on "Basic and Applied Aspects of Poplar and Willow biology, Uppsala, Sweden, August 26-29, 136.

- Avanzo E., 1975. Considération ultérieures sur la variabilité des surfaces terriers entre 64 families de Populus deltoides Bartr., In: la sixième année de plantation. 15éme Sess. C.I.P. FO/CIP/75/17, 1-17.
- Avanzo E., Anselmi N., Cellerino G.P., Sabatti M., Scarascia Mugnozza G., 1992. Natural populations of *Populus alba* in Italy: Sampling strategy and preliminary observations on growth habits, cold and rust susceptibilty (Summary). Proceedings 19th Session of the International Poplar Commission. Zaragoza, 22-25 Settembre, Vol. 1, 557.
- Avanzo E., Bisoffi S., Gras M. A., Mughini G., 1985. Strategie di miglioramento genetico dei pioppi appartenenti alla serie Aigeros adottato in Italia (Breeding strategies for "Aigeros" poplars adopted in Italy). Genetica Agraria, 39,308-311.
- Bennett C., Newcombe G., Aime C., 2004. Host-range studies of *Melampsora* on *Salix* in the pacific northwest region of the United States. Proceed. 22nd Session International Poplar Commission "The contribution of poplars and willows to sustainable forestry and rural development", Chile – Argentina, 28th Nov. – 9th Dec., FAO ID 47, p.161.
- Bisoffi S., 1989. Recent developments of poplar breeding in Italy, pp 18-45. In: Proc. Meet. IUFRO Working party 52.02.10 Hann. Munden, Germany.
- Bisoffi, S., G. Gemignani, M. A. Gros, S. May, and G. Mughini. 1987. Establishment of *Populus nigra* genetic reserves in Italy. Genetica Agraria, XXXIX: 105-114.
- Boccone A., Anselmi N., Cellerino G.P., 1984. Su alcuni effetti collaterali connessi alla lotta antimarssonina in pioppeti adulti con particolare riferimento alla copertura anticrittogamica ed alla deriva. Atti del Convegno sui "Trattamenti antiparassitari con mezzi aerei si colture agrarie". Padova, 20 Gennaio. Padova Economica, rivista della Camera di Commercio di Padova, I trimestre, 22-28.
- Castellani E., 1964. Report on two little-known poplar diseases, pp 89-96. In: Gerhold, H.D. Breeding Pest-Resistant Trees. Pergamon Press.
- Castellani E., 1971. Problemi posti alla pioppicoltura dalla *Marssonina brunnea* e soluzioni attuate. Acc. Agric. Torino, 1-16.
- Castellani E, Cellerino G.P., 1964. Una pericolosa malattia dei pioppi euramericani determinata da *Marssonina brunnea* (Ell. et Ev) P. Magn., Cellulosa e Carta, 15, 8, 3-17.
- Castellani E., Prevosto M., 1970. Effetti della ricerca sulla diffusione e sulle rese economiche della coltura del pioppo. (Effects of research on the economy of poplar culture), Cellulosa e Carta, 3, 54-62.
- Cellerino G. P. 1966. Prove di lotta contro la *Marssonina brunnea* del pioppo, Cellulosa e Carta, 17, 4, 13-28.
- Cellerino G.P., 1976. Reaction of 52 families of *Populus deltoides* to several diseases and to cold in Northern Italy. Proc. Cottonwood Symp., Greenville, Mississippi(USA), 205-213.
- Cellerino G.P., 1979. Le *Marssoninae* dei pioppi. Cellulosa e Carta, 2, 3-23.
- Cellerino, G.P., 1986. Evoluzione delle malattie del pioppo in Italia e strategie di lotta. Ann. Acc. Agric. Torino 128: 1-14.
- Cellerino G. P., 1999. Review of fungal diseases in Poplar. Food And Agriculture Organization Of The United Nations, Rome.
- Cellerino G.P., Anselmi N., 1982. On the susceptibility to *Marssonina brunnea*, *Melampsora allii-populina* and *Venturia populina* of *Populus deltoides* from Oklaoma. Proceedings FO:IPC:D/82/18, XXII Sess. FAO/IPC/DIS Casale Monferrato, 9 pp.
- Cellerino G.P., Anselmi N., Belisario A., 1987. On the main infections diseases of the poplar, willow and Eucalyptus and on control strategies in the Mediterranean area. Simposio "Silvicoltura y mejoramento genetico de especies forestales". Buenos Aires, 6-10 Aprile, Vol. 2, 175-189.

