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Introduction

The International Poplar Commission (IPC), founded in 1947, is a statutory body of the Food and Agriculture Organization of the United Nations (FAO). The functions of the IPC are to: (i) study the scientific, technical, social and economic aspects of poplar and willow cultivation; (ii) promote the exchange of ideas and material between research workers, producers and users; (iii) arrange joint research programs; (iv) stimulate the organization of congresses, meetings and study tours; (v) report and make recommendations to the Conference of FAO through the Director General of FAO; and (vi) make recommendations to National Poplar Commissions through the Director General of FAO and the Governments concerned. At present there are 37 member countries of the IPC, of which 14 are developing countries and five are countries with economies in transition.

IPC Sessions are held every four years. The previous meeting was in Budapest, Hungary in 1996. Five Working Parties as subsidiary bodies of the IPC reflect the main issues concerning the cultivation and utilization of the Salicaceae including (i) Poplar and Willow Genetics, Conservation and Improvement; (ii) Poplar and Willow Diseases; (iii) Poplar and Willow Insect and Animal Pests; (iv) Production Systems and Environmental Applications for Poplars and Willows; and (v) Logging and Utilization of Poplar and Willow Wood. There is also a Sub-committee on Poplar and Willow Nomenclature and Registration.

This report includes submitted abstracts to the meeting organizers including invited papers, oral presentations, and visual presentations (posters). They are listed here in alphabetical order by senior author's last name (from A to Z).

Evaluation and genetic identification of some Populus *species by using polyacrylamide elelectrophoresis separation of total soluble proteins*

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From 1990 to 1992 field surveys of poplar stand trees were conducted to select the mother trees of different poplar species for reproduction. For *Populus alba,* the mother tree was located at Sakha (Kafer El-Sheikh) as well as at El-Behera; for *P. nigra* the mother tree was located at Gharbia; for *P. deltoides,* male and female, and *P. euramericana,* the mother trees were located at Giza (H.R.I. farm). Stoolbeds were grown in the forest nursery from the different *Populus* species in February 1992. Stem cuttings obtained from the mother trees were used, with the exception of *P. deltoides,* which was propagated from stem cuttings for both the male and female trees as well as the sexual reproductive seedlings which were selected from germinated seeds during 1990 to 1992. Stem cuttings from stoolbeds were then taken during February of the two successive seasons, 1996 and 1997, and rooted in a mixture of 1:1 peat moss and clear sand by volume of 25 cm diameter in plastic pots. Every 21 pots represented one genotype and every pot contained two stem cuttings. At the beginning of August in the two seasons, the seedlings were lifted and the following data were recorded: percentage of plant survivals, plant height (cm), number of developed leaves, mean leaf area (cm^2), number of adventitious roots, and length of the longest root (cm). Also, polyacrylamide gel electrophoresis separation of total soluble proteins in leaves of each genotype was investigated. The results obtained indicated that among all studied genotypes, *P. nigra* was the best for vegetative reproduction, followed by *P. euramericana* (1); moreover, the hybrid *P. deltoides* exceeded their parental species *(P. deltoides* male and female) in this respect. On the other hand, *P. alba* proved to be difficult for vegetative propagation since more than 80% of the cuttings failed to grow and survive in both studied seasons. All poplar species under investigation showed significant differences in their vegetative characters, which means that vegetative growth of poplar seedlings was significantly affected by species. Data also revealed that polyacrylamide gel electrophoresis separation of total soluble proteins can be used as a genetic fingerprint for identification, differentiation, and comparison among the different species of *Populus* under investigation.

Breeding for resistance to leaf beetles attacking biomass willow in Europe

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Defoliating leaf beetles, mainly of the species *Phratora vulgatissima* and *Galerucella lineol*a, are among the most important insect pests in the biomass willow crop in Europe. Beetle-susceptible willow varieties of the species *Salix viminalis* and hybrids between *S. viminalis* and *Salix schwerinii* dominate in the plantations at present. Varieties of the generally more beetle-resistant species *Salix dasyclados (Salix burjatic*a) are less common. Since 1987, breeding to produce willow varieties suitable for biomass production has taken place at Svalöf Weibull AB in Sweden. The main breeding goals have been increased yield level and improved yield stability through breeding for resistance to Melampsora rust and tolerance to frost. Breeding for resistance to shoot-tip infesting insects such as the cecidomyid *Dasineura ingeris* and various lepidopteran species has also been included in the program, as a way of reducing problems with side-shoots at cutting production. Plant selections were based on field screenings. However*, P. vulgatissima* and *G. lineola* have been rare in plantations and there were no opportunities for selection of beetle-resistant clones up to 1997. Since then, beetles have been abundant at some experimental sites, and advanced breeding lines as well as clones potentially useful as resistance sources have been scored for leaf damage there. Plantations of potentially beetle-resistant clones include the North American species *Salix eriocephala* and the eastern European species *S. dasyclados* and hybrids between these and other species. It is evident that certain *S. dasyclados* types are very resistant and promising for breeding, whereas the *S. eriocephala* material studied has a lower potential as a resistance source.

Genetic variation in Populus alba *L.: A comparison of isozyme markers and quantitative traits*

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F-statistics were employed to analyse quantitative and isozyme variation among 14 families collected from seven native populations of *Populus alba* L. in Spain. Seven polymorphic isozyme loci that tested neutral were used to provide an empirical basis for constructing a null hypothesis to test natural selection as a determinant of quantitative evolution in phenotypic traits: growth variables, stem form, wood density, and survival. The average Fst value in isozymes loci (0.245) was compared with that obtained for phenotypic traits. Results show a strong influence of random effects on the pattern of variation of the species measured by isozyme loci. The importance of selection and random effect in the pattern of variation of quantitative traits is discussed to establish optimal sampling strategies of genetic diversity for use in genetic resource conservation of the species.

Recent advances in poplar resistance to insect pests in Europe (1992-1999)

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This report illustrates the contributions of European research on poplar resistance to insect pests in the period 1992-1999. Twenty-five papers were reviewed, dealing with genetic resistance (assessment of plant resistance behaviour and poplar resistance mechanisms), evaluation of resistance in genetically engineered poplars, and environmentally induced resistance. During the reported period, European research on poplar resistance to insect pests was almost completely sustained by France and Italy, probably on account of the high economical importance of poplar cultivation in these countries, but also because of the increasing public perception towards the problems of environmental pollution and human safety. Some outcomes are highly interesting. The development of screening techniques to characterise plant-aggressor interactions allowed the assessment of poplar clonal resistance to *Hyphantria cunea* and *Phloeomyzus passerinii* in Italy and to *Chrysomela tremulae* and *Chrysomela populi* in France. Moreover, the discovery of the role of phenolic glycosides in the resistance behaviour of poplars towards key pests like *C. tremulae* and *C. populi* or *Ph. passerinii,* as well as of a genomic region in *Populus trichocarpa* involved in resistance to *C. tremulae,* could represent a first step towards a marker-assisted selection for resistance to insect*s.* Noticeable results were recorded from studies on genome manipulation techniques, which led to the production of genetically engineered poplars modified by the insertion of genes encoding proteinase inhibitors or *Bacillus thuringiensis* endotoxin. This success shows new exciting perspectives in pest control, provided that European policies define clear strategies on deployment of transgenic trees.

Identification of different commercial clones of **Populus** *using AFLP*

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AFLP (Amplified Fragments Length Polymorphism) has been chosen as the most suitable molecular marker for clonal identification. AFLP is a dominant marker that covers a wide range of the genome obtaining a great number of polymorphisms and making it possible to identify individuals and try to detect specific polymorphisms between clones that show similar morphological

characters and similar behaviour in the field. A total of 29 different clones have been analysed. They belong to the *Aigeiros, Tacamahaca, Leuc*e, and *Leuce* x *Aigeiros* sections. Clones of *P. nigr*a, *P. deltoides,* and *P.* x *euramericana* hybrids were included from the *Aigeiros* section and clones of *P.* x *interamericana* were included from the *Tacamahaca* section. Different numbers of ramets were used for the different clones, including a total of 69 samples. From the analysis, 246 polymorphisms were obtained using two different primer combinations. The Dice similarity index was used to build a dendrogram using the unweighted pair group method average (UPGMA) clustering, where the clones are clearly grouped into sections and groups, and all the clones were identified showing different ramets at a Dice index higher than 90%. The genetic similarity level was higher than 50% among sections, higher than 70% among groups, and higher than 75% for those clones belonging to the same group. In the *Aigeiros* section, the *P. nigra* clones share a total of 39 polymorphic bands, 59 bands for *P. deltoides,* and 30 bands for *P.* x *euramerican*a. The *P.* x *interamericana* clones share 8 bands with the rest of the clones from the *Aigeiros* section and 60 bands between them. Comparing the different groups, *P.* x *euramericana* clones are different in 12 bands with *P. nigr*a, and in 5 bands with *P. deltoides,* and *P.* x *interamericana* clones are different in 9 bands with the *P.* x *euramericana,* in 30 bands with *P. deltoides,* and in 44 bands with *P. nigr*a.

Influence of elevated atmospheric CO_2 on natural pathogen infections of poplar

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Investigations have been carried out on the effects of elevated atmospheric CO_2 on natural attacks of various leaf diseases on *Populus* spp. A poplar plantation was established in central Italy with three poplar species, cultivated in plots with enriched carbon dioxide (550 ppm) or ambient atmosphere. The diseases considered are: rusts (*Melampsora allii-populina)* on *Populus nigr*a, clone Jean Pourtet, and on *P.* x *euramerican*a, clone I-214; leaf spots (*Marssonina populi-nigrae)* on *P. nigra* Jean Pourtet, and *Marssonina castagnei* on *Populus alba* clone 2AS11; and viruses by Poplar Mosaic Virus on *P.* x *euramericana* I-214. Elevated CO_2 level reduced the *Melampsora* attacks, although differences were not statistically significant. No effect of the CO_2 concentration on attack intensity of poplar mosaic virus and *Marssonina* spp. was evident. The incubation period of the latter pathogen under elevated CO_2 seemed shorter than in the ambient atmosphere.

Identification of selected willow (Salix L.) clones based on morphological, biochemical, and molecular data: a comparative analysis

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This study reports the identification of willow clones selected for biomass short-rotation intensive culture plantations and a comparative analysis among different approaches for clonal identification. In particular, seven willow clones (three *Salix eriocephal*a, two *S. exigu*a, one *S. eriocephala* x *exigu*a, and one *S. exigua* x *eriocephala* clone) were employed to record leaf morphology data (leaf length, leaf width, petiole length, distance from leaf base to leaf widest point, number of teeth per centimetre, stipule length, stipule width), iso-enzyme data from 10 enzyme systems (ACO, ACP, ADH, CE, GOT, PER, 6PGD, PGI, PGM, SDH), and RAPD data from two primers (Chl-2, Chl-4). Univariate statistical analysis of the morphological data showed that leaf parameters were unable to discriminate the clonal material. Fifteen variable loci were scored in the 10 enzyme systems studied. All clones presented unique multilocus isoenzyme genotypes with differences from each other ranging from 7 to 13 loci. By using two primers, 15 stable and repeatable RAPD loci were revealed. Six out of seven clones (86%) presented unique multilocus RAPD genotypes, while differences among clones ranged from 2 to 13. Leaf, isoenzyme, and RAPD data were subjected to principal component analysis, the latter two data sets after vector transformation. In all cases most of the variability was resolved in low multidimensional space, in particular 99% of leaf variability, 72.5% of the isoenzyme variability, and 89% of the RAPD variability in the first three axes. In general, three groups could be identified: the *S. eriocephala* and the *S. eriocephala* x *exigua* clones, the *S. exigua* clones, and the *S. exigua* x *eriocephala* hybrid. The conclusions of this study were: (1) leaf parameters were not suitable for clonal identification, (2) all clones were uniquely identified with 30-loci genotypes, (3) RAPDs were much more polymorphic than isoenzymes since there were 1.5 variable loci per enzyme system and 7.5 RAPD loci per primer.

Willow vegetation filters for waste treatment and soil remediation combined with biomass production

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Building complex treatment plants or landfills that meet the needs for satisfactory handling of wastes is very costly. Consequently, it is necessary to find much less expensive and more “natural” ways of waste treatment, which are efficient enough to be an alternative to complex technical solutions. One such method is the use of vegetation filters, regularly harvested, that remove unwanted, polluting subjects from the system. A crop used as a vegetation filter should neither directly nor indirectly be used as a food crop. Short-rotation willow coppice (SRWC), consisting of different species and clones of Salix, meets most of the requirements (non-food crop, efficient nutrient uptake, selective heavy metal uptake, high evapotranspiration rate, potential bioenergy fuel). Because of the presence of pathogens in municipal wastewater and sludge, attention must be paid to storage and distribution of this type of waste. In Sweden, trickle irrigation of wastewater is only occasionally accepted and instead, different types of drip irrigation techniques have been adopted. Sludge has to be treated or stored before it is regarded as safe. Humans could be infected after direct contact with the pathogens, which might happen during storage, by sprinkler irrigation through aerosols, and/or after ingestion of contaminated drinking water or swimming water. Indirectly, humans might be infected through zoonotic transfer of pathogens via livestock and pets. When localising vegetation filter systems in the landscape, it must be ensured that pathogens cannot affect humans. From our experiences and results so far, the following conclusions can be drawn:

- Nitrogen leaching from conventional SRWC is very low.
- SRWC can be used as an active filter for treatment of nitrogen-rich drainage water, thus reducing the nitrogen leaching to watercourses and groundwater. The economical benefit still remains to be investigated.
- Vegetation filters of SRWC can be used for soil remediation, especially concerning cadmium (Cd). A net export of 5-l0 g Cd ha^{-1} yr^{-1} was reached in the Swedish studies. If the wood is used as bio-fuel, it should be purified of Cd during the process of combustion; otherwise there are risks of further spreading of Cd in the environment.
- SRWC vegetation filters are efficient in taking up nutrients from wastewater. The production in stands irrigated with wastewater is expected to be higher than in conventionally managed stands, partly depending on the fertilisation effect, partly on the irrigation effect. The wastewater should be distributed using drip irrigation to avoid aerosol spreading of pathogens.
- Using municipal sludge as fertiliser in SRWC is probably one of the best ways to use sludge without the risk that different toxic compounds will enter the human food chain.
- SRWC can also be used as vegetation filters for treatment of landfill leachates. The aim of such a treatment is not to purify the leachate, but rather to keep the pollutants within the landfill area by increased evapotranspiration.
- Treatment of wastewater, sludge, and leachates in SRWC can compete economically with conventional treatment.

Quantitative trait loci linked with resistance in hybrid poplar to Chrysomela tremulae

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The leaf beetle *Chrysomela tremulae* is a serious pest of poplars in France causing significant defoliation that could prevent plantation establishment and decreasing biomass production in short-rotation coppices. Studies have revealed significant differences in responses among poplar species and hybrids, so learning about the host plant resistance and its genetic variation is a first step in achieving selection for durable resistance. To determine the genetic basis of inter-American inter-specific hybrids to *C. tremula*e, an experimental trial was installed in INRA Orléans to evaluate chrysomelid damages in natural conditions. A study of the sensitivity of 180 progenies of an INRA interspecific family *(Populus deltoides* x *P. trichocarp*a) is underway. Ninety progenies have been already used to evaluate the level of sensitivity to *C. tremulae* in laboratory conditions by feeding adults through multiple choice bioassays. This study allowed the classification of the progenies according to their level of sensitivity. To understand the genomic structure of resistance, two genetic maps have been realised using RAPD, RFLP, AFLP, and microsatellite markers: the first one corresponding to the female parent *P. deltoide*s, and the second one corresponding to the male parent *P. trichocarp*a. Preliminary analysis of variance clearly showed a genomic region involved in susceptibility to *C. tremulae* in *Populus trichocarp*a. The next step will focus on the behaviour of the whole progenies in both natural and laboratory conditions to validate or not this first result and to research other putative statistical links between genomic regions and phenotypic data.

Poplar clone susceptibility to the fungus Dothichiza populea *Sacc.et Br.*

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In Yugoslavia, *Dothichiza populea* Sacc. et Br. is still a major problem in both poplar nurseries and in plantations. *P.* x *euramericana* genotypes, which are widely used in afforestation, are especially endangered (clones I-214, Robusta, *45/5* 1, and Ostia). There is a permanent need to replace these genotypes with new ones that yield approximately the same or greater timber volume but that are

far less susceptible to *Dothichiza populea.* To meet this need, the Poplar Research Institute in Novi Sad has designed a long-range program of selection and hybridisation. At the moment, more than a hundred clones are in the selection procedure. To get information on susceptibility to *Dothichiza populea,* 125 poplar genotypes (sections *Aigeiros* and *Tacamahaca)* and their rooted cuttings were transplanted into two separate plots in 1975*.* Between 1997 and 1999, on 2-year-old plants, the total number of necroses caused by *Dothichiza populea* attack was recorded. Fungal infections were spontaneous. The number of necroses was recorded each year between February 23 and March 4. Based on the number of necroses, a relatively great variability of tested clone susceptibility was observed. There were no necroses on seven genotypes in 3 years, and this group of clones was classified as "unsusceptible." In 33 genotypes, only 1-3 bark necroses were identified, and they were classified as "low susceptible" clones. The clones with 4-9 bark necroses were classified in the group of 35 "susceptible" clones. The greatest number of clones (50) had more than 10 necroses in the bark tissue (clone I-214 had up to 70 necroses), and they were classified as "highly susceptible" clones. The number of clones in the groups "unsusceptible" and "low susceptible" (40 clones) leads to the conclusion that a sound basis has been created for the solution of the problem caused by *Dothichiza populea.*

Active gene preservation programme for Black poplar (Populus NIGRA L.) in Hungary

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The gene preservation program was initiated in 1997. In the program we combined the scientific description of genotypes and *ex situ* conservation with the promotion of the production of propagating material intended for the replanting of endangered species.

A detailed accession record was made on each specimen (genotype) chosen and their ex situ conservation and testing for species identity by DNA analysis is in progress depending on the financial resources available. To date 214 genotypes were found to be true to type using B. Heinze's method and further 200 collected samples await analysis. A central gene archive (ERTI-Sárvár) and regional gene collections (Derecske, Fadd-Tolna, Sárvár) were established. Preservation is carried out both in juvenile stage (stool bed) and adult tree stage.

Law N° LIV 1996 on nature conservation requires, that forest owners must use indigenous species for afforestation in the protected areas of flood plains e.g. Populus nigra. Therefore the demand for both generative and vegetative

propagating material is increasing steadily. Our working group has called attention to the occurring introgression due to Populus x euramericana cultivars. We recommended the use of easy to root genotypes that were found to be true to species by DNA analysis. Several ecologists debate the use of vegetative propagating material, therefore the use of seedlings is also significant, which is also a cheaper method. Seedlings were carried out by a non-random sampling for a DNA test. The samples were selected per 10 000 seedlings, in total 49 samples for DNA tests. We analysed specimens of extra size and peculiar morphological characteristics and found only 1 tree as a hybrid. By the number of samples taken the results can only be regarded as representative. A 0.6 ha stool bed containing clones of 40 DNA tested specimens was also established and the establishment of a clonal seed orchard containing clones of 45 genotypes is in process. The advantage of vegetative reproductive material of good growth parameters is that it better survives after the sometimes 1-3 months long and 2-4 meters high inundation by flood waters, than the smaller seedlings

Result data based on regions are presented. The populations in the Danube valley are well represented, so in the next phase we shall emphasise work on populations living along the river Tisza and its tributaries. Based on the collected samples we shall make preparations to carry out DNA testing of chloroptasts in order to estimate the genetic diversity.

Achievements in the utilisation of poplar wood—guideposts for the future

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Poplar wood is suitable and is utilised for a broad range of forest products world-wide. The utilisation of any species is governed by a number of factors, such as basic wood properties, overall quality, quantity and price of the resource, available processing technologies, local as well as international market conditions for the products, and the availability and price of competing products. The combined influence of these factors during the past 5 decades created a favourable environment for substantial growth in the poplar using industries globally, which is now stimulating major interest and investment in poplar growing. The many and varied uses of poplar wood include pulp and paper, lumber, veneer, plywood, composite panels, structural composite lumber, containers, pallets, furniture components, match splints, chopsticks, etc. The high cellulose and relatively low lignin content make poplars well suited for pulp and paper products. Poplar wood can be pulped by all commercial pulping methods, such as mechanical, semi-chemical, sulphate, and sulphite processes. Poplar pulps, in turn, are utilised in fine papers, tissues, paperboard, newsprint, and

packaging papers. Poplar kraft pulps, when blended with softwood kraft, are particularly well suited to fine paper manufacture because of inherently desirable properties such as excellent sheet formation, high opacity, good bulk, and good printability. Recent technical advances in anthraquinone-catalyzed sulphite pulping are helping to increase pulp yield and strength properties of paper. While poplar wood continues to be an important raw material in the traditional lumber, veneer, and plywood industries, the most remarkable "success story" in poplar utilisation is the phenomenal growth of the oriented strand board (OSB) and the structural composite lumber industries (e.g., composite I-beams, laminated veneer lumber or LVL, laminated strand lumber or LSL) in North America during the last decade. These products and their industries have grown to multibillion dollar scope in annual product value and are now the largest users of poplar fibre. One of the many advantages of composites is that they use wood fibre more efficiently than sawn lumber, and greater product uniformity is achieved through highly automated manufacturing processes. Future prospects for growing and utilising poplar fibre resources look excellent. On the resource production side, opportunities for genetically modifying important wood properties, such as chemical composition, fibre quality, and natural durability of wood, can now be realised. On the resource utilisation side, high value engineered composites and high yield pulp and paper products will represent the strongest growth sectors in poplar utilisation during the coming decades.

Populus *clones veneer yield and quality along trunks*

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Poplar veneer yields from an industrial peeling operation were analysed in several trunk sections up to a height of 12 m. Peeling was carried out with 13 clones of genus *Populus* from the Populetum of Zamadueñas (Valladolid, Spain). The wettest veneer was automatically removed, and this material was visually classified according to the required industrial quality. Clones showing the highest wet veneer percentage (more than 40% in some cases) were Flevo, Dorskamp, 1-476, and 1-Z. On the other hand, clone Lux showed the smallest values, about 7%. In clones 1-214, Mc, Campeador, Canada Blanco, 1-262, PA-1, 1-Z, and Lux, more than a quarter of the total number of veneers obtained were of first quality. In relation to veneer yield, there were no pronounced differences among clones. Veneer yields from logs of a trunk up to 12 m in length averaged 60 to 70% in volume. In general, the best performance was found in the middle to lower zone of the trunk. However, optimal yield was found to be maintained even above 10 m in trunks in clones 1-214, Flevo, Mc and PA-1.

Study of agro-forestry system, poplar (Populus *x* euramericana *cv. I-488) and crops: use of associated crops in Chile*

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To improve the use of soil in a forest of poplars, systems associated with crops were developed, and the effects of different crops on the growth of the trees were evaluated. In poplars of the clone I-488 in the first and second years of the plantation, established at a density of 278 trees/ha (6 x 6 m), the effect of annual associated crops was studied. The annual crops included onion, tomato, sweet corn, corn, green beans, dry beans, potato, wheat, broccoli, cauliflower, lettuce, beans, pea, oat-vetch, Italian squash, fresh corn, and similar crops. The effect on the crops was evaluated through the yield of each species; for the poplars the diameter at breast height (dbh) and at the base of the first branch, total height, and height to the first branch were evaluated. For the agro-forestry system, the incidence of photosynthetic active radiation (PAR), effect on the fertility of the soil, variation of the environmental and soil (30 cm depth) temperature and fluctuations of the water table were measured. The yields obtained in each crop in the first year of evaluation were not affected; in the second year, a negative effect was observed in some crops from the spring season. In relation to the growth of the trees, there were no statistical differences in comparison to the control without crop; however, some species showed a significant and positive effect on dbh in the first year (green beans and onion). For the rest of the variables, differences were not apparent in either of the 2 years. Regarding the PAR, during the first year, the trees did not interfere with the incident light on the crops. In the second year, an effect was observed only from spring, when the incident PAR decreased by between 10 and 50%. The results obtained in these 2 years show that the poplars are not affected by the competition of the associated crops and that the latter reduce their yield only from the spring season in the second year.

Performance of 'ex situ' genetic resources of multiclonal Populus alba L. vitroplants

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In the national forestry research program are included, both the 'in situ' and 'ex situ' native poplars genetic resources. So far, the results obtained in 'in situ' stands, covering all native poplars (white, grey, black, aspen), which include 43 populations with 208.5 ha (approx. 0.4% from the total area), have been published already.

The present paper deals with the performances obtained in the Arge valley, which crosses the territory of the Cornetu Station, 20km from Bucharest.