- Cellerino G.P., Anselmi N., Bisoffi S., Giorcelli A., Belisario A., 1986. Behaviour of *Populus nigra* from various sources toward *Melampsora allii-populina* and *Melampsora larici-populina*. XXIV Session FAO/CIP/DIS. Bordeaux 22-24 Settembre, 28 pp.
- Cortizo, S., 2003. Royas en álamos. Alternativas de control a mediano y largo plazo. Actas de las Jornadas XVIII Forestales de Entre Ríos. E.E.A. Concordia. (ISBN 1667-9253): 7 pp.
- Falk S.P., Griffin D.H., Manion P.D., 1989. *Hypoxylon* canker incidence and mortality in naturally occurring aspen clones. Plant Disease, **73**, 394-397.
- Giorcelli A., Vietto L., 1990. La defogliazione primaverile del pioppo in Italia (The spring defoliation of poplar in Italy). Inf. tore Agrario, 35:571- 578.
- Giorcelli A., Vietto L., 1995. Influenza delle defogliazioni indotte da *Melampsora* spp. sulla suscettibilità del pioppo a *Discosporium populeum* (Sacc.) Sutton. Convegno annuale SIPaV, Viterbo.
- Giorcelli A., Vietto L., Anselmi N., 1990. Distribution of *Melampsora larici-populina* Kleb and *Melampsora allii populina* and their physiological races in Italy, In: Proceed. 8th Congress Medit. Phytopath. Union, Morocco, 107-109.,.
- Giorcelli A., Vietto L., Anselmi N., 1992. *Xanthomonas campestris* pv. *Populi* in Italy. Proc. 19th session of the Intern. Poplar Commission. Zaragoza 22-25 September. ,Vol. I, 273-281.
- Giordano, E. 1971. Observations préliminaires sur les provenances de *Populus deltoides* Bartr. de 1'Oklahoma en Italie. 14eme Sess C I PFO/CIP/7V22.
- Kam M.de, 1984. Determination of susceptibility of willows to Watermark diseases: problems and prospects. Nederlands Bosbouwtijdschrift, 56, 1, 22-26.
- Manion, P.D.; Griffin, D.H., 1986. Sixty-five years of research on *Hypoxylon* canker of aspen. Plant Disease, 70, 803-805.
- May de Mio L.L., Amorim L., Moreira L.M., 2004. Progress of epidemics and evaluation of damage caused by rust in poplar clones. Proceed. 22nd Session International Poplar Commission “The contribution of poplars and willows to sustainable forestry and rural development”, Chile – Argentina, 28th Nov. – 9th Dec., FAO ID 20, p.164.
- Mehrotra M.D.,1992. *Rhizoctonia* leaf Web Bligh, a destructive disease of *Populus deltoids* in India and its Management. Proc. 19th session of the Intern. Poplar Commission. Zaragoza 22-25 September. Vol. I, 259-264.
- Merlo P.A., Carranza M.R., Aprea A.M.,1992 Alternariosis del álamo - Proc. 19th session of the Intern. Poplar Commission. Zaragoza 22-25 September. ,Vol. I, 231-235.
- Moricca S., Ragazzi A., Assante G., 2005. Biocontrol of Rust Fungi by *Cladosporium tenuissimum*. In: “Rust diseases of Willow and Poplar”, Chap. 19, CABI Press.
- Nasini M., Mazzaglia A., Giorcelli A., Anselmi N., 2004. Endophytic fungi in poplar trees. Proceed. 22nd Session International Poplar Commission “The contribution of poplars and willows to sustainable forestry and rural development”, Chile – Argentina, 28th Nov. – 9th Dec., FAO ID 167, p.165.
- Nischwitz C., Newcombe G., 2004. The use of *Sphaerellopsis filum* for biological control of *Melampsora* species on *Populus* species. Proceed. 22nd Session International Poplar Commission “The contribution of poplars and willows to sustainable forestry and rural development”, Chile – Argentina, 28th Nov. – 9th Dec., FAO ID 29, p.167.
- Ostry, M.E., 1987. Biology of *Septoria musiva* and *Marssonina brunnea* in hybrid *Populus* plantations and control of *Septoria* canker in nurseries. European Journal of Forest Pathology, 17, 158-165.

- Pandey P.C.,Khan S.N., 1992. Disease status of poplars in India. Proc. 19th session of the Intern. Poplar Commission. Zaragoza 22-25 September., Vol. I, 252-258.
- Pinon J., 1986. Situation d'*Hypoxylon mammatum* en Europe. Bulletin OEPP/EPPO Bulletin**,** 6, 543-546.
- Pinon J., 1992. Poplar rusts :variability and populations in France. Proc. 19th session of the Intern. Poplar Commission. Zaragoza 22-25 September. Vol. I, 211-222.
- Ridé M., 1993. *Xanthomonas populi* : cause of bacterial canker of poplar. in *Xanthomonas*, edited by J.G. Swings and E.L. Civerolo. Published by Chapman & Hall, London.
- Spiers A.G., 1998. *Melampsora* and *Marssonina* pathogens of poplars and willows in New Zealand. Eur. J. For. Path. 28: 233-240.
- Thielgs B.A.,1985. Breeding poplar for disease resistance. FAO, Forestry paper n° 56, 66pp.
- Uluer K., Özay F.S., Selek F., 2004. Investigation of the resistance of some poplar clones to the rust fungi *Melampsora alli-populina* Kleb. in Turkey. Proceed. 22nd Session International Poplar Commission "The contribution of poplars and willows to sustainable forestry and rural development", Chile – Argentina, 28th Nov. – 9th Dec., FAO ID 12, p.168.
- Vannini A., Cecca D., Monaci L., Anselmi N., 1995. Main tree pathogens of western Himalayan forest in Nepal: description and risks of introduction, EPPO Bullettin, 25, 1-7.