They are, mainly, the following:

1. 17 target trees of 4 *Populus alba* clones: Ro-345, Ro-361, Ro-366 and Ro-D18;

2. 22 quantitative and qualitative phonotypical indices of the trees: form, size, colour of the stem, crown branches, bark and tree health;

3. 7 qualitative indices of the basic traits, with obvious genetic importance: straightness, slenderness and oval form of the stem, stem pruning/height ratio, branch thickness and tree health;

4. Qualitative value of the clonal-stands: Ro-345 superior, Ro-361, Ro-366 and Ro-018 medium-superior.

Biomass potential of short-rotation poplar and willow plantations, tested in the Danube Delta

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The paper deals with the results obtained in the trials of short-rotation plantations (1-5 years) in the Danube Delta. The tested species and clones are: *Populus* x *euramericana* Robusta Ro-16, I-214, and Sacrau-79; *Populus deltoides* I-69/55; and *Salix alba* Ro-201, Ro-202, Ro-204, and Ro-326, all used in applied forestry. The main conclusions are:

1. The Danube Delta offers favourable pedo-climatic conditions for short-rotation plantations of poplars and willows;
2. The best results were obtained with *Salix alba* clones, with an annual above ground average yield of 27.9 to/ha (1 x 1 m) to 42.0 to/ha (1 x 0.5 m); Populus clones produced 16.3 to/ha to 32.3 to/ha;
3. The most productive species and clones are: *Salix alba* Ro-326 (46.6 to/ha/year) and *Populus deltoides* I-69/55 (34.4 to/ha/year);
4. The 2-year rotation age is more favourable than that of 1 year for above ground yield biomass, which was 0.2-1.9 times more for willows and 0.5-0.9 times more for poplars.

Root proliferation response to nitrogen-enriched microsites in cottonwood plantations: influence of whole-plant nutritional status

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Root proliferation in enriched nitrogen (N) microsites has shown a varied degree of response. We hypothesise that cottonwood roots will proliferate in enriched N microsites and that this root proliferation response is negatively related to whole plant N status. To test our hypotheses, a cottonwood plantation was established and plots within it received 0, 50, 100, and 200 kg N/ha. Time-release fertiliser was used to prevent disturbance effects associated with large pulses of N. To create an N enriched microsite, 90 ml of 7mM N solution (1:3 ammonium:nitrate ratio made from NH_4:NO_3 and Na NO_3) was injected into the soil. A second microsite received 90 ml N-free control solution (NaCl). The solutions were applied at two random locations along a clear, plastic minirhizotron. The minirhizotrons were located on one side of the tree row and placed horizontal to the surface at 15 cm depth. The two treatment solutions were also applied to similar locations on the opposite side of the tree row so that soil cores containing proliferating roots could be collected. Microsite treatments were applied to different locations at three phenological stages: leaf emergence, peak growing season, and budset. The microsites over minirhizotrons were monitored for fine-root production (sum of new root length), mortality (sum of missing root length), and standing crop (net amount of root length present). Cores were collected 3 weeks after application. Minirhizotrons treated at leaf emergence had greater production in N patches compared with the N-free controls, but not at peak growing season, suggesting that plant phenological stage could be a factor in root proliferation response to N enrichment. Plot fertilisation did not affect root sensitivity to microsite N, so the hypothesis was not supported. Also, no patch treatment differences were found for cores collected at any time in the season. Even though we know that cottonwood roots respond to N-enrichment in soil microsites, our findings from the field indicate that this response signal is difficult to detect within the noise of natural spatial and chemical variation in soil properties and the ability of soil to quickly buffer the addition of inorganic N. Therefore, larger concentrations of N in microsites and more careful monitoring and sampling may be required to rigorously test the hypothesis.

The Minnesota Hybrid Poplar Research Cooperative Program

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The Minnesota Hybrid Poplar Research Cooperative (MHPRC) was formed in 1996 to improve poplar genetics, increase yields, and provide technical assistance to cooperative members and the public. Genetics research being done by the MHPRC includes testing of native cottonwood sources, breeding of interspecific hybrids, and field-testing of new poplar clones. We are currently attempting approximately 150 crosses annually using native *P. deltoides* as the female and *P. maximowiczii* and *P. nigra* as males in greenhouses at NRRI.

Also, backcrosses of *P. deltoides* x *maximowiczii* hybrids to *P. deltoides* are being done to produce clones having higher resistance to *Septoria* canker. Of the 150 crosses made annually, our target is a minimum of 60 families having 100 seedlings per family for a total of 6,000 genotypes produced each year. Planting of field tests throughout Minnesota began in 1999 to evaluate these genotypes. In addition to breeding, clone tests have been established at 13 sites since 1997. These trials include native *P. deltoides* selections, *P. deltoides* x *maximowiczii* hybrids, and two commercial standards (DN34 and NM6). Data from our trials suggest that significant improvements in yield over the current commercial clones can be made. Results after 4 years of testing will be presented. The MHPRC is also conducting research to assess the nutritional needs of poplar plantations and improve cultural practices. Early results of fertilisation research at two sites suggest that yield can be increased by as much as 70% over unfertilised plots. We have established 16 fertilisation studies across a wide range of soil types since 1997. The goal of fertilisation research being done by the MHPRC is to develop tools to allow assessment of nutritional status and develop recommendations for supplemental nutrition. Research on cultural practices includes studies to test the phytotoxicity of new herbicides and optimise their effectiveness. The MHPRC has established an extensive network of growth and yield plots of clones recently recommended for commercial planting. Yield studies of these clones were established in 1995 and annually thereafter to assess the potential to improve yields over current commercial standards. Growth data and projections of final yield will be presented.

The importance of aspen and hybrid aspen in Finnish forestry

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European aspen *(Populus tremul*a) is the only species of the genus *Populus* that occurs naturally in Finland. Aspen, however, has never had much economic importance in Finnish forestry. Only during a few decades after the middle of the last century was there a short boom in aspen cultivation for raw material for the match industry. This was after hybrid aspen *(P. tremula* x *P. tremuloide*s) was found to have superior growth compared to the pure species. After the decline of the match industry from the 1970s on, the interest in aspen disappeared again. Because aspen was considered a weed, it was mostly removed from the forests. Presently aspen stands cover about 60,000 ha, which is only 0.3% of the Finnish forest area. The appearance of aspen decreases from south to north. It is estimated that the standing volume of aspen in Finland is about 21 mill. m^3, which is only 1.2% of the total. Since the 1990s, there is again a growing interest in aspen, this time as raw material for the pulp and paper industry. Aspen has been found to be very suitable as a raw material for new lean technologies in the paper production process, resulting in new grades of fine printing paper. The

fibre morphology is especially important. The wood quality of naturally grown aspen is, however, very variable. Little was known about the causes for this variation (genetic vs. environmental). Recent studies using three replicated clone trials with hybrid aspen in Sweden (age 7 to 13 years), consisting of 18 clones, estimated the genetic parameters for some important fibre and yield traits. The estimates for clonal heritability for fibre and yield traits ranged from 0.42 to 0.86 and from 0.38 to 0.77, respectively. Between some of the fibre and growth traits, a strong correlation was found. Using data from the aspen and hybrid aspen stands (full-sib families) that were established during the 1950s and 1970s, growth potentials for southern Finland were estimated. Under good growing conditions, the wood production for hybrid aspen was found to be nearly twice that of native aspen. Hybrid aspen also grows faster than any of the three dominant tree species in Finland: birch, Norway spruce, and Scots pine. The profitability of aspen and hybrid aspen compared to the other species depends, of course, on developments in wood prices. At present price levels, hybrid aspen offers a good alternative. Aspen is probably the best alternative for reforestation of spruce sites affected by the *Heterobasidion spp. (*formerly *Fomes spp.)* root rot. Besides its promise as raw material for the pulp and paper industry, aspen is currently also of interest for the enhancement of biodiversity in Finland. When individual trees or small stands are left standing during forest harvesting, they offer niches for many species of insects, birds, and fungi.

Genetic variation of Populus deltoides *family by molecular markers*

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There are two serious problems in *Populus deltoides* breeding in China: (1) narrow genetic basis for parent selection and (2) lack of detailed study on genetic variation for important traits. To broaden our genetic base, we collected plus open-pollinated *P. deltoides* families in the south of USA where *P. deltoides* grows naturally along rivers. This paper has studied genetic variation by use of both RAPD molecular markers and quantitative traits (height and diameter). To establish the linkage between the molecular markers and QTLs (quantitative trait loci), we used both the MB (marker-based) method and RAPD-based analysis to detect the probable number of QTLs related to plant height and diameter of *P. deltoides* and study their relationships. The main results are listed below:

(1) Fourteen out of 300 (10 bp) random oligonucleotide primers from PCR were screened for RAPD analysis among 11 open-pollinated *P. deltoides* families, 163 clones (5 *P. cathayana* clones used as contrast). Each primer produced 1-12 bands that ranged in size from 200 to 2000 bp. Thirty-four out of 97 (35.1%) bands amplified by 14 primers were polymorphic, and 10 out of 34

polymorphic bands were low frequency bands (<15%). Different primers had different frequencies for polymorphic bands, which may be related to regions of the genome. RAPD analysis allowed one to discriminate among all tested clones.

(2) The average Nei's Genetic Distance (D) between out-group and every family was 0.2. The D among 11 families ranged from 0.0164 to 0.1751, and the UPGMA dendrogram based on the 12 x 12 genetic distance matrix was effective in differentiating the out-group from 11 families. There were no obvious relationships within the 11 family dendrogram and the family's geographical location. For most families and clones, the genetic distance among clones from the same family was smaller (0.0606-0.5000), than the genetic distance among clones from different families (the largest was 0.8873).

(3) Variance analysis indicated that the family and the clone-within-family source of variation is highly significant for two traits (height age 1, diameter age 1). The data of variance component showed that the genetic variation exists mainly in clones within-family, not among families. So, it is possible to achieve genetic gain through selection among clones. The broad-sense heritabilities *(h^2)* of diameter is larger than that of height, which suggests that diameter growth of cottonwood clones is more controlled genetically than height growth. Estimates of non-additive genetic variance were small.

(4) According to one-way ANOVA, 9 out of 34 markers (26.47%), were significantly related to height and diameter (P<0.05) separately. Through two-way ANOVA, 7 1 out of 1,122 (6.24%) two-markers-recombination were detected linked with QTLs for height (45) and diameter (26) (P<0.001). Two-way ANOVA failed to detect interactions among most of the QTLs discovered by one-way ANOVA. The quantitative traits were controlled by many loci, and these loci were likely distributed randomly in the genome.

(5) The P value varied with larger range (0.0001-0.9239) and there are few markers related to quantitative traits with very low P value (P<0.00 1). Height and diameter of *P. deltoides* appeared to be under the control of many quantitative trait loci (QTLs), and few markers can explain more genetic variation. The results were consistent with other results based on genetic linkage maps, and they are potentially valuable for design of poplar breeding strategies.

(6) Four markers (L7, L8, L25, L13) were significantly related to QTLs of both diameter and height (P<0.05), esp. L13 and L25, which were highly significantly related (P<0.01) to QTLs of diameter and height. It seemed that one marker is related with two or more traits.

Integration of new tools into long-term breeding strategies

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According to the *State of the World's Forests* report (FAO), global forest cover is decreasing annually by 12 million ha, while the demand for wood and wood products is increasing steadily. It is therefore necessary to improve the yield of fast-growing trees that can be grown in intensively managed plantations.

Conventional breeding consists of the identification of plus trees, the generation of interspecific and intraspecific hybrids, and the selection of superior hybrids. Especially for forest trees, breeding cycles are long, mainly because of the long generation times and the fact that important traits, such as wood quality, can only be evaluated at rotation age. When viewed at the molecular level, conventional breeding combines a number of beneficial genes, residing from different parents, into a single hybrid clone. The principal question to be resolved is "How to identify the genes that underpin important traits in a forest tree; i.e., that can improve yield or quality?" Most fundamental knowledge on the function of genes comes from extensive research on model plants such as *Arabidopsi*s. For *Arabidopsi*s, the complete genome has been sequenced, and the function of approximately 50% of the genes is known. Many of these genes or homologues are candidates to be introduced into the poplar genome by genetic engineering, to alter quality or yield. For example, modifying the expression levels of the genes encoding enzymes of the lignin biosynthesis pathway has been shown to improve the quality of wood for the production of paper. Other studies have shown that insect resistance and growth can be improved by emphasizing certain genes in poplar. Experimental field trials have been established for several transgenic poplar clones.

Another promising field of research is based on molecular marker approaches. Apart from their value in fingerprinting individual clones for clone identification purposes, molecular markers have made it possible to create genetic maps. These genetic maps are extremely valuable to dissect the genetics of complex traits. Although until now, the direct value of genetic maps to improve poplar breeding has been limited, they hold an enormous potential as they get more refined and many more genes are being mapped. As a first step to identify genes explaining important traits, several research projects aim at exploring a potential co-localisation of QTL for a given trait with genes identified through other methods (e.g., EST or micro-array projects). Such a candidate gene approach is now feasible to identify genes for disease resistance. In addition, the knowledge of the complete sequence of the *Arabidopsis* genome will make it possible to investigate to what extent the *Arabidopsis* and the poplar genomes are co-linear. If microsyntheny (similar sequential order of the genes) exists, it will be possible to use map-information from the *Arabidopsis* research field for poplar improvement.

One of the main challenges for future tree improvement programs will be to integrate the knowledge and experience from breeders with the increasing wealth

of data being produced from molecular tools, to speed up the genetic improvement of trees.

Density effect on Populus deltoides *Marsh. cv. Catfish 5 individual growth in the Argentine Delta*

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The objective of this work was to evaluate the growth of two plantations of *Populus deltoides* Marsh. cv. Catfish 5, planted at two different densities. The experiment was performed at the First Section of the Delta Parana River Province of Buenos Aires, Argentina (34°S, 58°W). Mean annual precipitation and temperature was 1,021 mm and 16.5°C, respectively, and plantations are subjected to periodic flooding. The plantations were established in 1989 at two densities: i) 4 m x 4 m (LD: low density), and ii) 3 m x 2 m (HD: high density). In September of 1994, 95 trees of each treatment were marked at breast height (1.30 m). From this date until September 1999 (5 years), the circumference was measured at 3-month intervals (coinciding with the initiation of each annual station), using metric tape with 0.1 cm precision. At the beginning of the measurements, LD had 549 trees/ha with a mean diameter of 13.59 cm, 7.96 m^2/ha basal area, and 206 Reineke Density Index. HD had 1,517 trees/ha with a mean diameter of 13.36 CM, 21.27 m^2/ha basal area, and 555 Reineke Density Index. There were no differences of individual growth between treatments at the beginning of the measured period, evaluated by the mean diameter.

Annual mean diameter growth was 24.57 and 11.84 mm for LD and HD, respectively, during the first year (Sept. 1994 – Sept. 1995); 18.44 and 8.22 mm for the second year (Sept. 1995 – Sept. 1996); 15.48 and 6.32 mm for the third year (Sept. 1996 – Sept. 1997); 11.91 and 4.70 mm for the fourth year (Sept. 1997 – Sept. 1998), and 10.14 and 5.16 mm for the fifth year (Sept. 1998 – Sept. 1999). The growth was higher in LD than HD ($P<0.01$) in all growing periods. The higher increments occurred in the spring – summer period (98% of the total annual growth) depending on the year. This tendency increased as plantation development advanced and was higher in HD compared with LD. The results obtained for this particular site, age, and density conditions allow us to deduce that thinning would produce an increase of diameter growth, as LD showed a higher diameter growth than HD.

Reineke Density Index for cottonwood: Analysis of published data

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Our objective was to define a management range for cottonwood *(Populus* spp.) plantations using the Reineke Density Index (RDI). This method considered density as the number of trees per unit of area and as an expression of the competition within a plantation. To define a management range utilising this method, published data sets from the U.S. and Argentina, which proposed optimum management for cottonwood plantations, were reanalysed. This work included a wide range of clones, different initial spacing, and different soil types. Management range (number of trees per hectare) was converted into RDI, and the average RDI for each region was calculated. Maximum and minimum values of management of RDI for the U.S. and Argentina were defined. The estimated management range for the U.S. was 193 to 356 RDI and for Argentina was 250 to 380 RDI. Considering the average of the minimum and maximum values could be a first approach to establishing a management range for *Populus* spp. plantations. More investigations in this subject area will help improve management in this species.

Seasonal growth for three clones of Populus deltoides *in the Argentine Delta*

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The objective of this work was to evaluate the seasonal growth of three plantations of different clones of *Populus deltoides* (cv. Stoneville 71, cv. Catfish 5, and cv. I 72/51) planted at the same density. The experiment was performed at the Second Section of the Delta Parana River Province of Buenos Aires, Argentina (34^{o}S, 58^{o}W). Mean annual precipitation and temperature were 1,021 mm and 16.5°C, respectively. The plantations were established in 1993 with a spacing of 3 m x 5 m. In September of 1997, 110 trees of each treatment were marked at breast height (1.30 m). From this date until September 1999 (2 years), the circumference was measured at 3-month intervals (coinciding with the initiation of each annual station), using metric tape with 0.1 cm precision. At the beginning of the measurements the plantation of *P. deltoides* cv. Stoneville 71 (ST.71) had 612 trees/ha with a mean diameter of 10.40 cm, 5.21 m 2 /ha basal area, and 150 Reineke Density Index. The plantation of *P. deltoides* cv. Catfish 5 (CF.5) had 654 trees/ha with a mean diameter of 7.91 cm, 3.22 m 2 /ha basal area and 104 Reineke Density Index. The plantation of *P. deltoides* cv. I 72/51 (I.72) had 654 trees/ha with a mean diameter of 9.66 cm, 4.81 m 2 / ha basal area, and 143 Reineke Density Index. There were differences of individual growth between treatments at the beginning of the measured period, evaluated by the mean diameter ($P<0.01$). Annual mean diameter growth was 33.4, 25.56, and 19.87 mm for ST.71, CF.5, and I.72, respectively, during the first year (Sept. 1997 – Sept. 1998) and 26. 02, 22.57, and 22.80 mm for the second year (Sept.

1998 – Sept. 1999). The higher increments occurred in the spring – summer period (92 to 99% of the total annual growth). This tendency increased as plantation development advanced. CF.5 and I.72 presented principally spring growth (73 to 79% of the total annual growth) depending on the year; ST.71 distributed its growth in spring and summer (57 vs. 43%, respectively) as the mean of the 2 years of measurements. Results obtained allow us to deduce that the clone had a direct effect on the seasonal growth distribution under these particular conditions.

Silvo-pastoral system in the Argentine Delta Region

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The objective of the present work was to evaluate the wood and animal production of a silvo-pastoral system in the Argentine Delta Region. The experiment was conducted in Campana, located in Buenos Aires, Argentina (34^{o}S, 58^{o}W). Mean annual precipitation and temperature there were 1,021 mm and 16.5^{o}C, respectively. This area is characterised by periodic flooding, so the fields were protected to control this environmental factor. Plants of 1-2 years with roots of *Populus deltoides* cv. I 63/51 were planted at a density of 278 trees/ha (6 m x 6 m) after 1 year of mechanical fallow. Numerous pruning and thinning practices were done to obtain wood of high quality (trees with a diameter higher than 40 cm and straight and healthy wood). Natural grassland developed under the tree plantation, composed of valuable species as *Lolium* sp., *Trifolium* sp., *Stipa* sp., *Lotus* sp., *Paspalum* sp., *etc*. This grassland allowed the implementation of a silvo-pastoral system, where forest production is combined with the production of breeding cattle. Cattle were introduced when the plantation was 3 to 4 years old. Animals were pastured with oats (80 kg seed/ha in an area of 10 ha of 4-year-old cottonwood with 400 trees/ha (5 m x 5 m)). The percentage of births was 78%, with a mean animal production of 0.78 calves/ha/year and a weight of 170 kg/animal at weaning. Wood production at harvest for the *Populus deltoides* cv. I 63/51 plantation of 15 years old was: veneer production (diameter of 9 inches) – 250 t/ha (79%); saw log production (diameter from 6 to 9 inches) – 36 t/ha (11%); pulpwood production (diameter from 3 to 6 inches) – 31 t/ha (10%); total production – 317 t/ha (100%). The high wood and cattle production obtained in this experiment suggests this silvo-pastoral system for the Delta Region as an alternative to diversify the traditional production systems.

Poplars: A multiple-use crop for European arable farmers (PAMUCEAF) project overview

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Agricultural overproduction in Europe has resulted in large areas of farmland being no longer required for food crops. In recent years, obligatory 'set-aside' has been used as the main mechanism for controlling arable crop surpluses. Although this situation presents problems for policymakers, it also provides opportunities for environmental enhancement and production of non-food crops. Modern poplar hybrids are highly suitable for ex-arable land. Poplar wood has many potential uses and even the longest rotations are short, compared to those for other forest crops - increasing flexibility for integration into agricultural systems. Various studies have indicated that the economics of poplar production compare favourably with other forest trees and with most alternative, non-food crops. Poplars, therefore, offer an excellent opportunity for farm 'diversification' and could provide raw materials for small-scale rural industries, increasing employment. Widespread production on surplus arable land could also make an important contribution to European targets for reductions in fossil fuel combustion, reducing CO_2 levels, and could make a positive contribution to trade balances by reducing import requirements for paper pulp and hardwood timber. Against this background, the European Commission decided to support a research project that further develops recent work on site suitability and economics of poplar production, and takes a broader look at all aspects of poplar production on farmland - including studies of environmental impacts, existing and developing markets, and the attitudes of farmers and the general public. This project, *Poplars: a multiple-use crop for European arable farmers* (acronym *PAMUCEA*F) (EC FAIR CT98-4l93), has six main objectives:

1. To examine current levels of demand for various poplar *(Populus* spp.) wood products – including veneers, sawn timber, fibre and wood chips for energy production - and identify likely future market trends.
2. To determine the potential for widespread production of poplars as a non-food crop for surplus agricultural land, in the light of current economic and political factors and under a reformed European 'Common Agricultural Policy' - as proposed by *'Agenda 2000*'.
3. To determine the probable environmental impact of large-scale poplar production in agricultural areas –considering likely effects on soil and water resources, biodiversity, and landscapes.
4. To identify 'key areas' for poplar production, using GIS software.
5. To assess the attitudes of farmers and the general public to a potential increase in poplar planting on farmland and identify their main objections to this crop.
6. To produce revised recommendations for poplar production on arable or mixed farms – ensuring maximum profitability, full integration with other farm enterprises, and environmental acceptability.

Genetic engineering of reproductive sterility: the promise and problems of developing methods for commercial application

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Sterility will greatly reduce ecological concerns over use of transgenic plantations, and consultations with U.S. regulatory agencies indicate that it is likely to be required for commercial use of trees improved via genetic engineering. Additionally, sterility would reduce genetic pollution from exotic, hybrid, or monoclonal plantations. The most widely applicable methods for engineering of sterility either inhibit the functions of genes necessary for fertility or specifically induce cell death in reproductive tissues. Despite strong indications that one or more of these strategies can be successfully applied to trees, it has not yet been demonstrated that any sterility transgene fulfils the basic requirements for commercial use as a long-term containment measure. For this, engineered sterility must be complete and stable over multiple rounds of vegetative propagation and growing seasons, it must cause no detrimental effects on vegetative growth, and successful transformation events must be identifiable via molecular tests when trees are still juvenile. The different strategies for engineering sterility have distinct advantages and disadvantages, and which method will be best for use in trees is unclear. Important factors, which may be more or less problematic depending on the sterility transgene, include: 1) the likelihood of causing detrimental vegetative effects, 2) applicability to diverse species, 3) ability to identify sterile trees prior to flowering age, 4) degree of sterility, and 5) stability of sterility. For this reason, we have been studying various methods for engineering sterility in poplars. Highlights of our results to date will be presented. These range from 5-year-old field tests of transgenic poplars with heterologous promoter::cytotoxin transgenes to tests of novel poplar gene constructs in early-flowering poplars and model annual plants.

Phylogenetic analysis yields insights into genetic complexity in **Salix**

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Salix (willow) is the largest and most complex group of woody plants in the temperate zone. Willows have a highly important role in natural communities and are valuable in riparian revegetation and biomass production. Despite their importance, surprisingly little is known about their genetics. Knowledge of the fundamental genetic structure underlying presumed species, the relationships among species, and the role of evolutionary processes such as hybridisation is

essential to the management of willows. In our research we have employed a multi-gene approach, including chloroplast and nuclear data, to infer genetic relationships and processes. Chloroplast DNA, commonly used in plant systematic, provides resolution of major divisions within the genus. Two major subgenera and groups within the more ancient subgenus *Salix* are revealed. However, relationships within the subgenus *Vetrix* are poorly resolved, presumably due to a more recent radiation of species. To date, two kinds of nuclear sequence data are being used: ITS and starch synthase. The latter is providing much greater resolution of closely related species. Taken together, the several data sets reveal differing levels of resolution among taxa, and cases of incongruence among data sets suggest the importance of hybridisation in the genus. In addition, substantial genetic differentiation has also been discovered within some taxa. For example, *Salix eriocephala*, used in biomass production, is not genetically uniform throughout its range. The implications of this variation are that breeding and management activities need to be built on a solid foundation of genetic knowledge.

Populus sp.: Behavior in different places of Mendoza, Argentina

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In the province of Mendoza, Argentina, forest activity is based almost exclusively in poplar cultivation. Several parcel tests were carried out in different places to compare the behaviour of different poplar clones of both local and foreign origins. Results obtained in parcels located in Villa Atuel (Department of San Rafael), Nueva California (Department of San Martin), and El Capacho (Department of San Carlos), where clones of *Populus deltoides* and of *Populus* x *euramericana* were tested, are shown here. Circumference and height of the trees were measured annually and attacks of *Septoria musiva* Peck (cancrosis) were registered. In Villa Atuel, the best yield in wood volume was obtained from *Populus* x *euramericana* cv. Cima. The most susceptible clone to cancrosis attacks was cv. Cima. The clones Conti 12 and Harvard were more resistant to this plant disease. In Nueva California, the best yield in wood volume was obtained by *Populus* x *euramericana* cv. Conti 12. Cancrosis attacks were not significant. In El Capacho, the best yield in wood volume was obtained by *Populus* x *euramericana*, cv. Guardi; cancrosis attacks were more severe in cv. Longhi, cv. Cima, cv. I-29, and cv. I-488.

Growth stresses in five clones of Populus *x* euramericana*: I-214, Canada Leones, I-262, and I-MC in Spain*

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In this work, new knowledge about growth stresses in the type *Populus* x *euramericana* is presented. In 200 *Populus* trees of the Populetum of Zaragoza (SIA-DGA) and of the Populetum of Valladolid (INIA) in Spain, a study was done on genetic and environmental influences on the development of longitudinal deforms (a measure of the internal tensions or growth stresses) determined in the periphery of the trunk. At the same time, the effects of the forestry station, clone, and the morphological features of *Populus* on growth stresses were studied. The influence of the station was observed; all the black poplars from the Populetum of Zaragoza had greater average tension than those from the Populetum of Valladolid. There was also an influence of factor clone which had a different behaviour in Canada Leonés (the longitudinal deformation was 25%). The morphological features (height, diameter, quadrature, symmetry of the top, volume of the top, volume of wood, inclination tree) of *Populus* associated with growth stresses are: the inclination of the tree and the symmetry of the top. Trees that are more inclined and trees that have asymmetrical tops have greater growth stresses. However, the height, diameter, quadrature, and volume of wood have no significant influence on growth stresses.

Relations among the site, the pest (Platypus sulcatus *Chapuis), and trunk disease in a commercial plantation of* Populus deltoides *cv. Catfish-2 located in the low delta of the Parana River (Argentina)*

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In the Paraná delta area, poplar commercial plantations are planted in highlands and in lowlands surrounded and protected by dams, occupying 14,000 ha in the zone. The greatest wood volume is assigned to sawmills and veneering, and a lesser proportion is assigned to grinding. This work is aimed at studying the relation between plantation site quality with damage caused by "Taladro de los Forestales" *(Platypus sulcatus* Chapuis), and the relation with other diseases, such as cankers, that affect the trunks until 2 m high and reduce the wood quality and/or quantity. The taladro is a small, cylindrical Coleopterous insect in the *Platipodidae* family. This insect burrows galleries within trunks, affecting wood quality, decreasing its commercial value, and producing important volume loss in adult plantations when infected trees break with the wind. It is considered the most important poplar pest in the region. We also analysed incidence of trunk disease, which causes cracks in the poplar trunks and bark death. Consequently,

the commercial values of wood quality decrease and volume may be lost due to the windthrow of the infected trees. We carried out the study in a 2 ha plantation of *Populus deltoides* cv. Catfish-2, which is the most widespread clone in the delta area. The plantation was 12 years old; the plants were placed at 3 x 4 m intervals; and a direct relation was found among the forest site, the pest, and the disease.

The taladro attack was not at random because the most affected trees had greater diameter and height than those not infected, and they grew in soil types of *albardón endicado*. These trees showed the most active holes and cracks at gallery height, as a consequence of the wind. The percentage of infected plants was greater at the best plantation site, probably due to physiological causes, although plants affected by the pest had smaller diameters than the healthy ones. Low sites, typically from bañados protected by dams, had lower volumetric yields, fewer active holes, fewer plants broken by the wind at the height of galleries, and fewer cracks in the trunks.

Studies of population genetics through microsatellite analysis of Populus nigra L. growing on Ticino river banks

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Populus nigra L. is a tree of social and economic importance. It has direct economic values as a supplier of raw material for industries. It is a unique pioneer species of riparian ecosystems, which contribute to the natural control of flooding and water quality and which are characterised by a high level of diversity of fauna and flora. Some natural habitat may have been lost due to drainage of rivers. It is not known if the genetic diversity of the species has been reduced as a consequence.

In this work we studied the relationship between different populations of the same river, which arose from the recolonization of Europe by trees after the last glaciation, perturbation of riparian sites by human activities, seeds and pollen flow, and antropic dissemination. For the project we harvested and vegetatively replicated cuttings of two populations set along the Ticino River, which runs from the Maggiore Lake to the Po River. The two *P. nigra* populations are located 7 km from each other; the first wood is called *"La Zelata*" and the second *"Bosco Siro Negri*". About 80 *P. nigra* clones maintained in the repository of the poplar experimental station (Istituto Sperimentale per la Pioppicoltura) of Casale Monferrato (CN-Italy) were also analysed.

The strategy used in the present study to monitor the genetic similarity at molecular level utilises the microsatellite DNA. The microsatellites are particularly attractive in distinguishing differences inside a population or between two different populations, since the level of variation detected at microsatellite loci is higher than that detected by any other molecular assay, such as isozymes analysis. Microsatellites are highly polymorphic, tandemly repeated DNA sequences with a core sequence of 2-4 bases (GA, CTT, or GATA, for example). The polymorphism found in repeated DNA is due to variations in copy number of the core; for example, one tree may contain 10 copies of the repeat, whereas others may contain 11, 12, or more copies. The differences in repeat length can be visualised using the sequence tagged microsatellite sites (STMS) approach. For this PCR-based method, specific pairs of primers, which are complementary to unique flanking DNA sequences of the microsatellite, are used to amplify the fragment containing the microsatellite of the genome of *P. nigra*. Furthermore, microsatellites are co-dominant markers, so all the alleles present at the heterozygous state can be detectable. We used six pairs of primers to detect the different alleles of the populations, of the gene bank, and of the germinating seeds of three selected female trees of the *"La Zelat"* wood to detect if a putative dominant male exists in the population and the pollination is not a random event. The favourite individual will be detected comparing the microsatellite pattern of the seeds.

The molecular data produced were analysed with the most common statistical analysis packages for codominant markers such as Pop gene or Ntsys to determine genetic distance or similarity among individuals and between the two populations and the gene bank.

Poplar-Eucalyptus glued laminated timber

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The authors investigated the properties of small glued laminated beams (80 mm in width, 115 mm in height, and 2 m in length) composed of seven mechanically graded laminations of poplar *(Populus* x *euramerican*a, Neva clone) and eucalyptus *(Eucalyptus grandi*s) in different combinations. Tests were carried out to determine their modulus of elasticity, bending strength, and shear modulus; in addition, the bonding reliability was evaluated by means of delamination and shear tests in the glue lines. The bonding quality was very high in all cases; the maximum structural efficiency was obtained when only 2/7 of the transversal section of the beam was made of eucalyptus (i.e., two outer laminations in eucalyptus and five in poplar).

A willow breeding program for sawing and paper industries

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Willows *(Salix* spp.) are interesting and promising forest trees because of their high growth rate, their good performance in lowlands, their capacity for use as a renewable source of short fibre and biomass for energy, their positive effect against the erosion, and a value in the landscape. There is broad variability in the *Salix* genus. However, the number of studied species and forms is very small, so the commercial clones in the world are based on a restricted genetic base. In this technical contribution, a breeding program is proposed that considers a recurrent selection method to obtain improved material and to help increase the variability for future breeding programs. For *Salix humboldtiana*, the only native willow in South America, the germoplasm collection would also contribute to its conservation.

Poplar and global climatic changes: An overview with emphasis on field-grown trees exposed to elevated atmospheric CO_2

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Because of their prominent role in global bio-productivity and their complex structure and function, forests and tree species deserve particular attention in studies on the likely impact of elevated atmospheric CO_2 on terrestrial vegetation. The need to assess the role of forests in the global cycling of carbon and how that role will change as the atmospheric concentration of CO_2 increases has therefore spawned many experiments. In this contribution the results of field experiments on different poplar *(Populus)* species and hybrids over several growing seasons are reviewed. In particular the effect of elevated atmospheric CO_2 concentrations on the growth, development, and productivity will be reviewed, but also some ozone responses will be presented. Most poplar species and hybrids seem to respond quite strongly to increased CO_2 (and ozone) concentrations, but important species as well as clonal differences in this response have already been demonstrated. Experiments with trees in open-top chambers under field conditions have provided data on longer term responses to elevated CO_2 under field conditions, have confirmed some of the conclusions from previous seedling studies, and have challenged other conclusions at a larger scale. Below ground responses seem to be extremely important because they directly affect the interacting cycles of carbon, water, and nutrients. Results from various studies (incl. from the literature) will be discussed, together with

past and ongoing studies of our own research group within the frame-work of European funded research projects. Recent observations of a free air CO_2 enrichment (POPFACE) study on poplar trees will also be presented and discussed. Furthermore, some comparisons with responses of poplar to increasing tropospheric ozone levels will be made. Our current knowledge is sufficiently large with regard to how the carbon uptake process and individual tree growth respond under atmospheric changes, but more emphasis should be put in future experiments (such as FACE studies) on the interactions between various processes, as well as on below ground responses. Poplar has proven to be a very useful species in the studies of tree and ecosystem responses to increasing atmospheric CO_2 (and ozone) levels.

Xylem ABA accelerates leaf senescence by modulating polyamine and ethylene biosynthesis in water-stressed poplar plants

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The effect of endogenous and exogenous ABA on polyamines (PA's) and ethylene synthesis and the relevance to leaf senescence in 1-year-old rooted cuttings of a drought-sensitive poplar genotype *Populus* x *euramericana* cv. I-214 (Italica) and a drought-tolerant genotype *P. 'popularis* 35-44' (Popularis) were studied. The water stress (30% field capacity, soil water potential -2.108 MPa) significantly increased ABA concentration in xylem sap of both genotypes, and leaf abscission occurred only in Italica, following a sustained great increase of xylem (ABA) (1.73_M). However, under drought conditions Popularis exhibited a transitory and moderate increase of xylem (ABA) (0.69_M) and no leaves abscised. The supply of ABA to the transpiration stream, which increased xylem (ABA) to 1.7-1.8_M caused leaf abscission in both genotypes. Therefore, our results proved that ABA can replace drought in inducing leaf abscission with a threshold value around 1.7-1.8_M. Elevation of xylem (ABA) inhibited PA's synthesis but promoted ethylene synthesis simultaneously. ABA appeared to induce ethylene formation through stimulation of ACC. Ethylene emission was a transient response to ABA increase and typically declined within 3 days of treatment. The ABA increase over 1.7_M severely restricted PA's synthesis in aged leaves, and leaf abscission occurred following a progressive decline of PA's, when putrescine decreased below ca. 0,5_mol g^{-1}, and spermine (Spm) and spermidine (Spd) became almost undetectable by HPLC. In conclusion, drastic reduction in PA's, especially Spd and Spm may increase the sensitivity of leaf tissues to ethylene. Young leaves did not shed during the period corresponding to the increase in ABA, appearing to be the result of less reduced

PA's. Compared with Popularis, the inhibitory effect of ABA on PA's synthesis was more pronounced in Italica, the drought-sensitive genotype. On the other hand, Italica plants had typically higher ethylene emission rates than Popularis. These observations demonstrated our previous finding that the shoots of Popularis were more ABA tolerant than those of Italica.

Effect of mycorrhizal fungi, bacteria, a rooting hormone, and three levels of fertilizer on the growth and nutrient uptake of poplar cuttings

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Four poplar cuttings (MP, NP, AP, and WP) were inoculated with six species of ectomycorrhizal fungi *(Hebeloma longicaudum*, *Laccaria bicolor*, *Paxillus involutu*s, *Pisolithus tinctoriu*s, *Rhizopogon vinicolor*, and *Suillus tomentou*s), one species of arbuscular mycorrhizal fungus *(Glomus intraradice*s), two species of bacteria *(Agrobacterium* sp. and *Burkholderia cepacia*), treated with a rooting hormone (Stim Root 3, containing 0.8% IBA rooting powder) and grown under three levels of fertiliser for 10 weeks. In MP cuttings, higher seedling growth and lower shoot-root ratio was observed when inoculated with *G. intraradice*s, *P. involutu*s, *P. tinctoriu*s, and *P. involutus* + *B. cepacia* at all fertiliser levels. Mycorrhizal colonisation was significantly higher when inoculated with *G. intraradice*s, *P. involutu*s, *P. tinctoriu*s, and *P. involutus* + *B. cepacia* at all fertiliser levels. Zinc, copper, and iron contents were significantly higher when inoculated with *P. involutus* + *B. cepacia*. Nitrogen, phosphorus, potassium, boron, and manganese contents did not differ significantly between the treatments. In NP cuttings, higher seedling growth and lower shoot-root ratio were observed when inoculated with *G. intraradice*s, *L. bicolo*r, *P. involutu*s, *P. tinctoriu*s, and *P. involutus* + *B. cepacia* at all fertiliser levels. Mycorrhizal colonisation was significantly higher when inoculated with *G. intraradice*s, *P. involutu*s, *P. tinctoriu*s, and *P. involutus* + *B. cepacia* at all fertiliser levels. Phosphorus and boron contents were significantly higher when inoculated with *G. intraradice*s. Zinc content was higher when inoculated with *G. intraradices* and *B. cepacia*. Copper and iron contents were higher when inoculated with *G. intraradice*s, *P. involutu*s, and *B. cepacia*. The amounts of nitrogen, potassium, and manganese did not differ significantly between treatments. In AP cuttings, higher seedling growth and lower shoot:root ratio were observed when inoculated with *G. intraradice*s, *H. longicaudum*, *L. bicolor*, *P. involutu*s, *P. tinctoriu*s, and *P. involutus* + *B. cepacia* at 67% and 100% fertiliser levels. Mycorrhizal colonization was significantly higher when inoculated with *G. intraradice*s, *P. involutu*s, and *B. cepacia* + *P. involutus* at all fertiliser levels. Nitrogen content was significantly higher when inoculated with *L. bicolor*. The amounts of phosphorus and copper were higher when inoculated with *B. cepacia* + *P. involutu*s. Iron content was

higher when inoculated with *G. intraradices* and SR3. The amounts of potassium zinc, boron, and manganese did not differ significantly between treatments. In WP cuttings, higher seedling growth and lower shoot-root ratio were observed when inoculated with *G. intraradice*s, *L. bicolo*r, *P. involutu*s, *P. tinctoriu*s, and *B. cepacia* + *P. involutu*s. Mycorrhizal colonisation was higher when inoculated with *G. intraradice*s, *P. involutu*s, *P. tinctoriu*s, and *B. cepacia* + *P. involutus* at all fertilizer levels. Phosphorus, potassium, zinc, and boron contents were significantly higher when inoculated with *G. intraradice*s. Copper and iron contents were higher when inoculated with *G. intraradices* and *B. cepacia* + *P. involutu*s. The amounts of nitrogen and manganese did not differ significantly between treatments.

Cultivation of American poplars in Sweden

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The first American poplars were introduced to Europe more than 300 years ago. The development of the match industry led to increase interest in Sweden for hybrid poplars and hybrid aspen in the middle of the 19th century. But only a few hundred hectares of poplar plantations exist in Sweden today. Most plant materials in Sweden in former days came from Oregon and Washington from latitudes 42-480 N. Sweden is located 55-70 ^{o} N. Thus, there were phenology problems. The following poplar plant material exists in Sweden today:

1. the very old collection (origin unknown)
2. the 1940s collection (most from Oregon – Washington)
3. the Steenackers collection (most from Oregon – Washington, but selected for Sweden)
4. the British Columbia collection (from British Columbia and Alaska)

Some production results included:

SÅNGLETORP, 33 ha, hybrid poplars, planted in 1991, spacing 3 x 3 m.
Standing woody biomass: 60 tonnes DM/ha (2/3 pulp)
Production 1999: 14-18 tonnes DM/ha (Collection 2)

RYDSGÅRD, 11 ha, hybrid poplars, planted in 1991, spacing 3 x 3 m
Standing woody biomass: 65 tonnes DM/ha
Production 1999: 12-15 tonnes DM/ha (Collection 2)

HYBY, 29 ha, hybrid aspen. Planted in 1993, spacing 3 x 3 m
Standing woody biomass: 10 tonnes DM/ha
Production 1 999: 3-4 tonnes DM/ha (Collection 2)

KARINSLUND, plots, hybrid poplars, planted in 1990, spacing 3 x 2 m, irrigated, fertilised
Standing woody biomass: 10 kg DM/m ^{2}
Production 1 999: 1.5 kg DM/m ^{2} (10 best clones; Collection 3)

MALINS HED, plots, hybrid poplars, planted in 1998, spacing 3 x 3 m, irrigated fertilised (Collection 4)

There are still problems: They include leaf rusts, insects, bacterial cankers, economic factors. Also, all cultivation must be fenced because of herbivores.

Micropropagation of Salix *spp. for foliate meristems*

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In this article we detail the procedures used for the micropropagation of foliate meristems in 25 provenances of *Salix* spp. Detailed different protocols of chemical disinfection of the vegetative material were tested; the best results were obtained by alternate applications of a mixture of fungicides (Benlate and Captan) and a solution of commercial chlorine at 10% for 20 minutes. A culture medium modified from Murashige y Skoog (1962) was used. The vegetable hormones applied for rooting and multiplication of the explants were benzyladenine (BA) and gibberelic acid (GA3); the most effective concentrations were 0.1 mg/l of BA and 1.0 mg/l of GA3. In the acclimatisation stage, the substrate with best results was the mixture of equal parts of "Lampa sand" and Sunshine M16 5 Plug, which produced a survival of more than 80%. This technology was an appropriate tool for cleaning available vegetative material with quarantine problems.

Western Minnesota poplar plantations show consistent positive response to fertilization

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Optimal production of poplar requires large amounts of nitrogen (N) balanced with other essential mineral nutrients. Yet many poplar plantings in Minnesota are not fertilised and diagnostic techniques for identifying nutrient balance are not well developed. This study was initiated to compare fertiliser response for a variety of hybrid poplar clones growing at a number of sites in the Oklee, MN, plantation network. A total of eight experiments were established at six locations containing three different *Populus deltoides* x *P. nigra* hybrid poplar clones (DN17, DN34, and DN182). Treatments included unfertilised controls compared with two fertilised treatments. Both fertiliser treatments received 50 kg N/ha

applied as either urea or in a complete fertiliser treatment. The complete fertiliser treatment plots received an 18-18-18 formulation with 2.5% sulphur (5) plus micronutrients. Ammoniacal N and sulphate were included in the blend to lower pH to improve nutrient availability. The two treatments were expected to 1) stimulate tree productivity and 2) differentially affect nutrient ratios to test techniques for diagnosing poplar nutritional balance. Diameter growth, leaf and canopy characteristics, and foliar nutrient concentrations were measured. Consistent response to fertiliser treatments was observed for growth, leaf, and canopy characteristics. Fertiliser treatments increased growth for each site and clone, but the differences between the treated plots and controls varied from 12 to 41%. The average relative diameter growth increase over untreated plots was the same for both treatments (urea, 21.0%; blend, 21.5%), considerably less than that estimated using absolute growth (urea, 27.1%; blend, 33.6%). Significant increases due to the fertiliser blend over urea were found only for DN34. Leaf N and P concentrations increased significantly due to fertiliser treatments at several study sites; Ca and Mg tended to decrease in response to treatment. Diagnostic and Recommendation Integrated System (DRIS) techniques showed patterns consistent with fertiliser treatment, and they will subsequently be used to maintain balance through adjustments to the fertiliser blend treatment, and to monitor the controls and N-only treatment. This foliar nutrient analysis method is being developed for poplar as a simple tool for plantation managers to maintain optimal nutrition.

The strong positive growth response to moderate fertilisation treatment demonstrates the importance of fertiliser additions to Minnesota poplar plantations. The positive results were easily distinguished in this experiment due to the powerful multi-site design that allowed tests of clone, site, and treatment interactions. Although relatively large treatment effects were observed, optimal site-specific fertiliser prescriptions need to be identified; therefore, it is critical to further develop diagnostic techniques that include micronutrients and norms that define optimal balance for the range of poplar clones used in Minnesota. Nonetheless, productivity increases exceeding 50% of the controls are easily foreseen by proper nutrient management.

Transformation of elite white poplar (Populus alba *L.) with a stilbene synthase-encoding gene using* Agrobacterium tumefaciens

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The aim of this study was to obtain transgenic white poplar plants with enhanced resistance to fungal diseases. Internodal stem segments of *Populus alba* L. (cv. Villafranca) were co-cultivated with EHA105 disarmed *Agrobacterium tuinefaciens* strain. The binary vector pGA111 contained the coding region of the stilbene synthase *(StS*y) gene from grape *(Vitis vinifera* L.) and the neomycin phosphotransferase II *(npt*I) gene. Putative transgenic plantlets were regenerated from different calluses and then selected on a medium containing kanamycin to test rooting. Molecular and biochemical analyses of gene expression are currently underway. Villafranca kanamycin-resistant plant lines will be tested for improved resistance to *Melampsora* spp.

An overview of Melampsora *attack in Argentina*

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The different kinds of rust are among the most harmful phyto-pathological organisms. They parasitize a huge range of species and lead to important losses in various crops, and poplars are not an exception. Two large epidemics were reported in the Delta River Paraná area, Argentine. The first one, due to *Melampsora medusae*, forced the farmers to replace carolino stands *(Populus deltoides* subsp. *angulata* cv. *carolinensi*s) with criollo stands *(Populus nigra* cv. Itálica) in 1920, which were decimated by *Melampsora larici-populina* in the 1940s. Afterwards rust was not a problem for the commercial plantations, because trees were infected only towards the end of the growing season. However, since 1994 rust attacks have begun earlier and have become more and more intensive, causing severe defoliation with a concomitant lose of yield in stoolbeds and plantations.
In the past few years the intensity of infections has changed with environmental conditions during the growing season, the microclimate of the site, and clonal susceptibility. Nevertheless, the general behaviour of the attacks seems due to the emergence of a new race of rust that has overcome the resistant genes of the most widespread clones. That situation has created the need to modify the structure of commercial plantations and to intensify the selection for genetic resistance, as well as reduce the damage caused by rust in actual plantations. In the present paper, we report the resistance of clones cultivated in the Delta River Paraná area and in our breeding lines, as well as the results of chemical control in stoolbeds.

Economic evaluation of intercropping with annual crops associated with poplar plantations

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A weakness associated with poplar production in Chile is its low economic return. This situation occurs because of the long period between the establishment of a plantation and the sale of its production (from 9 to 16 years). To increase the profitability of the poplar plantation, an agroforestry system was studied to evaluate the economic impact of several annual species cultivated as intercrops from the beginning of the plantation. This impact was measured through the economic yield of the annual crops in the cash flow investment inputs for a 2-year period (1998-1999 and 1999-2000). The evaluations were made in poplar plantations (hybrid I-488) in the VI Region. During the first year of the poplar trees, the behaviour of the following annual crops was evaluated: onion, tomato, sweet corn, green beans, and potato. In the second year, winter species were included: horsebeans, peas, broccoli, cauliflower, lettuce, early onion, wheat, and oats; after these winter crops, a group of summer crops was used: tomato, corn choclero, Italian pumpkin, green beans and immature beans, onions, and lettuce. For the economic evaluation, the partial budget method was used. All the economic evaluations were made with real prices as of March 2000, without VAT. Economic indicators such as gross income, direct costs, gross marginal returns, relationship of gross income/operational costs and investments were determined all for 1 ha of the agroforestry system in the poplar plantation.

The results indicate that in the first year all the species showed a positive gross marginal return/ha of the agroforestry system, compared with the forest species alone. The range of gross marginal return fluctuated between 1.2 million pesos (onions) and 53 thousand pesos (tomato)/ha. In the second year, the gross marginal return for the winter crops was positive. However, the economic indicators began to decay for the summer crops, due to agronomic reasons (decrease of the yields because of an increase in shade).

Cottonwood leaf beetle defoliation impact on Populus *growth*

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The impact of cottonwood leaf beetle, *Chrysomela scripta* F. (Coleoptera: Chiysomelidae), defoliation on four *Populus* clones was measured under field conditions. *C. scripta* is the most important defoliator of many fast-growing *Populus* species in short-rotation woody crop systems in North America. Defoliation can result in decreased growth and biomass accumulation, multiple

terminals, increased susceptibility to other pests, and even tree mortality. However, there is a paucity of detailed information on long-term impacts of defoliation on biomass production under plantation conditions. The four *Populus* spp. clones used in this study were NM2, D105, DN 34 (Eugenei), and 94x04-03. A split-plot design was used for two growing seasons in central Iowa, USA. One half of each plot was protected from defoliation using *Bacillus thuringiensis* formulations applied at the peak egg hatch of each *C. scripta* generation. Native *C. scripta* were allowed to infest and defoliate the other half of the plots. Defoliation ratings ranged from 0 (no *C. scripta* feeding) to 4 (over 75% defoliation on leaf plastochron index 1-8) and were taken weekly throughout both growing seasons. Tree diameter at 1 m and height were measured at the end of the 1998 and 1999 growing seasons; these measurements were used to calculate above ground stem volume. Defoliation ratings were significantly higher on all clones in unprotected plots. Diameter, height, and stem volume for all four clones were reduced significantly in unprotected plots as a result of *C. scripta* defoliation. Stem volume loss was 42% in clone NM2, 50% in D105, 57% in Eugenei, and 58% in 94x04-03 after two growing seasons. Trees in the unprotected plots showed increased lateral branching and terminal mortality compared with trees in the protected plots. Results from this study quantify the deleterious impact that *C. scripta* defoliation has on *Populus* growth and stem volume accumulation. They are a measure of the value that should be placed on finding effective, environmentally sound management strategies for this pest.

Management of aspen and mixed aspen forests for sustainable production

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Of all the *Populus* species native to North America *Populus tremuloide*s, or aspen, has the largest native range and the greatest amount of harvested volume. Most of this aspen is harvested in the upper Great Lakes region and the boreal mixed-wood region of Canada. With over 20 million m^3 harvested in 1998, the utilisation of aspen in these areas has become an important economic consideration. Projected usage is expected to remain level or increase for the foreseeable future as aspen becomes a preferred species for products such as pulp, paper, and oriented strand board. As the harvest and utilisation of aspen has increased in the past 10 to 15 years, concepts such as ecosystem management, conservation of biodiversity, the importance of riparian areas, and mixed species management have mandated different approaches to aspen management. These silvicultural systems must capitalise on the biological attributes of aspen to allow forest managers to meet both their ecological and economic needs. The silvicultural systems designed to meet these needs are founded in basic biological concepts such as genetic variation and structure, reproductive characteristics, and site requirements.

The oldest aspen silvicultural system and the one upon which all others are based calls for the harvesting of stems to promote root suckers that become crop trees over the life of the next stand. This method takes advantage of aspens' regenerative powers to reclaim a site in an economically efficient manner while maintaining most, if not all, of the initial genetic diversity. Other silvicultural systems that leave trees, or undisturbed patches, or even commercial and precommercial thinning practices, still rely on a final harvest of mature stems to regenerate the stand. New advances in harvest and utilisation technology now allow for smaller material to be utilised and offer opportunities for increasing species diversity, decreasing soil disturbance, shortening rotation ages, and allowing multiple entries over the life of a stand.

Ten lessons from ten years of research in Populus production systems

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Ten years of experience with short-rotation *Populus* plantations in western Washington, USA, provided much information and experience on tree and stand response to cultural practices and management regimes. We learned 10 important lessons that can help researchers and managers assess and manage clonal poplar plantations. Our four key lessons on assessing and predicting tree and plantation performance were:

1. The size of terminal leaves is strongly related to tree growth, easy to measure, and offers a useful indicator of present and future productivity.

2. Large plots are needed to accurately evaluate clonal differences in tree growth, biomass yield per hectare, and stockability.

3. Use of simple competition indices in analysis of trials can clarify clonal responses to competition and cultural practices.

4. Harmonised equations provide more consistent estimates of biomass and biomass increment than do independent equations for each age and cultural treatment.

The other six lessons provide guidance about planting stock, selection and deployment of clones, and rotation length:

5. At least one above ground healthy axillary bud is needed on each cutting for establishment success; this becomes important when making cuttings for clones with high sylleptic branching.

6. Yield of monoclonal plantings is equal or greater, biomass is more uniform, and inventory is more evenly balanced among clones than in polyclonal plantings of the same clones.

7. Selection of wind-resistant clones is probably the most effective approach to reducing wind damage on most sites. Spacing and clonal deployment decisions can also help reduce damage.

8. Spacing has strong effects on individual tree growth, phenology, yield, patterns of biomass increment, and optimal rotation length. Spacing should provide approximately 6.5 m^2 per tree if mean tree diameter at harvest is targeted at 15 cm, as needed for reasonable harvesting costs.

9. "Woodgrass"—a system involving very high densities (100K to 600K rootstocks per ha) and annual harvests—has little promise for growing *Populus* biomass. Yields are lower, costs higher, and biomass characteristics less desirable than for wider spaced systems with slightly longer rotations.

10. Faster growth in short-rotation regimes of the same length (age) results in wood of increased mean fiber length and higher density because a greater proportion of the wood is contained in the outer, older rings.

Conservation of natural ecosystems of poplar and willow

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Natural ecosystems of poplar and willow are relatively scarce. To preserve these ecosystems, we must take into account not only the different species of plants and animals and their genetic structures, but also as the whole system. We know much about the different components that together make an ecosystem, but relatively little about the system as such. Ecosystem managers have to deal with many influences that come from the outside the ecosystem: not only upstream and downstream, but also perpendicular to the river.

One of the major problems is the influence of mankind. Nature is still rather often considered as secondary to economics. Channelled or dammed rivers in many cases are the cause of disturbed environments. Agriculture is another cause. Besides that, rivers most of the time run through more than one country, which is a political problem. We have to accept that man caused the loss of parts of ecosystems and sometimes even ruined ecosystems. In case we want to restore

such ecosystems, we will have to agree to what extent we accept that man should actively restore such ecosystems or that nature must do this job. Should it be a 100% natural process or can we allow it to be partly artificial?

The spontaneous dynamic character of the pioneer species such as poplar and willow causes another problem. At one particular location the situation will not always be the same: sometimes species disappear and other times they are replaced by other species in the succession. Do we want to keep the species as such or do we prefer a dynamic ecosystem? Does the conservation of ecosystems serve the conservation of genetic variation and biodiversity or do we conserve genes to restore natural ecosystems? Many of these questions will be discussed and will need to be answered by the group of specialists that will meet at the IPC 2000 in Portland, Oregon, in September 2000.

Growth, production, and contribution of farm forestry plantations in Punjab (India)

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The economy of the Punjab State is mainly agrarian with 83 to 84% of its total area under crop cultivation. The recorded forest area is just 5.7%, out of which only 2.2% has a crown density of more than 40%. To diversify the highly intensive and over exhaustive agriculture as well as to meet the ever-increasing demand for small timber and fuelwood, tree plantations have been encouraged on farmlands over the last 2 decades. The main thrust was on *Eucalyptus tereticornis* plantations in the early 1980s, and as a result the state had a surplus in farm-grown eucalypt timber leading to distress sales and low prices. Farmers are now planting poplar - *Populus deltoides* Bartr. Ex Marsh., clone G-3 and G-48 - and again are getting apprehensive about a poplar timber glut and sharp fall in sale price. A study was carried out at P.A.U. to assess the growth performance of poplar (1 year to 9 years old) both in block and border row plantations. The growth of tree height, dbh, and basal area were correlated with age, and regression equations were developed. Comparative growth performance of similar-aged plantations at 5, 6, and 9 years, as well as of intercropped and non-intercropped plantations, was studied. The maximum mean annual increment (MAI) potential of 59.1 m^3/ha/annum was achieved in well-managed intercropped plantations in riverbed areas. The resident farmers achieved a productivity of 444.14 m^3 at 9 years of age (MAI 49.3 m^3/ha/annum), but productivity was just 83.97 m m^3 (MAI 9.33 m^3/ha/annum) in neglected conditions. Timber volume and weight production in 18 block plantations were also worked out, giving MAI of 36.6 m^3/ha/annum and 49.0 m^3/ha/annum at 5-, 6-, and 9-year rotations, respectively. The farmers harvest their farm plantations generally at 6-7 years when trees attain 90 cm+ girth at breast height, and they sell the timber to plywood mills and timber yards. The growth of farm forestry has led to the

development of plywood and medium density fibreboard industries in Punjab and neighbouring states.

Potential impacts of hybrid poplar plantations on black cottonwood populations

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Hybrid poplar plantations *(Populus trichocarpa* x *Populus deltoide*s) are a relatively new feature on the landscape in the Pacific Northwest, and these plantations may soon include genetically engineered trees. Meanwhile, many wild cottonwood populations *(Populus* spp.) are highly degraded due in part to logging, dams, grazing, and agriculture. We are assessing potential genetic impacts of plantations on wild cottonwood by studying gene flow from plantations into wild populations, and comparing establishment and growth of hybrid and wild trees under natural and experimental conditions. To predict gene flow from transgenic plantations, it is necessary to understand both the dynamics of gene movement within and between populations, and the ability of hybrid trees to produce fit progeny. We have directly measured gene movement from hybrid plantations and in wild populations using molecular markers and paternity analysis methods. We have also assessed establishment and competitiveness of hybrid seedlings in the wild. Using data from these gene flow studies, field trials, remote sensing databases, and the literature, we have developed a spatially explicit computer model to simulate transgene spread from plantations in the Pacific Northwest of the United States. These studies have direct implications for the conservation of genetic resources of wild cottonwood populations, as well as for the prevention of gene escape from plantations of transgenic trees.

Tree growth and properties of wood from a poplar stand affected by acid rain and air pollution

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Wood properties from about 30 trees *(Populus euramericana*) selected from healthy damaged forests were measured to evaluate the possible impacts of acid rain on wood quality and utilisation. On the heavily damaged site, the mean pH value ranged from 3.7 to 4.5, and sulphate loading diminished from 40 to 20

kg/ha/yr. Quantitative and qualitative studies on ring width patterns and on physical and mechanical strength indicated that the responses of diseased and healthy poplars differed. Acid rain suppressed growth of trees in damaged forests. Compared with healthy poplars, the width of growth ring was lower in diseased poplars and the sapwood portion decreased as well; these differences between diseased and healthy poplars were significant. The water content across the stem area differed enormously between diseased and healthy poplars; the lower water content of sapwood in diseased poplar was associated with a decrease of sapwood portion. A difference of shrinkage percentage was observed in diseased poplar. Compared to wood from healthy poplars, the basic density, air-dry density, and oven-dry density of wood from diseased poplars was reduced by 4.01%, 3.97%, and 3.60%, respectively. A difference of shrinkage percentage of wood from diseased poplar was observed. The bending strength, compression strength, and hardness were at normal levels and independent of damage degree. The modulus of elasticity of wood from diseased poplars was 12.86% lower than from healthy poplar. Although the mean values of impact bending from diseased and healthy trees were the same, the deviation was entirely different.

Biomass production from I-214 poplars

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Experimental plantations with 1/0-year-old rooted cuttings of P. x *euramericana* (Dode) Guinier cv. I-214 were established at spacing of 0.50 m x 1.93 m, 1.50 m x 1.93 m and 2.50 m x 1.93 m, in two randomised blocks with three repetition plots. Green volume, dry weight, and energy values of wood were estimated for plantation plots to construct yield tables based on volume, dry weight, and energy production. Complete trees, including their stems, roots, and branches, were sampled. Incremental equations were developed for arranging yield tables, that were used in estimating the rotation ages for maximum production of green volume, dry weight, and energy as shown in the table below.

Kynd of yields		Period of rotations by plantatio spacing					
		0.50m x 1.93m		1.50m x 1.93m		2.50 x 1.93m	
		Age	Yield	Age	Yield	Age	Yield
Green volume (m^3 /ha/year)		5	21.291	7	13.671	8	12.086
Dry weight (ton/ha/year)		6	5.930	7	3.814	9	3.379
Energy	Lower (1000 kcal/ha/year)	6	25 826	7	16 624	9	14 736
	Upper (1000 kcal/ha/year)	6	26 403	7	16 995	9	15 065

Genetic modification of poplar wood physical and chemical properties

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On behalf of the U.S. Department of Energy, Biofuels Feedstock Development Program, the author executed an intensive appraisal of global literature on opportunities for and feasibility of genetically modifying wood properties of short-rotation poplars. In addition, a workshop was conducted to critique/revise results of the appraisal and to ensure that conclusions reflect the most recent as well as ongoing research. Findings indicate that recent advances in technology have reduced the costs and increased the efficiency with which both physical and chemical properties can be measured. Reflectance near infrared analyses, for example, can be used to quantify lignin and cellulose contents in just minutes rather than days or weeks, using less than a gram of wood. Even fibril angle, a critical but difficult to assess trait, can now be measured inexpensively. Accordingly, much new genetic information has been accumulated in recent years, most of which confirms and/or indicates that genetic variation and control are sufficient for improvement of wood properties via classical selection and breeding. While better information on correlation among traits is still needed, evidence suggests that such relationships, although sometimes negative, are unlikely to impede improvement. For most traits, genotype x environment interactions are not limiting. In consequence, traits such as dry wood substance production per unit area and time can be improved, with significant benefits to the energy, paper, and solid wood products industries. Results also indicate that lignin content *per se* can be reduced, albeit slowly, via this approach. Advances in recombinant DNA technology have made possible construction of genetic maps, and genetic markers can now be applied to manage breeding and production populations. These and newer techniques are being used to characterise quantitative trait loci and candidate genes. Continued research promises to facilitate improvement of important wood properties, especially those that are difficult or expensive to measure. Genetic transformation can add valuable genes from unrelated species and/or increase or decrease activity of genes governing important traits. Transformation can also save time via bypassing the sexual cycle and often lengthy generation intervals. Progress on genetic modification via this route has been significant. Several laboratories have produced and are field testing transgenic trees that have significantly reduced lignin and increased cellulose contents, but otherwise normal growth and development. In sum, recent developments have been such that opportunities for genetically modifying important wood properties, whether for energy, paper, or solid wood products, can now be realised. So-called designer varieties with rapid growth, high dry wood substance, and lower lignin content should be commercially available in the near future.

The genetic architecture of **Salix laevigata** *as a result of clonal site occupation under a range of hydrologic conditions*

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Salix laevigata has two means of occupying a site: sexual reproduction by dissemination of seeds and clonal spread by sprouting from vegetative material. We hypothesise that local environmental conditions have an effect on the relative importance of these two avenues to site occupation. Therefore, we expect to find variability in the genetic architecture of *Salix laevigata* in riparian zones across California. This study focuses on hydrologic variables, as they tend to have the most significant influence on vegetation in riparian zones. Forty years of hydrologic data are used to categories each site into groups by disturbance level, regression limb pattern, and peak discharge. Each site is then sampled for the size and distribution of *Salix laevigata* clones. We use Amplified Fragment Length Polymorphisms (AFLPs) to identify and map distinct genetic individuals. Using statistical analysis, relationships between hydrologic variables and variation in genetic architecture are analysed. Early data show significant differences in genetic architecture between sites subject to different hydrologic patterns.

Poplar silviculture: Applying the European model to American poplar farming

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In response to increased environmental regulation and declining public timber supply, Potlatch began farming short-rotation hybrid poplar in 1993. The 9,000-ha (22,500-acre) farm, located in north-central Oregon, was planned to produce 25% of the chip fibre requirements for Potlatch's Lewiston, ID, pulp and paperboard operations. Over the last 6 years, 7,000 ha (17,200 acres) of operational plantations were established at dense spacing, focusing on the production of pulp logs. In 1998 Potlatch began to examine the use of hybrid poplar in higher value solid wood products. We have identified that opportunities exist to market hybrid poplar for use in plywood, furniture stock, molding, and other non-structural applications. Realisation of these opportunities presented silvicultural challenges that have not been applied extensively to hybrid poplar in North America. Potlatch is in the process of converting the farm to saw log production, emphasising thinning in the dense plantations, branch pruning to maximise clear lumber recovery, and longer rotations to increase tree size. All future development will be planted at a wider spacing (3.7 x 3.7 m) and managed for longer rotations (11-12 years). Conversion activities, mill trials, and early

results from tree performance in response to thinning and pruning will be presented. In addition, results from herbicide site preparation and planting stock size trials will be discussed.

Effects of environmental conditions on some poplar species

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The present study was carried out in two successive seasons, 1995/96 and 1996/97, to evaluate the growth of the poplar species *Populus alba* L., *P. nigra* L., and *P. nigra* L. cv. Italica from five different provenances. The Horticulture Research Institute (H.R.I.) Giza represented the cultivated land. Seds (Bani Sweif) represented middle Egypt. Nobaria (EL-Behera) represented the north-western delta and calcareous soil. Shark El-Bohirat (southwest of Sinai) represented desert land in Sinai, and Sakha (Kafi El-Sheikh) represented the northern delta, which has saline soil and suffers from a high water table. Survival percentage of *P. nigra* and *P. nigra* cv. Italica showed a highly significant increase compared to *P. alba* in all provenances. The highly significant increment stem length and diameter were arranged as follows: *P. nigr*a, *P. alb*a, and *P. nigra* cv. Italica, in a descending order of all provenances. The highest stem length and diameter were obtained from H.R.I. The absorption of N:P:K was the highest in *P. alb*a, then *P. nigra* and *P. nigra* cv. Italica in descending order of all provenances. The other macronutrients and micronutrients did not have the same trend in all planted species. However, *P. alba* failed to grow in Sakha and Shark El-Bohirat due to an increase of soil Na content at Sakha and a reduction in organic matter at Shark El-Bohirat compared to the other provenances.

Molecular genetic maps of Populus deltoides and P. trichocarpa

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A FI progeny consisting of 91 individuals and issued from a cross between *Populus deltoides* and *P. trichocarpa* was used to build the linkage maps. Genetic maps of each parental species were constructed by a double pseudo-test cross strategy. RAPD, AFLP, RFLP, and SSR markers were used and integrated in the genetic maps when segregating in the ratio 1:1. The current maps were obtained using Mapmaker/Exp version 3.0 with a LOD score 3. The distance values were calculated using the Kosambi mapping function. In *P.*

*deltoide*s, 360 markers were clustered in 26 groups with more than three markers. The *P. trichocarpa* map consists of 290 markers distributed into 27 linkage groups with more than three markers. The average distance between markers is about 10 cm for the two maps. Genes involved in the common phenyl propanoid pathway and genes related to the lignin biosynthesis such as cinnamoyl CoA reductase, chalcone synthase, and the gene coding for phenyl ammonia lyase were mapped. RFLP and SSR markers, heterozygous in both parents and segregating 1:1:1:1, were used to compare linkage groups of the two species. Homology between *P. deltoides* and *P. trichocarpa* linkage groups and with linkage groups of already published maps will be discussed. The genetic maps have been used to identify genomic regions involved in various traits such as disease resistance.

Detection of genes and QTL related to rust resistance in poplar

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One mapping population is used for the analysis of rust resistance in poplar. It originated from an interspecific cross between *P. deltoides* used as female and *P. trichocarpa* used as male. Laboratory tests of rust resistance were done on foliar disks for races E1, E2, E3, E4, and E5 applied separately. The parent *P. deltoides* is resistant while the parent *P. trichocarpa* is susceptible for each race. Rust resistance was evaluated on the 343 progenies. Resistance to races E1, E3, and E4 showed a Mendelian inheritance. A partial resistance was observed with E2 and E5. This resistance was then decomposed in three epidemiological components for further analysis: latent period, size of uredia, and number of uredia. All components were recorded for E2 and only the latent period for E5. Analysis of variance was applied to estimate genotypic effects for all the variables. Results showed that the epidemiological components analysed exhibited genetical variation in this mapping population. Quantitative genetic analyses were used to evaluate broad sense heritabilities and genetic correlations among the traits.

Total resistance for E1, E3, and E4 was mapped in one *P. deltoides* linkage group. One SCAR marker is totally linked with this locus. For partial resistance to E2 and E5, QTL analyses were conducted for all the analysed components to underlie genomic regions involved in quantitative response. In *P. deltoide*s, all the traits were related to the locus governing total resistance to races E1, E3, and E4. One other region was linked with all the components evaluated for E2. Another putative QTL was detected for the number of uredia. A co-localisation between the chalcone synthase gene and the latent period was detected. A major QTL implied in size of uredia for E2 was detected in *P. trichocarp*a. Two

other minor QTLs were found for this trait. The major QTL was also detected in another study applied in four intraspecific halfsib families of *P. trichocarp*a. The male parent of these families is the male parent of the *P. deltoides* x *P. tricocharpa* pedigree. Two putative QTLs with minor effects were detected for the latent period evaluated for E2; one is closely linked to the phenyl ammonia lyase locus.

Study on technology of poplar deep planting in Korqin Sandy Lands

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Since 1992, a trial of deep planting poplar has been carried out in Xinglongzao forest farm and Tongyu forest farm, located in the centre and north of Korqin Sandy Lands. After several years of experimentation, under drought conditions, the survival rate of the planted poplar without root reached 90%. At 1.3 m depth, the height and diameter increment of trees of the deep planting method were better than those of the traditional planting method; the increment rates of height and diameter were 8 and 3.6%, respectively. When planted in autumn, the poplar cutting base re-absorbs enough underground water, and soil temperature rises slowly in the next spring, making it easier for cuttings to root. The cuttings grow roots first and leaves second in an environment suited to growth and survival of poplar cuttings. The technology of deep planting will spread to other places in the area.

Quantitative and qualitative performances of poplar clones tested in the Danube Valley and Danube Delta

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In similar cultures located in different ecological areas, the volumes of wood mass, cellulose content, and main traits of the wood fibres were determined for 45 clones: 29 of *Populus* x *euramerican*a, 13 of *P. deltoides* and 3 of *P.* x *interamerican*a. The volumes were based upon medium diameter at 1.3 m and medium height, using Romanian tables. The cellulose content and dimensions of wood fibres were determined on samples extracted with a Pressler drill from four trees of the clones studied. The percent of cellulose was determined using the uncorrected Hurschner-Hoffer method, based on acetic acid (d=1.4) and ethyl alcohol 96% treatments, and the diameter and length of wood fibres were measured with the apparatus “Lanametru” (precision 0.1 m) used in the wool industry.

The poplars of highly productive *Populus* x *euramericana* Sacrau 79 and I-214 had the largest unit volumes of wood mass, 3.700 - 3.867 m^3 at 28 year old and at 7 x 7 m spacing. In the cultures situated in the Danube Valley, *P*. x *euramericana* Veronese, and Dorskamp, and *P.* x *interamericana* Rap and Donk reached high production, with a medium increase in volume of 22.0 - 33.7 m^3/year/ha at 20 years old and 8 x 4 m spacing. The clone Robusta had constant values in all the situations, but below average for the tests. Cellulose content increased with the age, and the clone Robusta Ro-16 (49.3 - 53.0%) had the highest values. The length of the fibre mass in the same clones was greater in trees from the Danube Valley compared with those from the Danube Delta, and it increased with age. In the Danube Valley, tree diameters were larger than in the Danube Delta. The increases in size appear between 11 and 20 years to the Robusta Ro-16, and between 6 and 15 years in the other clones. Taking into account the standard indices for paper quality established by the Romanian paper industry, i.e., 35 - 45, all investigated clones satisfy these values, but Robusta Ro-16 is at the top and can be called the 'paper-clone'.

*Expansion of aspen (***Populus tremuloides***) in the Gaspé Peninsula, Québec, Canada, during the 20th century*

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Aspen is an important constituent of the forest mosaic in some river basins on the Gaspé Peninsula. Major disturbances such as fire, clearcutting, and spruce budworm outbreaks have been of crucial importance in the establishment and development of aspen in the area. Explorers' reports dating from the end of the 19th century suggest that aspen was distributed in the landscape in a more scattered way than it is today with only a few areas of larger concentrations. The actual distribution of aspen on the Gaspé Peninsula seems to be related to human activities. As a pioneering species, aspen can colonise disturbed sites. Our data indicate that, in the Gaspé area, it either replaced black spruce *(Picea marian*a) or balsam fir *(Abies balsame*a). However, it seems on certain stands that the successional processes are, in some ways, interrupted or non-applicable. For different reasons, black spruce can be excluded from a site and replaced by aspen after a disturbance. Then, considering its autecology, its comeback as a dominant species is somewhat illusory. On many sites where balsam fir was involved, our data suggest that periodic spruce budworm outbreaks could contribute to the maintenance of aspen dominance for some generations. Our research was conducted under the hypotheses that aspen had expanded in the Gaspé area during the 20th century and that when it replaced black spruce on a site, that change may be irreversible. It turned out that, in

some aspects, both hypotheses were right. Aspen has expanded, and the awaited shift, suggested by the classical successional model, from an aspen stand to a coniferous stand similar to the one it replaced, could, sometimes never be achieved.

Pathogenic and genetic diversity within Melampsora *spp. causing poplar rust in Europe*

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In Europe, poplar rusts are caused by three *Melampsora* species -*M. larici-populina*, *M. allii-populina*, and *M. medusae* -which are distinguished by morphological traits and host range. Within *M. larici-populina*, eight virulences have been identified, which could theoretically give rise to 256 pathotypes, of which at least 40 were already found in nature. These virulences overcome all the race-specific resistance genes present in commercial poplar cultivars. Rust population studies have shown that a new virulence can spread very fast and that its frequency can increase dramatically within a few years when the poplar population becomes uniformly susceptible to the new virulence. Rust populations are clearly adapted to host populations: numerous and complex races are found in commercial poplar stands, while few and simple races occur in native stands of *P. nigr*a. Variability in aggressiveness was also evidenced within and between pathotypes of *M. larici-populina*. Within *M. allii-populina*, incompatible interactions have been found between isolates and poplar cultivars, although no cultivar has been selected for complete resistance to this rust fungus.

The three *Melampsora* species could be readily distinguished on the basis of their ITS sequence of the rDNA. The interspecific homology of ITS sequences among the three species ranged from 87 to 90% identity, whereas the intraspecific homology ranged from 99.3 to 100% identity. The use of DNA markers also confirmed the interspecific status of *M. medusae-populina*, a new rust taxon first described in New Zealand and subsequently discovered in South Africa, but not present in Europe. Analysis of ITS sequences and DNA fingerprinting with RAPD markers confirmed that *M. medusae-populina* was an interspecific hybrid between *M. larici-populina* and *M. medusae*. *M. medusae-populina* should be considered a serious threat for poplar cultivation in Europe in case of introduction or appearance through hybridisation between *M. larici-populina* and *M. medusae*, which may occur on larch, the common alternate host.

RAPDs were used to assess the genetic diversity within *M. larici-populina* populations. A very high degree of genetic diversity was found in a collection of 96 isolates collected from different hosts in France, Belgium, and the United

Kingdom. No relationship was found between genotype, pathotype, original host, and geographical origin. This high genetic variability is likely due to the sexual reproduction on larch. Sexual versus asexual populations of *M. larici-populina* are currently under study to assess the actual role of the alternate host in the variability observed.

Spring and autumn frost tolerance of two poplar clones

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New Zealand's oceanic climate produces unpredictable weather patterns within a growing season: out-of-season frosts can be common in both spring and autumn. This frost presents problems for breeding new plant varieties, particularly when parent material originates form high latitudes and/or continental climates with defined growing seasons and hardening and de-hardening patterns. Performance of new poplar clones in New Zealand can thus be limited by susceptibility to these out-of-season frosts. Determining the frost tolerance of poplar clones can therefore assist in matching these clones with appropriate sites.

Cuttings of two poplar clones - *Populus deltoides* x *P. maximowiczii* Eridano (moderately frost tolerant) and *P. deltoides* x *P. yunnanensis* Kawa (frost susceptible) - were grown under natural conditions. At various times in the autumn and spring of 1999, cuttings were placed in controlled environment frost rooms over-night and subjected to differing levels of frost, ranging from -1 to -20°C. Cuttings were then removed to an outdoor shelter and observed for visual damage and recovery over the subsequent growing season until January 2000, when all cuttings were measured for biomass.

Eridano produced greater absolute biomass compared with Kawa. Both clones showed sharp delineation between lethal and non-lethal frost temperatures, as well as distinct trends of gradual hardening over autumn and rapid de-hardening over spring in terms of survival and subsequent growth response. Relative to control cuttings (no imposed frost), Eridano produced greater biomass at sub-lethal mid autumn frost temperatures (-12°C) compared with Kawa. There were few differences between clones after they were subjected to spring frosts, although biomass response (relative controls) was greater in Kawa compared with Eridano for a sub-lethal early spring (-4°C) frost. These differences appear to be related to phenology; Kawa was late to set and burst buds compared to Eridano. Use of controlled frost conditions to screen large amounts of trial material for frost tolerance/susceptibility shows promise, particularly for autumn frosts. Further experiments are planned to examine environmental factors that initiate hardening and de-hardening in poplars.

Effect of variability of alluvial soil properties in the Middle Danube Basin on the productivity of some black poplar clones

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The main characteristic of alluvial soils is the marked bedding and variability of mechanical composition in the layers throughout the depth of the soil profile. It is well known that even in small areas, the variability of soil properties significantly affects the productivity of poplar plantations. This study was performed in a 3.6 ha comparative experimental plantation established in the Middle Danube Basin, of uniform micro relief, with seven poplar clones and four replicates. The study results show a high effect of variability of the above soil properties on the timber volume productivity of study clones. After 19 years of test plantation development in the Middle Danube Basin, the main characteristics of the seven study clones are as follows:

a) fluvisol
- sandy form of fluvisol: diameter at breast height for seven study clones is 22.1 to 28.1 cm, volume from 210.1 to 330.4 m^3/ha
- sandy clayey form: diameter at breast height 26.5 to 28.5 cm, volume from 316.8 to 336.1 m^3/ha
- clayey form of fluvisol: diameter at breast height 29.0 to 33.5 cm, volume from 360.3 to 432.2 m^3/ha;

b) humofluvisol: diameter at breast height 28.7 to 37.4 cm, volume from 355.4 to 478.4 m^3/ha.

The study results show that the clones reacted differently to changes in soil properties. The productivity of all clones increased with the increase of the fraction silt + clay in soil layers per profile depth. The research also shows that some clones reacted more markedly to the increase of the fraction silt + clay, while some clones were more tolerant to changes in the mechanical composition of the soil in the Middle Danube Basin.

Properties of young Populus *clones*

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Studies were conducted to establish baseline information for use in characterising poplar clones *(Populus* spp.) as an energy or fibre feedstock. Size and survival of 4-year-old trees varied significantly among the 29 clones evaluated, but larger trees generally had the best survival and are highly important in clonal comparisons. The high average mortality indicated that coppicing as a management strategy to grow these clones for fibre is questionable, at least with the clones being tested. Characteristics of the wood were similar to those of soft hardwoods; the mean value of gross heat of combustion was 18.9 kJ/g (4520 cal/g); the fibre length was relatively short (0.84 mm); the ash content was 0.39%; and the specific gravity was 0.37. Mean specific gravity values for the bark + wood were 0.37 at the tree base and 0.34 at DBH (all based on green volume).

In general, wood was lower in gross heat of combustion and higher in ash content than bark, but specific gravity did not differ significantly. The whole-tree bark/wood heat of combustion was between the values for the two components. Chemical properties between selected clones were not different. Steam gasification of four poplar clones (selected from the better clones) conducted in a fluidised-bed, bench-scale reactor over a temperature range of 595º to 617º C showed no significant differences among them. The response variables considered were dry gas composition, gas higher heating value, dry gas volumetric and mass yields, carbon conversion to gas, and energy recovery.

Comparison of new P. x interamericana *clones in medium altitude areas in Spain*

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The aim of this work is to present the first results obtained by CIFOR-INIA in five experimental parcels in which the last and most modern clones of poplar are being investigated, mainly, P. x *interamericana* in relation to the most rustic clones of P. x *euramerican*a. The I-214 clone is a control, to which a productive index was set and expressed at 100%. Moreover, in some of these experimental parcels, other rustic clones that belong to *P. nigra*, *P. trichocarpa*, and *P. balsamifera* etc., are being investigated. The experiment is being carried out on dry agricultural land abandoned by traditional agriculture (winter cereals) and is located in a difficult environment for the *Populus* crop at an altitude of 1,400m. Experimental site characteristics include non-intensive populiculture, medium altitude, sustainable, no irrigation, without water table, with minimum tilling (one ploughing per year) or no ploughing in some parcels on naturally harvested grassland. The experimental plots were established in Campisábalos and Galve de Sorbe (Guadalajara, Spain) between 1996 and 1998, at 5 x 5 m spacing, with deep-root planting (2-2.5 m), 2-year-old plants and 1-year-old plants according to

the parcels, and a statistical design in random blocks. The total number of clones being investigated is 48.

Results included:

1) Clones with growth very superior to the control I-214 (> 20%): Vanagler (143%) ≈ USA:49-177 (141%) > TR-56/52 –Gazi- (129%) > USA:55-264 (124%) = USA:184-411 (124%) ≈ Hunnegem (123%).

2) Clones with growth superior to the control I-214 (between 10 and 20%): Lombardo Leonés (119%) > USA:50-197 (116%) ≈ Raspalje (114%) > TR-56/75-Anadolu- (110%) = 71.015/1 (110%).

3) Clones with a very acceptable level of growth, similar to the control I-214: 71.009/2 (109%) = Boelare (109%) > 0102/78 (105%) @ Beaupre (104%) = USA:198-565 (104%) > 69.038/6-Hoogvorst- (101%) ≈ Campeador (100%) = I-214 (100%) = Florence Biondi (100%) = Unal (100%) > Cobat-1/95 (97%) = 69.039/4-Hazendans- (97%) ≈ AFO-132 (95%) = China-2 (95%).

The five clones of *P. balsamifera* behaved the worst; their growth barely reached 25% of the control.

Poplars: trees of the people, trees of commerce, trees of the future

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Poplars have been and are important in human history and affairs. People and poplars (and willows) have been co-evolving for thousands of years. Perhaps more than any other family of woody plants that is not important for human food (fruits, nuts), poplars and willows have been "domesticated;" that is brought into continuing, purposeful interaction with human cultures. Despite their widespread use by humans, poplars and willows have never achieved the degree of recognition and research focus directed on conifers, oaks, and tropical "rain forest" species. This may be because, as their name reflects, they have been, throughout history, "trees of the people." Their rapid growth, ease of propagation, and broad ecological amplitude have made them accessible and useful to people who historically were denied access to "real" forests by geography or politics. Now, with modern breeding techniques, the continued existence of extensive areas of "wild types," and greater ecological understanding, poplars seem poised to assume an even larger role in human culture. Among their future uses will be:

• Wood supply
• Protein/feed supply

• Watershed and riparian rehabilitation and protection
• Aesthetics and urban environmental improvement
• Carbon sequestration
• Phytoremediation
• Environmental assessment and monitoring

If this future is to be realised, research on poplars has to be expanded and co-ordinated. A public awareness and attitude must be created that recognises the importance of poplars in environmental improvement and sustainable development. Emphasis must be on the vast reservoir of biological diversity that poplars represent, and on the role of that diversity in meeting human environmental and production needs. The critical ecological role of poplars in riparian zones and on mountain slopes must be linked to their use as planted trees to provide shade, feed, wood, and soil stability. An enhanced effort to collect and protect poplar germplasm, wild types, and genomic knowledge is warranted by the utility of poplars now and in the future, and by their potential role as a central organismal model for biological research on trees.

Comparison of known poplar clones in medium altitude areas in Spain

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The aim of this work is to present the first results obtained by CIFOR-INIA in six experimental parcels where known poplar clones of P. x *interamericana* are being investigated in relation to the most rustic clones of P. x *euramerican*a. The I-214 clone is a control, to which a productive index was set and expressed at 100%. Moreover, in some of these experimental parcels, other rustic clones that belong to *P. nigr*a, *P. trichocarpa* etc., are being studied. The experiment is being carried out on dry agricultural land abandoned by the traditional agriculture (winter cereals) and located in a difficult environment for the Populus crop at an altitude of 1,400 m. The experiment site characteristics include a non-intensive populiculture, medium altitude, sustainable, very long freezing periods (September to June), no irrigation, without water table, without plowing because it is on naturally harvested grassland. The experimental plots were established in Campisábalos (Guadalajara, Spain) between 1994 and 1996, at 5 x 5 m spacing, with deep-root planting (2-2.5 m), 2- year-old plants and 3-year-old plants according to the parcels, and a statistical design in random blocks. The total number of clones being investigated is 25.

Results obtained include:

1) Clones with growth similar to the control I-214±10%):

TR-56/52-Gazi- (105%) Agathe F (104%) = Beaupre (104%) > I-214 (100%) Unal (99%) > Raspalje (92%) Ghoy (91%) Donk (90%).

2) In difficult conditions (floodplain in spring), the clones 2000 Verde, Campeador, Gibecq, I-214, I-MC, L. Avanzo, and PA-1 behaved worst with a high degree of mortality.

3) In contrast, the P. x *euramericana* clones Agathe F, Florence Biondi, and Oghy showed a good response to these soil and climatic conditions.

Assessing the determinants of canopy light-use efficiency among native and hybrid poplar in a high-density planting

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Rapid canopy development among hybrid poplar, which results in high levels of light interception, is often cited as a key determinant of superior growth rates. At high planting densities (e.g., 1m spacing), canopy closure occurs quickly and light interception may reach maximum levels in two or three growing seasons. However, among clones that intercept nearly the same amount of light, there may be large differences in growth rates. As a result, poplar clones differ considerably in their light-use efficiency (LUE – biomass produced per unit light intercepted). It would be a helpful advance in the selection of native and hybrid poplar genotypes if we could elucidate the structural and functional determinants of canopy light conversion efficiency.

In May 1997, a completely randomised monoclonal block plantation of five hybrid poplar clones was established from unrooted hardwood cuttings. Two clones were *Populus deltoides* varieties (252-4 and D-105) and three were interspecific hybrids (Bucky 1 and DN-34 *[P. deltoides* x *P. nigra*], and NM-6 *[P. nigra* x *P. maximowiczii*]). Five replications of five monoclonal blocks of 36 trees each were established at 1 x 1m spacing. Canopy closure occurred for all clones by July of 1998. In 1999, intercepted light spanned a narrow range of about 8% among clones. However, above ground net biomass gain (ANBG–T acre-1) extended over an 80% range (4.0 to 7.1). As a result, LUE varied greatly among clones, and the native cottonwoods had the highest light efficiency conversions. Key traits that explained variation in LUE were canopy averages for leaf angle and leaf size, and lower canopy averages for area-based nitrogen concentrations (N_{area} —the product of leaf mass per area and mass-based N concentrations). In addition, ANBG and LUE were both strongly related to estimates of whole-canopy photosynthesis (WCP).

It is likely that all poplar clones have an “optimal” planting density, and different combinations of canopy traits may maximise LUE at various stocking levels. If these traits and their interactions could be described as the determinants of LUE, it would greatly improve the ability of growers to match clones to specific applications. In this study, high LUE was associated with traits that enhanced canopy C balance (WCP) at strong levels of canopy competition—low light attenuation at a given leaf area index (LAI) and strong physiological acclimation to light environment. Small leaves with steep inclinations allowed efficient transmission of light throughout the canopy, and low N_{area} at a given light level was able to maintain the best C balance in the darker canopy regions. Low LUE was associated with traits that constrained canopy C balance at this level of competition—high light interception at a given LAI (large, planophile leaves) and low physiological acclimation to light (high N_{area} at a given light level). At lower planting densities, the combinations of traits that would generate the highest LUE might reverse as efficient light interception would be favoured in sparse canopies.

Past, present, and future of a center for poplar culture in Hainaut (Walloon Region-Belgium)

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Since the 1950s, interest in poplar culture has increased considerably in Belgium and, in particular, in the western part of the Walloon Region where the traditions of agriculture are still well represented. Situated in western Europe, this region, called Hainaut, has one of the densest network of roads, railways, and rivers. It contributes to the development of business connections with neighbouring countries such as France, the United Kingdom, The Netherlands, Italy, and Germany. Within this area, the Centre de Populiculture du Hainaut (C.P.H.) has played a great part in spreading poplar culture. Since 1959, its main purposes have been to:

* study the problems of the poplar culture,
* support research on the best ways to increase the profitability of the poplar silviculture, and
* promote and co-ordinate different activities that improve the poplar culture.

Accordingly, the C.P.H. is supported by 570 members; almost all are landowners. It is also responsible for editing a quarterly bulletin, organising workshops or technical excursions, and maintaining a library and an office where technical advice can be provided.

The area devoted to the poplar culture in the Hainaut has grown by more than 2,100 ha in the last 30 years and is about 7,900 ha today. Among these stands, 15% are composed of young trees, 17% of juvenile trees (not yet pruned), 12% of middle-aged trees (pruned), and 56% of mature trees. The latter have a circumference, measured at breast high level, of 120 cm or more and, therefore, are potentially ready for harvesting. The average amount of wood harvested yearly is about 60,000 m^3 and should increase to more than 80,000 m^3in the next 10 years. According to sustainable forest management, the objective of the poplar silviculture developed by the C.P.H. is to produce trees with the highest wood quality and technological properties. Therefore, the pruning of living branches on the bole is highly encouraged with the result that more than 56% of the mature trees are pruned up to 8m high. While the poplar silviculture is still dominated by the old euramerican hybrids and in particular by the Robusta, new euramerican and especially interamerican hybrids have been progressively introduced. This tends to increase the genetic diversification as well as fight against the leaf rust *(Melampsora* sp.). Accordingly, one-third of the recent plantations consist of GHOY, a new euramerican hybrid of second generation. Under the favourable influence of the C.P.H. and because of the high growing potential combined with a greater resistance to the illness, their importance should increase in the near future to achieve the goal of production, i.e., a high quality poplar silviculture in the Hainaut.

The problem of Sciapteron tabaniformis *Rott. in poplar nurseries*

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Sciapteron tabaniformis Rott. is present in all regions of Turkey and presents a problem in poplar nurseries. To limit the damage it causes, attacked plants must be eliminated. In the case of intensive attack, chemical treatments are required.

Observations made while monitoring all plants (approximately 17,000 plants were examined) of different clones in 1- and 2-year-old clonal nurseries at Diyarbakir (a town in southeast Turkey) and Behiçbey (near Ankara) to determine the intensity of attack by *S. tabaniformis* have shown that in similar nursery ecological conditions, different degrees of attack can be observed on clones located immediately beside each other (see Tables 1 and 2). In Table 1, the cause of diminished intensity of attack on several clones in 1990 compared to 1989 was the scars that prevented identification of wounds in 1990; in this case the 1989 data were estimated). On the other hand, any clone massively attacked in one nursery may grow without suffering from *S. tabaniformis* in another (see Table 3).

Following observations made only on clones with rooting of more than 50%, we were surprised to see that there is no correlation between the intensity of attack

and the vitality of plants and that the insects preference for a clone is only related, generally, to the local nursery conditions. In other words, the resistance of a clone is not valid in all nurseries. This is why it is not possible to use the results obtained on the intensity of attack for a given clone without making local trials.

Wood properties from 12 clones of poplars grown in the province of Zaragoza (Spain)

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Moisture content, basic density, bark, and wetwood percentages were studied on wood samples taken at different trunk levels from 12 clones, 7 of *Populus* x *euramericana* and 5 of *Populus* x *interamerican*a. From each clone, six trees from a randomised complete block design were used. All trees were 14 years of age. The influence of clone factor and the position of wood sample within the log on the value of every studied property is discussed.

As a general rule, it can be concluded that basic density and bark percentage increase from base to top, but moisture content and wetwood percentage decrease.

Based on the average basic density from base to 13 m height, the different clones can be classified as:

- Low density (310 to 340 kg/m^3): Campeador, I-214, Raspaije, Boelare, Hunnegem and B-1M
- Medium density(340 to 370 kg/ m^3): Triplo, Beaupre, Unal, MC, and Flevo
- Very high density (400 to 430 kg/ m^3): Canada blanco (Virginie de frignicourt)

The wetwood percentage is low in Campeador, I-214, Canada blanco, and Beaupre clones, with average values below 26%, and the wetwood percentage is high in Boelare, Triplo, and B-1M clones, which exceeded 35%.

The bark percentage in terms of volume did not vary much among the clones. The lowest percentage was registered by the clones B-1M, Campeador, Unal, Raspalje, Beaupre, and Boelare, with values below 10%, while the Canada blanco and Triplo exceeded 11%.

Breeding of poplars in the section Leuce *Duby at the Poplar Research Institute in Novi Sad*

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Autochthonous poplars in the section *Leuce (P. alba*, *P.* x *canescens*, and *P. tremula*) are widespread over a relatively large area in Yugoslavia in the form of smaller groups or solitary trees and rarely in the form of larger stands, but their economic significance in forestry is not great. Based on the morphological characters of the leaf, bract, flower, bark, and habit, several varieties were taxonomically determined, the most significant being *P. tremula* var. *typica* syn. *genuina*, var. *willosa*, var. *freinii*, *P. alba* var. *alba* syn. *genuina*, var. *nivea*. Grey poplar, as a hybrid species, has a great number of forms, some of which are morphologically similar to aspens, and some to white poplars. Groups of poplars with extraordinarily beautiful habit—*P. alba* var. *nivea*, f. *Bachofenii* and *P. canescens* var. *Bachofenii* - grow at the Deliblato Sands (Deliblatska pescara).

The results of the study of variability of several morphological and derived parameters of the leaves of selected clones in several taxa show significant interclonal differences and high values of the coefficients of heritability of the particular parameters, which can be used in the differentiation of clones in nursery production. By the study of isoenzyme variability in aspen leaves, we deciphered two loci of isoperoxidases with two alleles each: Px-A_1, Px-A_2, Px-B_1, Px-B_2. The study of natural aspen populations shows a high intrapopulation and interpopulation variability regarding the above alleles. The degree of their heterozygosity ranged from 42 to 48%.

More than 20 combinations of interspecies and intraspecies hybrids with a great number of combinations of plus trees of the same taxon were produced by the controlled hybridisation of the selected plus trees in autochthonous natural populations, using the pollen of American aspens *(P. tremuloides* and *P. grandidentata*). The data obtained in a series of experimental plantations with these progenies, together with a simultaneous use of half-sib and clonal progenies of plus trees, show marked differences between the progenies in their genetic potential for the production of good-quality wood, adaptation, and susceptibility to pathogens. The superior progenies that on marginal lands reached more than 15 m^3/ha/yr of average annual increment of good-quality wood deserve attention in poplar cultivation.

Production technology of three-layer thick core plywood from poplar

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Three-layer thin plywood consists of two kinds of veneer. The face veneer with a thickness from 0.3 to 0.4 mm is peeled from imported wood species, and the thick core is poplar veneer with a thickness that ranges from 2.5 to 2.8 mm. The wet thick core veneer is generally clipped and then dried by hot platen dryer to make the veneer smooth at the end stage of drying. The core must be spliced with glue to make it act as a whole, and then it is blended on a single side and formed into a two-layer mat. After being pre-pressed, the mats of core plywood must be checked one by one to ensure they are free of overlap and open joint and must be repaired by hand. The two-layer core plywood is single-face blended once more and formed with face veneer, and the three-layer thin plywood results after the whole mat is hot pressed for some time.

The research and production of surface fined oriented strand board from poplar

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To increase the use of Oriented Strand Board (OSB) and make the types of products more abundant, the surface-fined OSB production line, from which five-layer OSB was manufactured, was developed. This paper introduces the technology of the product. Fine particles from screened overlarge strands being refined were mixed with those from screening and used as material for the surface layer. After being blended with a high speed blender, the fine particles were formed onto the surface of the three-layer OSB mat by two surface forming headers, and then the five-layer whole mat was pre-pressed and hot pressed. The final product is a surface-fined five-layer OSB that has both OSB properties and the good surface performance of common particleboard.

A survey of poplar utilisation in China

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The extent of fast-growing poplar in China has been 600 million cubic metres since the species was planted in Jiangsu province in the 1980s. The only way to solve the lack of wood resources in China is to plant fast-growing wood species such as poplar and other species, and then use them in an efficient way. Currently, fast-growing poplar is a main wood resource for the wood-based panel industry in China. For instance, it is used widely and successfully as raw material

for three-layer and multilayer plywood, solid blackboard, honeycomb blackboard, medium density fibreboard, particleboard, and oriented strandboard. A program to produce and use laminated veneer lumber from fast-growing poplar is also underway.

Kraft pulping opportunities from Canadian aspen clones

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We sampled 22 aspen clones in north-east British Columbia. The wood density varied from 305 to 430 kg/m^3. Two statistically significant fibre length envelopes centred at 0.85mm and 1.05mm were observed. Nine clones were selected for pilot-scale kraft pulping. Total yield (5%) and H-factor (900) variations at kappa 17 were significant, and are attributed to genetic effects, not to tension wood content or environment. We observed a range of kraft pulp properties, and one clone, in an unbeaten state, achieved a tensile index in excess of 70N-m/g. Such variations in properties indicate that opportunities exist to develop aspen clonal plantations for specific end-use applications by selecting superior clones from within natural populations.

The effect of widely spaced poplar trees on sward growth and soil characteristics in New Zealand pastoral hill country

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Poplar trees are commonly planted in New Zealand pastoral hill country to reduce soil erosion, which can significantly reduce pasture production. The degree to which trees alter this physical environment has received limited attention, but has important implications for determining optimal planting regimes and appropriate site management. An experiment was therefore undertaken to describe and quantify the interactions between poplar trees, understorey pasture, and soil properties in a hill country silvo-pastoral system. Three pasture swards were sown underneath 8-year-old *Populus nigra* x *P. maximowiczii* trees spaced 5-20 m apart in gullies of 5-10º slope and of easterly and southerly aspect. Swards were made up of mixtures of improved grasses *(Lolium perenne* cv. Grasslands Nui, *Dactylis glomerata* cv. Grasslands Wana, and *Agrostis capillaris* syn. *A. tenuis* cv. Grasslands Muster) and legumes *(Trifolium repens* cv. Grasslands Tahora, and *Lotus uliginosus* syn. *L. pedunculatus* cv. Grasslands Maku). Each sward treatment and the resident sward was replicated three times, with open plots (swards without trees) providing controls. Soil moisture content in the tree and open plots was measured approximately fortnightly using time

domain reflectrometry (TDR). Measurements were made at two depths (0-20 cm and 20-40 cm) at distances of 1, 2, 4, and 8 m on the north and south sides of the trees. Pasture yield and botanical composition were determined every 6 to 8 weeks over the 2-year experiment. Mean soil water content ranged from 0.10 m^3/m^3 to 0.47 m^3/m^3 under trees and from 0.07 m^3/m^3 to 0.44 m^3/m^3 in open plots during the course of the experiment, and there was a pronounced seasonal cycle. The biggest differences in mean soil water content across the tree profile (8 m north to 8 m south of the tree) were observed as the soil was drying out in early-middle summer and as the soil was re-wetted again, in late autumn-winter. During these times the moisture profiles were curved, with mean soil water content at 1 m and 2 m from the trunk typically 10-30% lower than at 8 m; larger differences were observed at the 0-20 cm depth. Soil water content was frequently lowest on the northern side of the trees, indicating that radiation may also affect the water content, particularly at the shallowest depth. Sward type had no significant effect on soil water content. Herbage mass production on the northern and southern sides of the tree was not significantly different, while production in the open plots was slightly higher than around the trees in the summer. The nutritive value of the introduced and resident pasture swards was not influenced by the poplar trees. Soil pH and calcium, sodium, and magnesium concentrations were higher underneath trees, while no significant differences in nitrogen, phosphorus, potassium, sulphate, and organic carbon were observed between tree and open plots.

Intercropping of Lolium perenne *and* Populus deltoides *Marsh. poplar of different ages: production and quality evaluation*

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Perennial ryegrass intercropping during poplar development and its use as soiling and silage for cattle feeding would improve the net income per hectare with minimal changes to cattle systems. However, the production and forage quality could be affected by shade from trees.

The objective of this research was to determine the production and quality of *Lolium perenne* sown intercropped with 3-, 5-, and 8-year-old poplar trees. The study was carried out in San José de la Mariquina (39º 36´ S.L.), Chile, on volcanic ash soil with 1,700 mm of annual rainfall and average temperatures of 16.9ºC maximum and 1.7ºC minimum. The experimental design included poplar plots at a density of 6 x 6 m (277 trees/ha). The ryegrass was evaluated in 3-, 5-, and 8-year-old poplar trees whose cover index was 3.2, 4.5, and 5.8 m wide, respectively. *Lolium perenne* was sown in March 1999, and the evaluation period was between March 1999 and March 2000. The ryegrass dose was 25 kg/ha and its fertilisation was 50 kg N/ha, 147 kg P_2O_5/ha, and 96 kg K_2O/ha . After the first

cut (September) and second cut (October), another 50 kg N/ha was added to the pasture. During the evaluation period, the pasture had four cuts: September, October (silage cut), January, and March. Dry matter was evaluated when the ryegrass reached 30 cm in height. In October the pasture was harvested for silage at ear emergence stage. Bromatological analysis of total protein, soluble carbohydrate, and metabolizable energy was done only on the silage cut.

The annual dry matter production was 7,137, 6,234, and 1,851 kg/ha ($P<0.05$) under poplar trees of 3, 5, and 8 years old, respectively. On the cut silage, the dry matter content was 14.6, 12.8, and 12.2%; total protein was 11.5, 11.7, and 16.7%; metabolizable energy was 2.7, 2.6, and 2.6 Mcal/kg; and 14.7, 10.5, and 4.6% soluble carbohydrates under trees of 3, 5, and 8 years old, respectively.

On the basis of these results, the forage obtained under the older trees could present fermentation problems due to the low dry matter and low soluble carbohydrate content of the ryegrass forage. Besides that, ryegrass as an intercrop may not be appropriate with poplar trees older than 5 or 6 years because of the decrease in yield of ryegrass.

Characteristics of soil used for poplar and willow growing in Yugoslavia

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The characteristics of soil used for poplar and willow growing in Yugoslavia have been analyzed. The largest complexes of poplar and willow are situated in inundations of the rivers Danube, Tisa, Sava, Morava, and Tamis, and in fragments along the smaller watercourses. Outside this region, poplars and willows grow in shelterbelts and windbreaks.

The floodplains of the above rivers have significantly different terrain configurations, mineralogical and mechanical compositions, hydrological regimes and forms of natural plant communities. The dominant process of floodplain genesis is fluvial sedimentation, which is functionally related to the transport competency of a river. The numerical analysis of this law shows that fluvial sedimentation of the average silt + clay content at the cross section of the floodplain profile has the form of the logarithm function: $Y = 21.221 + 10.2769 \ln X$; $r = 0.82$; (X is the distance from the streambank). Depending on the transport competency of a river, three genetic portions of floodplains can be distinguished: along the bank, central, and terrace. Each has its evolution-genetic series of soil, specific hydrological regime, and characteristic forms of plant

communities. According to these parameters, from a production-ecological aspect, floodplains are classified into several topographic-hydrological positions.

In the above floodplains, the soils belong to the hydromorphic order with the following soil classes: undeveloped hydromorphic soil, semigley, and gley. From the systematic aspect, at the level of soil type, the following soils are most often used for poplar and willow growing:
- fluvisol, morphological structure (A) or A - I - II - III - ... nG,
- humofluvisol, morphological structure A - C - G,
- humogley, morphological structure Aa - Gso – Gr, and
- eugley, morphological structure Aa - Gr.

From the aspect of poplar and willow cultivation, the most significant property of these soils is the content of the fraction silt + clay (particles <0.02 mm). According to the quality assessment of the state of usable water content, the above soils are classified into the following categories of physiologically active water content: very poor, poor, medium, good, and very good. It can be generalised that the production potential of the above soils depends on the nature of the relief, soil mechanical composition, and naturally prevailing water-air regime. In the process of establishing poplar and willow plantations, the choice of the variety and planting technology is largely determined by the properties of the soil.

Bioassay on Anoplophora glabripennis *L. larvae with phenolic glycosides of* Populus deitoides

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Asian long-horned beetle (ALB) (Coleoptera *Anoplophora glabripennis* Motsch.) is the most harmful and widely dispersed pest to Chinese poplar trees. The chemical plant defence mechanism was studied in the experiment. The beetle can oviposit on many trees from different cultivars of *Populus deltoides*, but the hatch and survival rate often varied for different cultivars. From eggs to three-instar is the critical stage for the larvae survival, so something was suspected to pose adverse effects to the young larvae in the bark. The secondary metabolite of *Populus* species is dominated by phenolic glycosides, and it has been proved that phenolic glycosides have adverse effects on the growth of other insects. This study was conducted to test the hypothesis that the phenolic glycosides in the bark of poplar have similar effects on the beetle and account for the differences for larvae performance.

First, the natural composition of bark was studied, then the bioassay tests were designed according to the natural composition and level of phenolic glycosides compounds by artificial feeding. The bioassay result showed that all three kinds of phenolic glycosides could prolong duration of larval stadium. Salicortin especially at high levels (more than 2%), reduced the survival rate of neonate larvae, pupate rate and growth weight were decreased too. So the association between insect resistance and the chemical have been proved. The reason for varied performance of larvae can be partly explained by the varied concentration of phenolic glycosides for different trees.

Simulation of plant growth and eco–physiology by L-System based : Fractal generated : Turtle interpreted computer graphics model

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An L-System-based: Fractal-generated : Turtle-interpreted : OOP techniques-implemented computer graphics model (LFT) has been encoded for theoretical plant growth and eco–physiology study. The model is divided into four function modules for parameter input, plant growth and forest stand modelling, results output, and virtual experiment design and conduct. Based on input parameters abstracted from field experiments and theoretical constants, the model preliminarily can graphically and dynamically simulate plant/tree growth and their stands, calculate leaf area index (LAI) of a stand, and determine optimal leaf density in a defined space and light interception ratio, etc. for plant growth, physiology, ecology, and theoretical biology study. Modelling results can be put out as a data table, line/bar chart, and/or graphics.

Evaluation of CTMP from nine aspen clones growing in northeast British Columbia

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Chemi-thermo-mechanical Pulping (CTMP) pulps were prepared and tested from nine selected "wild" aspen clones from north-east British Columbia. The results indicated that although the interclonal variability was low in eight of the nine clones, the specific refining energy required to reach a given freeness varied by up to 45% depending upon the clone selected. Similarly, the properties, i.e.,

tensile index, tear index, scattering coefficient, etc., for the pulps prepared from the clones also varied widely. Such variations are due to genetic differences between the clones. This can explain the variability of the aspen pulps produced by commercial pulp mills. More importantly, this highlights the opportunities that exist within Canada's native aspen populations to develop industrial plantations with superior, cold-climate clones.

Environmental plantings of hybrid poplars in the Pacific Northwest

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The rapid growth of hybrid poplars makes them an ideal tree species to use in various environmental plantings for uptake of excess nutrients from municipal and industrial wastes and agricultural runoff, shading of streams to moderate water temperatures and competing undesirable vegetation, carbon sequestration, and other applications. Results from several studies will be presented to illustrate how hybrid poplars are used for these applications. Experience in the Pacific Northwest of the United States suggests that waste application can have a detrimental impact if a thorough assessment of site, clone, and type and quantity of waste is not done before these practices are implemented.

Comparison of basic density and longitudinal shrinkage in tension wood and opposite wood in young stems of poplar (P. euramericana *cv. Ghoy) when subjected to a gravitational stimulus*

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In a greenhouse under controlled conditions, young shoots from poplar cuttings *(P. euramericana* cv. Ghoy) were artificially inclined to quantify the modifications induced by a gravitational stimulus. At the end of the growing season, basic density and longitudinal shrinkage were measured on very small samples taken from pure tension wood tissue observed on the upper face of the inclined axis and compared with opposite wood tissue, free of gelatinous fibres, developed on the opposite lower face.

Because of the very small sample dimensions (average volume 0.1 ml and 15 mm length in axial direction), the repeatability of measurement techniques for volume and shrinkage was established. The results indicated an accuracy up to

0.001 ml for the measurement of saturated volume needed for basic density calculation and up to 0.01 mm for the measurement of longitudinal shrinkage.

When young stems were inclined at 30^{o} from the vertical, a difference of 5% was observed between basic density in opposite wood (384±18 kg/m^{3}) and tension wood (402±17 kg/m^{3}). On the same samples, longitudinal shrinkage reached 0.2% in opposite wood and was four times higher in tension wood. This difference is significant in whatever stems were considered. This ratio, in accordance with the literature, was obtained in our case with samples composed exclusively of gelatinous fibres or normal fibres.

When wood basic density increased, longitudinal shrinkage (R^2 = 0.228) decreased in the opposite wood and increased in the tension wood (R^2 = 0.225). This inverse behaviour between two opposite faces of an inclined stem could induce more and more important strains in samples following the increase of wood basic density.

When young stems were inclined at two levels (10^{o}and 30^{o}), basic density was different again considering the two types of wood. The shrinkage was systematically higher in tension wood and at 30^{o} but without mutual interaction.

The experimental approach followed in this work allows the quantification of the impact of a gravitational stimulus, of controlled intensity, on physical properties of poplar tension wood tissue.

Improvement of arborescent willows and multispecies hybrids by hybridization, transgression, back crossing, selfing, and inbreeding

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The first results of breeding the Chinese willow *(Salix matsudana* Koidz.) and the white willow *(Salix alba* L.) show that hybrids are obtained easily if *S. matsudana* is used as a female parent. There were difficulties in hybrid production when the hybrid of the F_1 or F_2 generation was used as a female parent in breeding by transgression, back crossing, selfing, and inbreeding. The hybrids of the F_1 generation exhibited vigorous growth at an early age compared to the Chinese willow *(S. matsudana*), and the same as the best clones of the white willow *(Salix alba*). Back crosses of F_1 generation hybrids were made on the Chinese willow, while for the production of F_2 generation hybrids, the genetically divergent (New Zealand, Croatia) hybrids *Salix matsudana* x *Salix alba* were used. In all produced hybrid families, a remarkable variability was established enabling the selection of the plus variants. The cloning of the plus variants realises a

considerable genetic improvement in the short-rotation biomass production. The hybrid progenies bred by selfing have an extraordinary depression of growth, i.e., their vitality is poor. The purpose of producing plants of the divergent genetic constitution by selfing is the production of line hybrids. For now we have found that the majority of the plants bred by selfing are male and that the monoecious plants transform into the male sex.

Conservation of European black poplar (Populus nigra *L.) genetic resources in Croatia*

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Conservation of European black poplar *(Populus nigra* L.) genetic resources by the *ex situ* method began by the selection and autovegetative propagation of adult trees over the last 6 years. The selection was made not only in the area of the Drava, Sava, Mura, and Danube Rivers, but also on sites that until recently were inaccessible because of mines and that present the most valuable riparian forest areas in Europe. After the successful reproduction of European black poplar adult trees in spring 1995 a European black poplar clonal archive with 83 clones was established as part of a *Salicetum* in the Cakovec Forest District. In spring 1998, the second European black poplar clonal archive was established in the Darda Forest District. Presently, it contains 63 European black poplar clones, but it will be completed in the future depending on the old tree selection and reproduction program. In the nurseries another 37 clones are under reproduction, and they will be included in the clonal archives. Conservation of the European black poplar and its natural stands by means of the *in situ* method was included in the permanent protection either within nature parks and special forest vegetation reserves (the Danube River islands near Vukovar) or within the parts of riparian forests exempt from regular forest management (the Drava River forests near Slatina, and near Osijek). The Republic of Croatia has been a member of EUFORGEN *Populus nigra* Network since 1994, and it has participated in all six meetings held so far. Because of the extension of *P. nigr*a. Network plan to white poplar *(Populus alb*a), and considering the general condition of riparian forests in Europe, these areas are important for conserving the biological diversity of natural areas of Croatia.

Poplar as a potential model for gene resource conservation in forest ecosystems

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Conservation of genetic resources has become a major objective in the management of forests. Much theoretical work has been devoted to the subject, and implementation has already started at local, national, and international scales.

Poplars are probably the most representative and threatened forest tree species of old natural floodplain forests in the temperate zone. It is a very didactic model for conservation genetics since various topics of interest are addressed: the integration of gene resource conservation and intensive breeding within a coherent frame of gene resource management; the co-evolution between wild and cultivated gene pools; and the necessary link between species conservation projects and preservation of habitats (in particular for a pioneer species in a dynamic ecosystem). These topics will be discussed and illustrated by the European experience for the conservation of *Populus nigr*a. Different methods are developed that are considered complementary: *ex situ*, *in situ*, and restoration projects. Simultaneously, the conservation of riparian ecosystems is also a priority.

The question now is the evaluation of such an integrated strategy. Research in genetics and ecology can provide *a priori* guidelines to achieve the objectives faced within each conservation method, although exact threshold values are generally difficult to obtain. *Vice versa,* practical implementation can raise new questions for research, and in that particular case the *in situ* method appears to be quite complex: ecosystem modelling including the genetic dimension has to be enhanced. Criteria and indicators for the follow-up of gene resource management are being progressively developed, but still need to be tested on a real scale. In the field of gene resource management, also, the poplar model is almost unique even among other forest tree species. Breeders and environmentalists, geneticists and ecologists, forest managers and river managers are indeed actively collaborating for the same objective.

Allometrics and growth potential of hybrid poplar and hybrid aspen in Sweden

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Little is known about growing poplars for energy purposes in Sweden. The few existing plantations are mostly restricted to locations in the southernmost provinces. Recent studies indicate though, that selected clones of both hybrid

poplars *(Populus trichocarpa* Hook. x *deltoides* Bartr.) and hybrid aspen *(Populus tremula* L. x *tremuloides* Michx.) have a high biomass production on former agricultural land in the whole country. In the current phase of poplar studies in Sweden, before any larger trials or plantations are established, there is a need for developing accurate non-destructive biomass estimation methods. A variation in growth of different clonal material within a wide range of production systems and ecological conditions must be captured.

Biomass estimation procedures used in short-rotation poplar production were largely adopted from traditional forestry. They are based on allometric relations between tree dry weight and easily measured linear dimensions such as stem diameter and tree height. These relations were tested by regression analysis based on the data of a large number of destructively sampled trees from two trials and three plantations. In addition, sample trees from smaller trials in central and northern Sweden were included. The spacing was 1 x 2 m in both trials, and 3.3 x 3.3 m in the plantations. Dry weight (W) was related to stem diameter (D) at breast height using the general equation W = a + b Hupf Dc + d Hupf Dmc, where the variables a to f represent the parameters. By allocating Hup and Dm to each single entrance, the parameters were obtained in a single run for the whole data set. This function includes the upper height (Hup) and mean stem diameter (Dm) of the stand. These two variables describe the specific allometric relations affected by heritable characteristics of clone material, initial (and actual) spacing, and ecological conditions.

The regression analysis showed that the general equation used fit the data well. The obtained R^2 was 0.99. The results of the production estimates indicate high production potentials of both hybrids in Sweden. Densely planted plots of hybrid aspen (spacing 1 x 2 m) near Uppsala, central Sweden, produced 60 t/ha over a period of 9 years. The two clones of hybrid poplar *(Populus trichocarpa* x *deltoides* C: OP5 and OP42, spacing 3.3 x 3.3 m) planted on soils of medium fertility produced between 60 and 70 t/ha over the same period. The last year increment was 15 t/ha.

The equation including the upper height and mean diameter of a stand could be used to estimate the biomass production in both hybrid poplars and hybrid aspen grown under different ecological conditions. It also facilitates the comparison between different production systems and clones. In general, the results indicate surprisingly high production potentials of both hybrid poplar and hybrid aspen on fertile agricultural land in Sweden.

Comparative growth of several half-sib families of American origin of Populus deltoides *Bartr. in Pakistan*

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On account of higher demand for poplar wood mainly in match industries and in house construction on the one hand and slow growth in indigenous species on the other, there was no way left for foresters but to test exotics in Pakistan to meet the local requirements. Out of four indigenous poplars, *Populus euphratica* Oliv. is a lowland riverine species and the other three species, *P. alba* L., *P. ciliata* Wall, and *P. nigra* L., occur in temperate areas (1,600-3,000 m altitude) either as individual trees or in very small patches in northern Pakistan. The midland area, which is irrigated, has virtually no suitable poplars. *Populus euramericana* (CVI-214) has been found most suitable for farmlands and irrigated plantations since the mid-1950's. However, this species also has the problem of heartwood rotting as the tree reaches maturity, especially after age 10. Alternatively various clones of *P. deltoides* were tested in the 1960s but none on a commercial scale until now. Nevertheless, this proven germplasm could be used to develop cultivars for the different ecological zones of Pakistan.

To bring about further genetic improvement in *P. deltoid*es, seeds of 181 open pollinated progenies were procured for the first time from Arkansas, Colorado, Kansas, Oklahoma, and Texas in 1982. The latitudinal, longitudinal, and altitudinal amplitude was 28 32° - 38 25° N, 94 00°- 103 45° W, and 08-1,268 m, respectively, in its native habitat. Seedlings of only 45 individual families were successfully raised and out planted in RCB design at six locations in Pakistan. Depending upon the available stock, number of half-sib families and replications varied from site to site. The latitude of planting sites ranged between 29 10° - 34 25°N, while the longitude and altitude varied between 69 00 - 733 20°E and 100-2,000 m, respectively.

The data collected on height growth revealed that ramets originating from Texas outperformed all others at six sites in spite of great geoclimatic intersite diversity, indicating the scope of large-scale planting of propagules from plus trees of the species from Texas. The seven Texas counties rated as best growth include Bosque, Brazos, Coke, Conzales, Haskell, Randall, and Young. Further strategies on the development of clonal forestry in collaboration with international agencies are also highlighted and discussed to develop suitable clones for wider adaptability and better growth over a range of sites in Pakistan.

Use of microbial inoculants in populiculture

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Use of selected microbial strains in intensive culture of *Populus* trees (populiculture) may improve the establishment of introduced *Populus* trees on previously cleared agricultural or disturbed sites in the Canadian prairie

provinces. Container-grown aspen *(Populus tremuloides* Michx.) and balsam poplar *(P. balsamifera* L.) seedlings and hybrid poplar cuttings (Walker, Assiniboine, Manitou, and Northwest) were treated with six species of ectomycorrhizal fungi *(Hebeloma longicaudum* Pers.: Fr., *Laccaria bicolor* [R. Mre.], *Paxillus involutus* [Batsch: Fr.], *Pisolithus tinctorius* ([Mich.: Pers.] Coker and Couch), *Rhizopogon vinicolor* A.H. Smith, and *Suillus tomentosus* Kauffman), an arbuscular mycor-rhizal fungus *(Glomus intraradices* Schenck and Smith), two species of bacteria *(Agrobacterium* sp. and *Burkholderia cepacia* Burkholder), and a growth hormone (Stimroot No. 3, containing 0.8% IBA rooting powder). Seedlings and cuttings were grown for 10 weeks under three levels of fertiliser (33%, 67%, and 100% of the fertiliser regime used in the nursery). Both treated and non-treated seedlings and cuttings showed enhanced growth with high levels of fertiliser. Aspen and balsam poplar seedlings showed higher growth and nutrient uptake (N, P, and K) when seedlings were co-inoculated with *P. involutus* and *B. cepacia* as compared to other treatments. The amount of calcium and magnesium did not differ significantly between treatments. Ectomycorrhizal and endomycorrhizal colonizations were not affected regardless of fertiliser treatment. For hybrid poplar cuttings, higher seedling growth and micorrhizal colonization, and lower shoot-root ratio were observed when inoculated with *G. intraradice*s, *L. bicolo*r, *P. involutu*s, *P. tinctoriu*s, and *P. involutus* + *B. cepacia* at all fertilizer levels. While N, P, and K contents did not differ between treatments, Cu was higher when inoculated with *P. involutus* + *B. cepacia*. This study provides candidate beneficial microbial inoculants that offer promise for development of commercial inoculants for populiculture.

Performance of hybrids of Populus ciliata *x* maximowiczii *in field trials*

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Hybrids in poplars are increasingly being used for various reasons that could relate to either planting on harsh sites, disease or pest resistance, and sometimes for accelerated growth. Hybrids of *Populus ciliata* x *maximowiczii* were raised for sites not suitable for either *P. ciliata* or falling outside its zone and where *P. deltoides* clones were found unsuitable. Initial growth differences in the nursery (32.60 N, 77.30 E) were reported to be greater by the parent at one site. Subsequently these were planted at three sites: i) Katrain (31.45 N, 77.30 E) representing river floodplain deposits, ii) Palampur (32.60 N, 77.30 E) representing a tea garden with no irrigation, and iii) Nauni (31.10 N, 77.20 E) representing a) seasonal water source, and b) dry fallow land. Growth differences were site specific, and poor performance with diameter growth of less than 10 cm in 4 years was observed at site ii and iii-b where water availability was seasonal. The growth at site i varied between 15 and 20 cm at age 4, and

the growth at site iii-a ranged between 20 and 25 cm with a good height growth of about 20 m. The rooting was profuse in these hybrids in comparison to *P. ciliat*a; the leaf size was double that of *P. ciliata* and four times than that of *P. maximowiczi*i. Siblings showed a range of variation in branching pattern from the rosette shape of branching in *P. maximowiczii* to the simple alternate type in *P. ciliata*.

Rooting behaviour – an indicator of plantation success and growth in poplars

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Whereas the post-war 20th century belonged to eucalypts, tropical pines, poplars, and *Casuarina* species, it seems that the first quarter of the 21st century is going to belong to poplars. The impatience for quicker production of wood today has raised our expectations for harvest at 6-10 years, and this has been made possible by poplars in manmade plantations. These plantations are being raised in all kinds of edaphic conditions, but their survival, growth, and development depend on the root system these plants support. Poplars are reported to have a variable type of root system made up of strong horizontal surface roots from which develop vertical plunging roots. The development of the plunging roots, which were earlier considered to be limited by the level of water table or by the soil conditions, has been found to be under strong genetic control and clone specific. Different clones derived from the progeny of a single family can show different rooting behaviour that is mainly categorised into five different types (Category A, B, C, D, and E) depending mainly on the frequency and type of vertical plunging root system and the strength and volume of the horizontal anchor root system. The root behaviour, which can be identified and establishes itself by the 4th month (120 days after planting), remains consistent till the end of the planting season in the nursery and continues into the plantation. Plantation success depends on the root pattern and behaviour. Many clones fail to establish in the field due to poor rooting behaviour. During establishment of plantations, the white roots appear first on the submerged portion of the stem up to the collar zone and then on the cut root ends of the ETPs or barbatelles. However, the basic plunging and anchor root system specific to the clone soon appears and is the cause for rapid growth and development of plants in plantations. Genetic differences between different clones in rooting behaviour can account for double the growth differences between the different clones.

Poplar wood as raw material for sawnwood and peeled veneer manufacture

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The trend of modern mechanical conversion of wood is to utilise the raw material as completely as possible. In this sense, primary sawmilling is oriented to target manufacture with a suitable degree of finishing. The manufacture of peeled veneer has similar tendencies. Also, the quality characteristics of produced semi-finished and finished products should not be disregarded.

This paper presents the structural, physical, and mechanical properties, as well as the chemical composition of wood of poplar clones *Populus euramericana* clone I-214, cv. Robusta, and eastern cottonwood *P. deltoides* clones 457, 618, and 725. Sawmilling of poplar roundwood with a certain degree of finishing (production of pallet components) was also studied. The sawing of poplar (I-214 and cv. Robusta) round wood was monitored in a sawmill plant for unedged sawnwood and partial conversion into packing stock (pallets). The manufacture of peeled veneer from the logs of several poplar clones (I-214, 457, 618, and 725) was studied in parallel, with the assessment of the utilisation percentage and the share of full veneer sheets. The first logs 4-6 m long were peeled in the factory manufacturing peeled (construction) veneer. The logs were cut into lengths immediately before peeling, depending on the expected assortment and potential sizes of veneer sheets.

The study of sawmill processing of wood of the above poplar clones indicates a primary sawing plan must be considered. Meeting this goal depends mainly on the right choice of the production program and its consistent realisation. It is also necessary to respect the flexibility of the production program and to adapt to market conditions. This means that uniform solutions are not always present in the balance of different components of poplar wood sawmilling. The study of peeled veneer shows that the clone does not affect the utilisation percentage; log diameter has the primary effect. The effect of the species has some significance in the interaction with log diameter. The diameter of logs has a significant influence on the percentage of full veneer sheets, as well as on veneer quality characteristics, while the interaction of clone and diameter is not significant. A stochastic correlation was also established between the utilisation percentage in peeling and the percentage of full veneer sheets.

The adoption of internal rate of return in evaluation of poplar plantation investments

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In this study, comparisons were made between periods of rotation based on the plantation age of maximum financial output and on the maximum of the current and mean annual wood increment from I-214 poplar plantations established on three different sites and at seven various spacing. Internal rate of return (IRR), net present value (NPV), and net benefit/cost ratio (NBCR) were used in estimating the periods of financial rotation.

The analyses showed that the periods of rotation based on the ages of maximum IRR and current annual wood increment have promise, whereas periods of rotation based on the ages of maximum NPV, NBCR and mean annual wood increment have promise at a later plantation age class. Since the periods of rotation based on NPV and NBCR varied depending on the interest rates, adoption of IRR in evaluating plantation investments is regarded as more suitable.

The economic impact of technological innovations in poplar plantations in Turkey

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In this study, financial analyses were made comparing conventional and innovative techniques of operations conducted in poplar plantations. The methods of calculating net present value (NPV), net benefit/cost ratio (NBCR), and internal rate of return (IRR) were adopted for the financial analyses. Due to the higher cost of machinery and equipment required for newly introduced technologies of operations conducted in poplar cultivation, comparative analyses resulted in favour of the conventional technologies. Compared with hybrid poplars *(Populus* x *euramericana* cv. I-214 Dode-Guinier), black poplar *(P. usbekistanica* cv. Afghanica) plantations are established in much closer spacing, which significantly increases operating standard times and plantation costs without plantation benefits. Therefore, financial analyses gave higher values of NPV, NBCR, and IRR for plantations with I-214 poplars.

Main characteristics of poplar and willow wood as raw material for fibre and energy production

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The raw material base in FR Yugoslavia, especially in Serbia, is dominated by deciduous tree species, so the supply of coniferous wood for fibre production is limited. In this case, the lack coniferous wood is mainly compensated for by using poplar and willow wood.

As wood used for energy purposes, beech holds the top position, followed by wood of other hard broadleaved trees. However, in lowland regions, willow and poplar wood is also used for energy. The properties (structural, physical, mechanical properties, and chemical composition) of poplar and willow wood were researched at the Poplar Research Institute in Novi Sad to assess the parameters in the technological procedures of groundwood, semichemical, and sulphate pulp production. The experimental material was poplar wood *Populus* x *euramericana* (I-214, cv. Robusta), *P. deltoides* (457 and 618) and willow wood *Salix alba* (107/65//7). The analyses referring to semichemical and sulphate pulp production were performed in laboratory conditions, while the analyses pertaining to groundwood were carried out in industrial conditions. The yield, chemical properties, and physical-mechanical characteristics of fibres intended for papermaking were determined.

During the research of poplar and willow wood utilisation for energy, we determined the calorific value of wood of P. x *euramericana* (I-214), *P. deltoides* (PE 19/66), and willow *Salix alba* (378). The experimental materials were 1- and 2-year-old seedlings, as well as 12-year-(I-214), 8-year-(PE 19/66), and 14- year-(378) old wood. In addition to higher heating value, the fuel value index (FVI) was also determined.

Genetic improvement of Salix *for the Northeast and North-Central United States*

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Willow is rapidly coming to the forefront as a biomass crop when grown under short-rotation intensive culture, and the State University of New York College of Environmental Science and Forestry (SUNY-ESF) has been a leader in North America in research aimed at dedicated willow crop systems. SUNY-ESF has assembled a diverse collection of willow germplasm from across the north-east United States and south-east Canada and is currently testing the material in replicated clone-site trials. Significant increases in yield and wood qualities are

likely to be attained through the development of genetically superior clones by traditional breeding. Willow breeding began at SUNY-ESF during 1998 with the goal of producing progeny that are well adapted to a wide variety of site conditions. Breeding efforts during 1998 focused on producing F 1 *Salix eriocephala* progeny and identifying combinations of willow species that can be successfully mated. During 1999, breeding focused on producing interspecific hybrid progeny. Controlled crosses to produce F 2 full-sib progeny were completed during February 2000. The SUNY-ESF willow germplasm collection will be expanded during 2000 in co-operation with the USDA Forest Service, North Central Research Station in Rhinelander, WI, to provide new germplasm for breeding and to develop new willow clones that are well adapted to the north-east and north-central United States. The breeding strategy with the new germplasm will be to test as many clone combinations as possible, including intraspecific and interspecific matings, with the objective of identifying favourable combinations of parent clones and maximising the possibility of producing progeny exhibiting heterosis. Large genetic diversity will be maintained in the breeding population to maximise breeding options in anticipation of changing pest populations and wood quality demands.

Genetic and environmental controls on root phenolics, leaf phenolics, and growth in cottonwood

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What are we missing by ignoring root traits in breeding *Populus* for biomass production? Trees with higher growth rates often have lower contents of phenolic glycosides and condensed tannins, which have been linked to leaf defence. Little attention, however, has been paid to root defence. Is the same trade-off seen between growth and root defence? Is genetic variation in growth rate correlated with allocation of leaf and root defensive compounds in *P. deltoide*s? We examined these questions in a preliminary study of 12 eastern cottonwood *(P. deltoide*s) clones with a wide range of growth rates determined after 5 years. For each clone, we measured concentrations of phenolic compounds and condensed tannins in both roots and leaves. We found little correlation between tree growth and leaf phenolic compounds or tannins, indicating that there may be significant species or environmental factors influencing the expected trade off between growth and leaf defence. Contrary to our expectations, there was a close positive correlation between tree growth and root condensed tannin concentration (Root % tannins = 0.98 (dbh (cm)) = 0.03, r^2 = 0.74). Whether a root tannin concentration plays a role in determining tree growth potential is unknown. If root turnover declines with increasing root tannin content, the reduced root loss might lead to increased carbon availability for allocation to tree growth or more effective soil resource acquisition. During spring and summer 2000, we will sample the same 12 *P. deltoides* clones in four sites of a regional *Populus* trial (Westport,

MN; Ames, IA; Arlington, WI; and East Lansing, MI) to test for GxE interactions affecting concentrations of phenolic compounds and condensed tannins in leaves and roots. We expect that tree growth and root tannin concentration will be positively correlated in trees growing at all four sites, and that any GxE effects on growth will also affect root tannin concentration.

Structural lumber properties of Wisconsin-5 hybrid poplar

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Aspen *(Populus tremuloide*s) is an important component of the resource of the Lake States of Michigan, Minnesota, and Wisconsin. In recent years, concern has surfaced that the aspen cut will exceed its growth. This concern arises from the increased demand placed on the aspen resource by paper, composite, and solid wood industries. To satisfy this demand for forest products, it is expected that much of the future timber will be from improved trees grown on managed plantations. It is critical that the mechanical properties of this resource are clearly understood so that alternative uses of this material can be evaluated. My talk today will give an example of the kind of study that should be conducted to assess the mechanical properties of particular hybrids. This study examined the drying behaviour and mechanical properties of Wisconsin-5 hybrid. Results suggest that this poplar clone would produce visually graded material that is similar in properties and characteristics to aspen and cottonwood. Close to 65% of the material produced made grades of either standard or No. 2. The Machine Stress Rating grade most likely to be produced from this material would be 1450f-1.3E. To avoid excessive drying, this material should be dried in flitch form.

Timberbelts: windbreaks that enhance production and produce profitable wood products

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Windbreaks have historically provided valuable protection to soils and crops in many areas of the United States. They are a modern conservation practice still needed in today's agriculture. Field windbreaks can protect livestock and a variety of wind-sensitive crops, improve crop yields, and control wind erosion. However, many field windbreaks are removed or not planted because of the

perception that they take too much land out of production and compete with adjacent crops.

An exciting new concept called a “timberbelt” can protect crops and soil from the wind, while at the same time produce wood products. Timberbelts are multiple-row windbreaks that are planted with commercially valuable, fast-growing trees, such as hybrid poplar. Producing a direct income from these windbreaks also would diversify sources of farm income and reduce overall financial risk.

The technology of growing hybrid poplars for wood and fibre products is rapidly advancing throughout many regions of the country. Because of their rapid growth and marketable products, hybrid poplars fit well into the timberbelt concept. New hybrid poplar clones have been developed that can produce saleable wood products in short rotations–commonly 7-12 years. Poplar markets currently exist for pulp and oriented strand board, and are emerging for veneer and solid wood products.

Timberbelts potentially provide all the benefits of windbreaks and if planted to hybrid poplar would produce 3-8 cords/tons of wood per acre per year depending on the region (irrigated poplar producing at the higher end). Carbon sequestration credits from the carbon stored in the timberbelt could help offset planting and establishment costs. Hybrid poplar timberbelts could store 30-80 metric tons of carbon per acre in 7- to 12-year rotations.

A timberbelt demonstration was planted in co-operation with the USDA National Agroforestry Center; University of Minnesota’s Center for Integrated Natural Resources and Agricultural Management; a land-owner in Chippewa County, Minnesota; the WesMIN and Prairie County RC&Ds; and CENTROL, a crop consulting company.

Ten 9- to 14-row timberbelts were planted in the spring of 1998. Seven hybrid poplar clones and clones of eastern cottonwood were used. They were designed to protect adjacent crops (corn, beans, and sugar beets) and to produce wood products in 10- to 12-year rotations. Current data will be presented in the paper on timberbelt design, clone suitability and growth, adjacent crop yields, and estimated financial returns.

Better willow varieties for biomass plantations

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Short-rotation willow *(Salix*) coppice has been marketed for 10 years in Sweden, and so far 18,000 ha have been planted. During five winters from 1996 to 2000 about 5,000 ha were harvested. The yields varied from 1 to 15 tonnes dry matter

(odt) per hectare per year, and the average yield was 4.5 odt per hectare. Most plantations were harvested for the first time, which partly explains the relatively low yield figures. The yield will rise when the plantations are well established. Willow has until now been a low priority crop on the farms as the main part of willow coppice in Sweden is an alternative crop on "set- aside" land. That explains why fewer than 25% of the plantations have ever been fertilised. Fertilisation and better weed control would certainly improve the yield figures a lot. Another important factor for achieving higher yields in the future is the improvement of the planting material through plant breeding. Very few plantations of new varieties have been harvested yet. Some of the commercial varieties now available for planting have a yield more than 50% higher than that of material used earlier.

Table I: Relative yields and the leaf rust scores of commercial varieties of willow from Svalöf Weibull AB compared to the most widely used old variety, L 78183. No. of trials within brackets.

Varieties	Rel. yield(%)	Rel. rust score(%)	Marketing year
L 78183	**100**	100	1990
SW Rapp	**113** (30)	43	1993
SW Jorr	**119** (37)	35	1995
SW Björn	**133** (18)	1	1997
SW Tora	**149** (23)	1	1997
SW Sven	**151** (6)	1	2000
SW Torhild	**155** (6)	6	2000
SW Olof	**209** (6)	15	2001

Willow is a crop that has not been bred for biomass production, which means that there are possibilities to make rapid improvements both in yield and in pest and disease resistance. A breeding program was set up in 1987 at the plant breeding company Svalöf Weibull AB. Breeding of willow at Svalöf Weibull AB aims at producing new varieties with higher dry matter yield, improved resistance to pests and diseases, better frost and drought tolerance for certain areas, and a plant shape suited for mechanised harvesting. Through plant breeding, the relative yields of willow have been increased dramatically compared with earlier grown varieties, and levels of leaf rust have been reduced to almost nil. Fifteen varieties of willow are now protected for plant breeders in the European Union and marketed in a number of European countries. Plantations of willow for biomass production have been established in Denmark, France, The Netherlands, Poland, Sweden and the United Kingdom.

Disseminating technical information on hybrid poplar via the Internet: the Oregon State University Hybrid Poplar Working Group Home Page (http://dwp.bigplanet.com/poplargroup/door/)

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Faculty members at Oregon State University (OSU) have developed a unique mechanism for communicating technical information on hybrid poplar culture and utilisation. The website, known as the "OSU Hybrid Poplar Working Group Home Page", was developed by Forestry Extension Agent Mike Reichenbach (now with the University of Minnesota). The website was created in response to a need to improve internal communication. Numerous OSU faculty members conduct research on hybrid poplar. They represent several colleges and are located all around the state – at OSU's central campus in Corvallis, at county extension offices, and at regional agricultural experiment stations. Lacking a mechanism for internal communication, it was nearly impossible for faculty members to ask one another questions and to simply know "who was doing what, where, and what they learned" about growing and utilising hybrid poplar. A unique feature of the website is that it is a "dynamic web page." The term "dynamic" is appropriate in that selected users (the "Working Group"), as opposed to a single webmaster, may change the content of the website. The information on the page is available to the general public, but a username and password are needed to post or remove information from the site.
The OSU Working Group Home Page includes several topic areas, including:

- Demonstration projects
- Genetics
- Economics
- Ideas for Smaller Acreages
- Wood Products and Markets
- Cultural Information
- Related Web Sites

Each topic area is a separate page to which Working Group members may post information. Information may be posted by simply entering text into a web-based form, by entering HTML code, or by creating a link to an existing web page. The website also contains an interactive calendar that allows Working Group members to post and view educational events as well as links to allow visitors to contact members of the Working Group or post a question via e-mail to the entire Working Group. The website is currently not living up to its potential. Many of the topic pages are still blank and the interactive calendar is also largely empty. This underutilisation is likely due to a combination of factors. One factor is certainly that faculty staff are busy, and converting reports to HTML format can take a good deal of time. Another likely factor is lack of familiarity with dynamic web page technology. Dynamic web pages are relatively new to the staff involved (including the webmaster) and therefore folks who are not experienced web programmers may be somewhat reluctant to try posting information to the site. It is unclear at this time how to overcome these limitations. A training program for

the Working Group is a likely solution, but convening this widely dispersed group of people will certainly be a challenge. An interactive website has excellent potential for fostering communication and dissemination of information about a multidisciplinary topic such as hybrid poplar. The practical utility of such a site, however, will depend on a dedicated staff member to collect and convert information to HTML format, keep the site up-to-date, and promote the site.

Studies on Variations in Growth, Photosynthetic, and Morphological Traits and Correlation Analysis in New Clones of **Populus tomentosa** *Carr.*

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Growth, photosynthetic indices, and morphological and phenological traits were studied on 1-year old *Populus tomentosa* Can. clones growing in container, including 15 triploid clones and 6 diploid clones. Considerable variation in growth, photosynthetic indices, and morphological and phenological traits were found. Most triploid clones showed obvious superiority over diploid clones both on stem height and basal diameter growth, with a longer period of rapid growth and a higher growth rate. The repeatability of stem height and basal diameter measured on different dates ranged from 0.8476 to 0.9461 and 0.8468 to 0.9025 respectively. Similarity of within-tree photosynthesis patterns was found for 3 triploid clones B330, B301, and B304, and 2 diploid clones BM33 and BM86, but higher photosynthetic rates in old leaves for clones B330 and B30 1. Net photosynthetic rate, single leaf photosynthesis (net photosynthetic rate*single leaf area) whole tree photosynthesis (net photosynthetic rate*total leaf area per tree) and total leaf area per tree were significantly correlated with growth. Whole tree photosynthesis and total leaf area per tree showed a more significant correlation with growth(r = 0.806 - 0.836). For leaf, branch, and internodes traits, repeatability ranged from 0.33 to 0.95. The degree of genetic control was stronger for leaf and internodes traits than for branch traits, the highest for internodes length (R = 0.95). Single leaf area, leaf blade length, leaf width and internode length showed high genetic correlation with stem height and basal diameter(r>0.72). Time of leaf flush, bud set, and leaf fall was also under strong genetic control, but only showed weak correlation with growth. Several morphological and physiological traits such as leaf size, internodes length, total leaf area per tree, net photosynthetic rate and whole tree photosynthesis might be responsible for good performance of the triploid clones in growth. The results suggested that such traits could be useful for the early selection of rapid-growing clones of *Populus tomentosa* Can.

Recent advances in genetics and breeding of Populus davidiana *Dode in China*

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In this paper a general introduction is given to research advances in genetics improvement and breeding of Chinese aspen (*Populus davidiana* Dode) in China. This introduction includes natural distribution and collection, conservation, gene diversity, provenance trial, crossing breeding, vegetative propagation and disease resistance etc. Based on the current situation of forest tree breeding in China, some strategic suggestions concerning the future development of Chinese aspen genetics improvement in China are presented, taking into consideration the existing domestic demands of forestry production and international trends in forest tree breeding.

Ecolotree® systems-poplar-based environmental engineering

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Poplar trees now grow within 30 miles of Portland, Oregon, to both cover landfills and treat wastewater. It is the tenth anniversary of the 1990 planting of the Lakeside, OR, Landfill. We will look specifically at poplar's role as the transition crop between a newly completed landfill with an unplanted soil cap to a densely forested ecosystem. This Oregon landfill was the launching point for other installations worldwide. Poplar provides one way to filter pollutants from the soil gases and groundwater with deep root systems while growing a marketable, perennial wood fibre crop. Ecolotree® installed Lakeside and many other landfills with important technical collaboration by CH2M Hill, Inc.

Crown architecture of poplar trees in intensive and extensive cultured plantations

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Crown architecture (including vertical distribution of primary branches, leaf area, and cumulative leaf area index; crown form, vertical changes of branch inclinations) of intensive and extensive cultivated poplar (*Populus simonii* x *P.*

pyramidalis cv. Chifengensis 36) plantations were studied in Liaoning province, China. The results showed that the layer with maximum branch length in intensive culture trees is relatively lower than that of extensive ones. Most trees in intensive culture plantations have conical crowns. But in extensive culture plantations, trees have parabolic cylinder crowns. The distribution pattern of the primary branch of trees in intensive culture benefits light interception. Branch inclination angle also varied significantly with crown length. The estimated leaf area index (LAI) by destructive method was 3.0362 $m2^{m-2}$ for the intensive culture plantation, and 2.1786 $m2^{m-2}$ for extensive one. The cumulative leaf area index (CLAI) for intensive and extensive culture plantations can be simulated by the following models, respectively: $ICLAI = 0.2607*Z^{1.8030\ e\ -0.1643Z}$ ($R^2 = 0.9919$) and $ECLAI = 0.0639*Z^{2.6480\ e\ -0.2530}$ ($R^2 = 0.9960$), where Z is the length of crown. If simulated by the crown length of standard trees in two plantations, the CLAI was 3.1221 $m2^{m-2}$ and 2.2619 $m2^{m-2}$ for intensive and extensive culture plantations, which differed by about 2.8% and 3.8% from results found in destructive method estimations, respectively. In conclusion, there is a high linear correlation relationship between the standard tree and simulated model for both plantations. The cultivation measures have significant effects on the crown architecture. The conical-shaped crown, large branch inclination angle, and higher CLAI contribute to the higher productivity of intensive culture poplar plantations.

The study of photosynthetic productivity in the poplar plantation

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Combining the results obtained on the leaf area dynamic and light distribution in the canopy, photosynthetic productivity was studied in intensive and extensive cultured poplar *(Populus simonii* x *P. pyramidalis* cv. Chifengensis 36) plantations in Liaoning province, China. During the growing season, the relation between CO2 exchange and the intensity of photosynthetically active radiation (PAR) was studied in the two plantations. The daily change of PAR in different types of weather (sunny, cloudy, and rainy days) was also studied. The photosynthesis model was established, and the photosynthetic productivity of the two plantations in different types of weather was calculated. Comparing the results in the two plantations, it was found that the mean light saturated assimilation rate (Amax) in the upper and lower crown in July, August, and September in the intensive culture plantation was 1.74 and 1.40 times that of the values of extensive culture one, respectively, which means the photosynthetic capacity of leaves was higher in the intensive culture plantation. The photosynthetic productivity in the intensive culture trees was higher than that in extensive ones, especially later in the growing season. In conclusion, management measures have obvious effects on photosynthetic productivity.

Light distribution in the canopy of a poplar plantation

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In this paper, light distribution and transmittance in the canopy of intensive and extensive cultured poplar (*Populus simonii* x *P. pyramidalis* cv. 'Chifengensis 36') plantations were studied. The experiment site was in Heishui Forest Farm, Liaoning Province, China. Based on data on total solar radiation and Photosynthetically Active Radiation (PAR) in the two plantations, equations transforming from total radiation to ground PAR were established. Combined with the leaf area index (LAI), and its vertical distribution in the canopy, the extinction coefficient (K) and the vertical distribution of PAR in two stands were calculated, respectively. The daily and seasonal change of K and PAR transmittance were also studied in the intensive plantation. The results showed that the maximum K value and the minimum PAR transmittance appeared in July, because the trees had the maximum seasonal leaf area and they absorbed more PAR. The relationship between PAR transmittance and cumulative LAI within the canopy was established; the result showed it was a linear model. We compared the absorption of PAR in the two stands, because the intensive culture plantation had a higher leaf area in different canopy layers. The interception of PAR in the intensive culture stand was higher than that in the extensive culture plantation; this interception resulted in higher productivity in the former. These results can be used for further studies of photosynthetic productivity.

Cloning of Xylem-Specific-Expression Promoter of Glycine-Rich-Protein (GRP1.8) Gene from Populus tomentosa *and induced expression in hetero-organism* Escherichia *coli*

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The Xylem-Specific-Expression Promoter of the Glycine-Rich-Protein (GRP1.8) gene was amplified by the PCR method from total DNA extracted from *Populus tomentosa* and bean, and cloning into pUC18-T vector. The PCR products were sequenced. Compared with the sequence of French bean, an extremely high

cogenetic level (about 98%) was found. The expression vector pBI was constructed by inserting the promoter sequence upstream of the GUS gene in pBI121, resulting in the replacement of the original CaMV35S promoter by the GRP1.8 promoter. Adding X-GLUC (5-Bromo-4-Chloro-3-Indolyl-D-glucuronide) as a substrate and induced by a specific inducing factor, the blue stain of *Escherichia coli* indicated that the GUS gene in *Escherichia coli* was activated by the GRP1.8 gene promoter, which was induced by a specific inducing factor.

Phylogenetic analysis of Populus euphratica *based on the divergence of chloroplast DNA*

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The intergenic region of trnL and trnF was amplified by polymerase chain reaction (PCR) for seven samples (varieties) of *Populus euphratica* Oliv., and one sample of *P. cathayama* Rehd. The PCR products were cloned into the pGEM-T vector and their sequences were further determined. The phylogenetic analysis of the poplars based on the genetic distances among the above sequences was performed using the Neighbour-Joining method. Three samples collected from Pakistan, Iran, and Kenya are closely related and form a separate group. The variety of *P. euphratica* called *P. pruinosa* from Xinjiang (China) represents a separate branch in the phylogenetic tree, while the three samples from Xinjiang, Gansu (China), and Turkey are grouped in an additional major branch. These results indicate that the major branches represent three different species, given their early divergence as indicated by the phylogenetic tree. Because *P. pruinosa* is far from any other samples, a separate subsection under the section *Turanga* could be considered. The present study supports the use of the intergenic sequence of the chloroplast genome for the reconstruction of phylogeny of this section.

On poplar's role and position in the Three-North Shelterbelt Program of China

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At present, forest pests and diseases severely threaten poplar resources in the Three-North Region of China. As a result, people are getting worried about poplar development and starting to have doubts about poplar's future and position. Some people even have negative attitudes towards poplar development. By introducing years of research experiences and results, in combination with the increasing social and economic demands for forestry in the

region and the development of some major national forestry ecological programs, this article will try to prove that poplar has always played a very critical role and its function is irreplaceable. From the strategic point of view, it is quite practical to identify poplar as the dominant planting species in the Three-North Region. Our challenges now are to tackle the existing problems, try to improve management, and make use of the unique advantages of poplar to better serve the Three-North Shelterbelt Program so that it can play a more important function in the process of greening and developing the Three-North Region of China.

Study of research progress on Populus simonii *through review of scientific documentation in and outside of China*

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Reviewing the scientific documentation on *Populus simonii* from both national and international sources is an important part of scientific research on the species. Through reviewing and sorting 195 articles from the CAB and 200 articles from CTC and CFA on the research of the species, the present status of distribution of the scientific documentation in terms of times, countries, and subjects resulted in knowledge of the scope and present status of the research on the species in and outside of China. Research on the species involves 23 aspects of 14 subjects, such as forest biology, tree breeding, and forest protection. Among the research aspects, the study of breeding and resistance physiology through bio-engineering techniques has become popular nation-wide.

Primary research on complex evaluation of poplar clone introduction in sandy land

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The primary research of the project is one of poplar clone introduction and selection to evaluate clone quality based on integrated appraisal at the seedling stage. In 10 years of trials, 28 clones have been selected through the appraisal of and integrated appraisal of seven indexes. It was found that in Jian10# *(P.* x *euramericana* cv. ND182*),* Xiaohei 8401 *(P. simonii-Baicheng* x *P. nigra-Aertai 840*1), Bailin 2# *(P. nigra* x *P. pyramidali*s), Euro-America 1-M *(P. euramericana* cl. I-M), Zhonglin 86-22 *(P. Zhonglin 86-22*), Heilin 1# *(P. xiaohei* x *P. p15A* cl.), Liaoza2# (*P. simonii* x *Xiaozhuannica* cl. Liaoza-2), *Niqing* x *Shanhaiguan (P. nigra* x *Populus deltoides* cv. Shanhaiguan), Zhongchi Heixiao *(P. nigra* x *P.*

simonii cv. Zhongchi), Faku1# *(P. simonii* x *Xiaozhuannica* cl. 'Faku-1), etc., the growth increment is higher than that of Baicheng 41# *(P. simonii* x *Xiaozhuannica* cl 'Baicheng-41) and Baicheng 2# *(P. simonii* x *Xiaozhuannica* cl. 'Baicheng-2) as local main tree species. Meanwhile, cold resistance, disease and pest resistance, and stem form are also adequate. So the above clones are very suitable for planting and expansion in Korqin Sandy Land.

Poplars: a multiple-use crop for European arable farmers (PAMUCEAF) (Task 4 - a GIS-based analysis of suitable areas for poplar production in Europe)

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The PAMUCEAF project aims to assess the potential for diversification of arable agriculture into commercial poplar production across Europe. As part of the first stage of the project, a pan-European analysis was required to assess the physical scope for poplar production across the region. The potential for commercial poplar production is defined by limits to the rate of growth, as defined by soil characteristics, water resources, and temperatures. This poster describes a methodology for analysing the spatial distribution of the potential for poplar growth in Europe, using data available at both European and regional scales.

The analysis was carried out on a regular grid of 0.5^{o} latitude/longitude, using available pan-European data. Physical suitability of areas was assessed using an interpretation of soil types. Water resource use was investigated using modelled evapotranspiration figures. A calibrated stochastic weather generator was used to assess the occurrence and frequency of damaging frost early and late in the growing season. The same simulated daily weather data were used to model the start of the growing season across Europe. Characteristics representative of an intermediate poplar clone were used to assess these factors across Europe.

The results give an overview of the areas in the EU15 and Poland where poplar is likely to grow well, along with indications of where additional water resources would be required for maximum growth, and where a risk of frost damage during the growing season exists. The results should be interpreted in the light of current developments in poplar breeding, which may be able to overcome some of the limits encountered through the development of regionally better adapted clones. The methodology developed during this part of the study will be used with regional scale data in the future to identify key areas for poplar growth in the five partner countries involved in the PAMUCEAF project.

Poplar biomass production in short rotations

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The results of a study performed in 27 test plantations located on different types and forms of alluvial soil along the rivers Danube, Sava, Drava, and Tisza refer to poplar biomass production in short rotations. Test plantations were established during 1960-1985, with different densities varying between 1,111 and 16,666 trees/ha and different spacing systems, using cuttings, roots, and 1- and 2-year-old rooted cuttings. The study includes about 50 varieties–clones of Euroamerican poplar and eastern cottonwood. In some denser test plantations, reproduced by stump re-sprouting, there were several rotations (2-4) with 2- or 4-year felling cycles.

The results indicate that, depending on soil fertility, planting density, and clone type in dense plantations with more than 5,000 trees/ ha, in 3 to 6 growing seasons, the amount of produced biomass was 70-150 m^3/ha(wood and bark), with average diameter at breast height $d_{1,3}$ = 5-10 cm and height of 6-11 m. In dense test plantations with 8,333-6,666 trees/ha, reproduced by stump sprouting, in four 2-year rotations (8 years) or in 2- to 3-year rotations (6-9 years), the amount of produced biomass was 170 to 205 m^3/ha with diameter at breast height of 4-7 cm, and height of 5-9 m.

In test plantations with 2,000-4,000 trees/ha, in 5 to 9 growing seasons, depending on density, age, soil properties, and clone type, the amount of produced biomass was 95-275 m^3/ha, diameter at breast height 13-17 cm, and height 14-18 m.

In test plantations with 1,000-2,000 trees/ha, in 6 to 9 growing seasons, the amount of biomass produced was 51-263 m^3/ha, average dbh ($d_{1,3}$) was 11-19 cm, and height was 12-19 m. In the same test plantations, at ages between 10 and 14 years, biomass production was 225-414 m^3/ha, average dbh was 16-28 cm, and height was 18-25 m. At ages between 18 and 23 years, there was a significant natural decline of trees (30-60%); biomass production was 446-778 m^3/ha, average dbh ($d_{1,3}$) was 22-29 cm, and height was 27-33 m.

By adequate selection of soil, planting density, poplar variety, and planting stock, significant quantities of biomass can be produced in short rotations. Biomass produced in dense plantations in 2- to 4-year rotations, i.e., small trees with a high percentage of bark, can nowadays be evaluated for energy. Test plantations with somewhat lower densities (2,000-4,000 trees), in 5- to 9-year rotations, produce poplar biomass that is partly used in fibre manufacture and partly for

energy. Test plantations with 1,000-2,000 trees/ha produce significant quantities of biomass that is used predominantly for fibre.

Influence of temperature and leaf wetness duration on the monocyclic components of poplar rust in Brazil

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Poplar rust is the most important disease in nurseries and in the field in Brazil. Most clones are susceptible and the epidemic is more severe year after year. The objective of this study was to quantify the influence of temperature and leaf wetness duration on the infection of *Melampsora medusae* on three poplar clones: Latorre – highly susceptible; SM – moderately susceptible; SJ – resistant. In a first trial, potted plants were inoculated with a uredospores suspension (10^4 spores/ml) and subjected to different temperatures (8, 11, 12, 16, 21, 26, and 31°C). The same suspension was distributed into Petri dishes with water agar medium for assessment of spore germination after incubation for 24 hours in the following temperatures: 6, 11, 12, 16, 21, 26, and 31°C. In a second trial, potted plants were inoculated with a uredospores suspension (10^4 spores/ml) and subjected to different leaf wetness periods (0, 3, 6, 12, and 24 hours). In this trial all plants were kept at 21°C. The estimated latent period was 7 days for clone Latorre and 8 days for SJ (both at 21°C). The range of optimum temperature for infection was between 16 and 21°C. No symptoms of the disease were observed at 31°C and 8°C. The optimum range of temperature for uredospore germination was between 11 and 21°C (around 80%), although germination was also observed at 6 and 26°C (around 40%). At 31°C, only 10% of the spores germinated. The number of pustules increased with the increase in the leaf wetness duration. The minimum wetness period necessary for infection was 3 hours. There was no difference in the number of pustules in plants subjected to 12 or 24 hours of leaf wetness.

Pest-resistant cottonwood clones for the north central region of the United States

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In 1988, a project was begun to develop new *Populus* clones for use in biomass energy production in the north central region of the United States. Emphasis is being placed on improving breeding and selection techniques, selection and breeding for pest resistance, dry weight yield potential, and ease of propagation. In 1999, we completed 56 new crosses and planted over 11,000 seedlings at three progeny test sites. We produced planting stock for 20 promising new clones for a new regional test. We scaled-up 12 new clones to be distributed for commercial-scale testing plantations.

We found that 1999 was an abnormal year for *Melampsora* leaf rust development with the infections starting earlier, but not expanding significantly until very late. As in 1998, the 1999 epidemic started earlier in Ames than in the Minnesota population with larch, the alternate host from which the initial inoculum purportedly originates. We found the canker pathogen *Cryptosphaeria populina* attacking and killing DN hybrids in some additional plantings, and *Agrilus* borers were strongly associated with the canker fungus. So far, we have found only six *P. deltoides* x *P. maximowiczii* clones that may have sufficient resistance for *Septoria* canker to allow commercial use.

Field experiments to determine the feeding performance of larval cottonwood leaf beetle (CLB) on eight *Populus* selections were completed. Overall, performance declined throughout the season. Larval performance was generally lower on clones with higher *Tacamahaca* parentage. Long-chain fatty alcohols and alpha-tocopherylquinone (-TQ) were monitored on these eight clones with and without larval *C. scripta* defoliation. Total alcohol amount, _-TQ amount, and total alcohol : _-TQ ratio varied greatly among generations. The long-term study of the effect of CLB on growth and biomass accumulation in the 1998 replicated plantings of four select *Populus* clones was continued using Novodor® and Raven®, both commercially available *Bt* products. These treatments were quite effective in managing the beetle during the first two generations. After two growing seasons, volume reduction in the unprotected clones was highly significant. CLB pupae from the laboratory colony were evaluated to determine if correlations existed between various pupal or adult parameters and fecundity or longevity. Pupal or adult weight was not a good indicator of fecundity, total oviposition events, number of eggs/beetle/day, or adult longevity.

Field trials of transgenic hybrid cottonwoods demonstrate high levels of resistance to chrysomelid beetles and glyphosate herbicide

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Weed and insect pests often have significant impacts on survival and growth of poplar plantations. We tested herbicide and insect resistance genes that are widely used in agricultural crops and are expected to improve the efficiency of pest control and reduce management costs. We screened over 110 transgenic lines (i.*e*., products of asexual gene transfer) of hybrid cottonwood for resistance to glyphosate (active ingredient in Roundup herbicide) during several years of field trials. The lines were produced with a construct provided by Monsanto that encoded two resistance genes - one for glyphosate degradation and one that imparted glyphosate insensitivity. The studies included 40 triploid hybrid lines *(Populus trichocarpa* x *P. deltoide*s) that were grown at two field sites (east and west of the Cascade Mountains) and 73 diploid hybrid lines *(P. trichocarpa* x *P. deltoides* and *P. trichocarpa* x *P. nigr*a) that were grown at a single site (eastern Oregon). Most of the clones used for gene transfer are employed in commercial production. In each trial, a number of transgenic lines were discovered that showed no foliar damage or reduction in growth after spraying at or above herbicide concentrations used commercially.

For insect resistance, we field-tested 53 hybrid lines *(P. trichocarpa* x *P. deltoides* and *P. deltoides* x *P. nigr*a) that were transformed with a rebuilt *Cry3A Bacillus thuringiensis* toxin gene provided by Mycogen. This gene was intended to impart resistance to the primary insect pest of poplars in Oregon, the cottonwood leaf beetle *(Chrysomela script*a). Nearly all of the transgenic lines were virtually free of feeding damage under natural infestation in eastern Oregon, whereas the non-transgenic lines sustained significant levels of defoliation. As a consequence, the non-transgenic plants grew an average of 13% less in a single year than did the transgenic lines. Both kinds of genes appear to hold considerable promise for use in short-rotation plantations after a method for reducing gene flow has been developed and studies of environmentally prudent management strategies have been completed.

Transpiration of a monoclonal poplar stand: model calibration and validation

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The knowledge of water use from a poplar stand is important for the better understanding of its impact on the hydrological cycle and for regional water balance studies. Poplars prefer moist to wet soils for optimal growth and

production levels. In this research, it was the aim (1) to calibrate and validate a water balance model using two different approaches: comparison between measured and simulated soil water content and comparison between the simulated stand transpiration and values scaled-up from sap flow measurements on individual representative trees, (2) to quantify the transpiration of a fast-growing monoclonal poplar *(Populus trichocarpa x P. deltoides* cv. Beaupré) stand in East Flanders (Belgium) for 5 consecutive years.

To quantify the transpiration of the stand, we simulated the terms of the water balance by the water module of the model WAVE (Water and Agrochemicals in soil, crop and Vadose Environment) model. It describes the one-dimensional water transport in the soil using the Richards (1931) equation, based on soil hydraulic properties. The model was calibrated by comparing the soil moisture content measured by TDR sensors and simulated by the model. The model gave a very good agreement between measured and simulated soil water content, even at shallow depths of 10 and 25 cm. During August 1997, sap flow was measured to quantify the transpiration, using the heat field deformation method with linear radial heating and a combined sensor. The model was validated by comparing the measured (sap flow technique) and the modelled transpiration data. The totals over the whole period from August 9 to September 3, 1997 showed good agreement between the modelled and measured transpiration, i.e., 141 and 149 mm, respectively. Simulation by the model yielded for the growing season (April 1 until October 31) a transpiration of 325 mm (average 1.5 mm/day and 5.3 mm/day maximum) for 1995, 195 mm for 1996 (0.9 mm and 5.2 mm), 311 mm for 1997 (1.5 mm and 5.1 mm), and 288 mm for 1998 (1.4 mm and 4.9 mm).

Circumference-height relationship for cv. P. *x* Ghoy*,* P. *x* Beaupré, *and* P. *x* Boelare

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The total production of timber and the dominating height of forest trees are weakly linked. This relationship is fundamental in calculating tables or production models since it is independent of the quality of the site. Verification of this dendrometric principle for the three poplar cultivars *P.* x *Gho*y, *P.* x *Beaupré,* and *P.* x *Boelare* is considered here. In the 111 plots of 20 to 25 trees sampled (2,319 circumferences measured), the total production was estimated using the basal area. The total height of trees was measured using the 'Vertex' dendrometer on 392 trees. The 31 plots of *P.* x *Gho*y, 4 plots of *P.* x *Boelare,* and 39 plots of *P.* x *Beaupré* sampled are located in the Mosan basin, and in the whole potential area of the *P.* x *euramericana* and *P.* x *interamericana* (Hesbaye, Condroz, Famenne, and Gaume) poplar cultures. The localisation, spacing between trees, pH at 20-30 cm depth, groundwater level, and soil type represent parameters with which

each plot can be identified. The result obtained can be expressed in an equation relating the mean height and mean circumference of the poplar stands, with a mean spacing between trees of 8 m. After comparing the coefficient values, it was noticed that the use of this relationship can be extended to individual tree cases. In other words, the variability within the plots has not affected the precision of the curves obtained. In addition, the similarity of the curves obtained for *P.* x *Boelare* and *P.* x *Beaupré* enable the data to be grouped and thus generate one equation for the two cultivars.

For the *P.* x *Gho*y: ln(height) = 0.1538 (ln(mean circumference))^2 -1.2153 ln(mean circumference) + 6.5087. For the *P.* x *Boelar*e, *P.* x *Beaupré:* ln(height) = 0.0729 (ln(mean circumference)) ^{2} - 0.2032 ln(mean circumference) + 3.4626. The use of the circumference in these equations is sufficient to express the relationship of productivit y sought, since the plantation density is constant. The influence of available site parameters was tested for the two models obtained. No systematic error was detected. The difference between the above two models is minimal, but they show that *P.* x *Boelare* and *P.* x *Beaupré* are slightly longer (less stocky) than *P.* x *Gho*y, especially for trees with a circumference exceeding 150 cm. The limits of heights correspond to a total variation of 2 m in relation to the mean value for *P.* x *Gho*y, and of 3 m for *P.* x *Boelare* and *P.* x *Beaupré*. The relationship between mean circumference and total height simplifies life for the practitioner. Starting from the mean circumference of a stand with a spacing of 8 m, the practitioner may estimate the probable limits of the total height variation without having to measure them. This value for a given age enables the productivity of poplar stands to be compared. Extrapolation to spacings of 7 to 9 m does not change these results much, but additional data should confirm this hypothesis. In addition, estimation of the total volume (of the trunk) per tree or per stand becomes more precise using the circumference-height relationship discussed.

Aromatic fingerprinting of Populus *(Poster)*

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Phenolics are the only class of secondary compounds in the *Salicacea*e. These carbon-based compounds include phenolic glycosides, flavanoids, and tannins. No nitrogen-based compounds are known to exist in *Populu*s. Bud exudates of almost every species of *Populus* have high concentrations of flavanoids. Their abundance and diversity have made them helpful in chemical taxonomy where they have been used to discriminate between poplar species, hybrids, and even clones. Foreseeing the interest in such a tool, research was carried out to improve the methods for identifying reproductive material of *Populu*s.

The main objective of the study is to propose an aromatic fingerprint tool. It must be able to distinguish hybrids and clones and be related to genetically important economic traits. This first investigation shows the discrimination level of aromatic profiles. It also examines the efficiency of the method, seeking reproducible, low-cost results on the basis of neither random nor restricted markers. The aromatic technology obtained with gas chromatography gives a stable fingerprint of species, hybrids, and clones. The clone discrimination and identification is one of the main results of this aromatic fingerprinting with the method used. From the aspect of methodology, the aromatic fingerprint method is located between the RAPD and the AFLP technologies.

The knowledge of specific phenol composition of poplar species has practical issues. Indeed, for reproductive material for which nothing is known, the aromatic fingerprint can identify the probable species or hybrid compounds. After this first step in the investigation, *P. trichocarp*a, *P. nigra, P. deltoides, P.* x *interamericana*, and *P.* x *euramericana* can be distinguished.

A long-term planned P. trichocarpa *breeding program, included domestication*

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In the framework of an IUFRO program *(R. Koster-collectio*n, NL), IBW began in 1973 a *P. trichocarpa* provenance trial with about 2,000 seedlings from 64 different seed sources in British Columbia, Oregon, Washington, and California. After frequent observations to study susceptibility to rust, form, and vigor, the original number was reduced to 337 seedlings at the end of the 1980s.

In the same year, in the context of a long-term planned *P. trichocarpa* breeding program, 27 intraspecific crossings were realised (2 F_1 and 25 F_2). The selection of the parent trees was based partly on the photoperiodic adaptation to the latitude, stem form and straightness, *Melampsora larici-populina* tolerance, and *Xanthomonas populi* resistance. Various combinations of both resistant and susceptible parents were used. The reaction of the 1-year-old seedlings to *Xanthomonas populi* was tested by artificial infections. One year after infection, the percentage of field-resistant clones within the different families ranged from 10 to 99%. In total, 2,310 seedlings of a total of 9,225 showed a sufficiently high resistance to bacterial canker.

Recently the remaining seedlings (about 220 in the provenance trial and 375 in the intraspecific breeding trial) were evaluated again. Data for the different provenances/crossings regarding survival, rust resistance, canker resistance, growth, form, and other characteristics are given and discussed in detail.

Vegetative propagation of selected trees has begun, and where already possible trees have been tested again for rust and canker resistance. All results will give more information concerning different important characteristics for further breeding work, choice of parents for controlled intraspecific and interspecific crossings, and elimination of non-selected trees to create a seed orchard based on strongly selected trees. Meanwhile, these trials became very productive seed plantations, allowing further steps in the breeding program. A special goal of the trial will be to demonstrate the domestication possibility of an introduced species and the value of the use of seedlings in west European poplar plantations. Seedlings of the best families or synthetic populations can be used at different spacing, i.e., 3 x 3 m up to 8 x 8 m, for biomass production or for timber production.

Phytoremediation potential of poplar and willow: differences in cadmium accumulation between poplar and willow species

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Potentially, poplars and willows may be used for the *in situ* decontamination of soils polluted with Cadium (Cd), such as pasturelands fertilised with Cd-rich superphosphate fertiliser. Poplar clones, Kawa *(Populus deltoides* x *P. yunnanensis* NZ 5006) and Argyle *(P. deltoides* x *P. nigra* NZ 5015) and Tangoio willow *(Salix matsudana* x *S. alba* NZ 1040) were grown in soils containing a range (0.6 to 60.6 mg/kg dry soil) of Cd concentrations. The willow clone accumulated significantly more Cd (9 to 167 mg/kg dry matter) than the two poplar clones (6 to 75 mg/kg), which themselves were not significantly different. As Cd uptake from the soil is reportedly influenced by transpiration rate, a more detailed study into the differences in water-use characteristics between the species was initiated using one poplar (Kawa) and one willow (Tangoio). Lysimeter experiments allowed measurement of the daily water-use differences between the two species. Periodic measurements of stomatal conductance were also made. The area of the plant where Cd accumulates was also investigated for poplar and willow. Willow showed consistently higher daily water use than poplar when given on a per leaf-area basis and stomatal conductance (gs) values were consistently higher for the willow compared to the poplar. Leaf age has a profound influence on Cd concentration in both species indicating water-use history as a contributor. Despite similar distribution patterns between species, the old leaves of willow (high water use) had higher concentrations of Cd than poplar (low water use). This study indicates that although biomass production is a key contributor to bioaccumulation, water-use characteristics and stomatal response function also play a key role.

Interspecific hybridization between Populus alba *Oliv. and* P. euphratica *L. using ovule and ovary culture*

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An *in vitro* method was used to produce hybrid poplar plants between *Populus alba* L. and *P. euphratica* Oliv. in two directions. Developed ovaries and ovules were isolated from *P. alba* L. female branches, that had been pollinated with *P. euphratica* pollen grains by using twig and pot breeding techniques. The same procedures were carried out for isolation of developed *P. euphratica* Oliv. ovaries and ovules that had been pollinated with *Populus alba* L. pollen grains on mature trees.

Isolated ovaries and ovules of both crosses were then transferred to growth regulator free, half concentrated MS agar medium for embryo germination. Fourteen-days-old *Populus alba* L. ovary and ovule embryos produced the highest number of plantlets, while 45-days-old ovary and ovule embryos of *P. euphratica* Oliv. were necessary to obtain hybrid plants. A maximum of two to three plantlets were observed in both *Populus alba* L. and *P. euphratica* Oliv. ovary culture. Ninety percent of pollinated *P. euphratica* Oliv. and *Populus alba* L. ovules successfully produced plantlets, whereas the efficiency of pollinated ovaries in producing plantlets was 70% for *Populus alba* L. and 67% for *P. euphratica* Oliv. Plantlets were cultured in the same medium in jars before being transferred to potting soil. Seventy-five interspecific *P. alba* L. x *P. euphratica* Oliv. plants and 26 *P. euphratica* Oliv. x *Populus alba* L. hybrid plants were successfully acclimatised in the greenhouse.

Wood quality of Hungarian Leuce *hybrids*

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Besides the better known *Populus* x *euramericana* clones, there is an increasing interest in some of the native Hungarian *Leuce* hybrids *(Populus canescen*s), the so-called “grey poplars” for timber production in Hungary. They are natural hybrids of *Populus alba* and *Populus tremula,* and the trees have a wide range of morphological characteristics. One of their advantages is that they have a high tolerance to adverse environments, such as dry site conditions. Therefore, the planting of grey poplars is currently preferred over *Pinus* species in the arid Hungarian Great Plain. The Wood Science Institute launched an extensive investigation on wood properties of grey poplars 2 years ago. The main goal of this research is to explore and identify hybrids of the best wood quality. Some

results of this still ongoing project are presented in this paper. From the Kelebia Forestry Company, a total of 20 sample trees from three stands were selected and harvested for the assessment of macroscopic, microscopic, and physical properties. The following characteristics were measured: percentage of bark, sapwood, and heartwood; growth ring width; radial changes of fibre length; moisture content, density, and dimensional changes of sapwood and heartwood. In general, the investigated grey poplar hybrids from all the three stands produced wood with favourable properties that could be converted to lumber and utilised in the production of pallets.

Resistance screening for Melampsora *leaf rust on hybrid poplars and superior aspen clones in north-eastern Alberta*

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Melampsora leaf rust is an important foliar disease of hybrid poplar and aspen in nurseries and young plantations. Early season defoliation can reduce productivity and increase susceptibility to other pathogens or environmental stress. Resistance has been identified and attempts to exploit natural resistance genes in the poplar genome may lead to improved stock of high yielding trees for fibre. Infection type (IT) rating was evaluated on 10 hybrid poplars and 12 superior aspen clones under controlled conditions using two *Melampsora* species indigenous to Alberta. A range of IT was observed in response to each species including the hypersensitive response (0), necrotic fleck (1), necrotic fleck with pustule (2), chlorotic halo with pustule (3), and pustule only (4). Other parameters such as size of uredinia and day to pustule formation (slow rusting) will also be evaluated. Results from this investigation will assist in selection of improved hybrid poplar and aspen for use in north-eastern Alberta.

Winter raptor use of hybrid poplar plantations

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Studies of wildlife use of hybrid poplar plantations in North America are limited. I documented raptor use of a 7,050 ha complex of hybrid poplar plantations during the winter of 1999-2000. Diurnal and nocturnal raptors were surveyed in the interiors and along the edges of various-aged plantations, as well as in surrounding agriculture and shrub-steppe habitat. A total of 11 species of diurnal raptors and 5 species of nocturnal raptors were observed during this study. In

1999, relative abundance (#birds/km) of diurnal raptors was greater ($P<0.01$) along the edges of 5-year-old stands in comparison with surrounding shrub-steppe habitat, the interiors of the 1- to 4-year-old stands, and the edges of 1- to 3-year-old stands. Owl detections in the surrounding shrub-steppe habitat were lower ($P<0.034$) than along the edges of 5- year-old, 4-year-old, and 1-year-old stands. In addition, owl detections on the edges of the 5-year-old stands were greater ($P<0.048$) than along the edge of the 3-year-old stands, as well as inside the 5- and 1-year-old stands. During 2000, relative abundance of diurnal raptors was greater ($P<0.033$) along the edges of 6-year-old stands in comparison to the interiors of 3- to 5-year-old stands. No differences ($P>0.05$) were observed for owl detections among treatment means during 2000. No difference ($P>0.05$) in overall abundance of diurnal raptors was detected between 1999 and 2000. However, overall owl detections were significantly lower ($P<0.05$) during the winter of 2000. The differences in owl detections between 1999 and 2000 surveys could be a result of disturbance due to harvesting activities during 2000. Annual variation in owl abundance might also be explained by environmental factors such as temporal variation in prey abundance. The results of this study suggest that industrial-sized hybrid poplar plantations may be important habitat for wintering raptors in this region, especially along the edges of older trees. Consideration should be given to wintering raptor populations when scheduling harvest activities in industrial plantations. Long-term monitoring may be needed to accurately interpret trends in winter raptor use of hybrid poplar plantations.

Breeding for resistance to Septoria canker in Québec, Canada

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Septoria canker causes severe damage on susceptible clones in hybrid poplar trials in Québec. The pathogen *Septoria musiva* is found in natural stands, causing only leaf spots on *Populus deltoide*s. Its distribution is limited to the southern part of Québec where only resistant clones are now planted. With the extension of intensive poplar cultivation, the possible expansion of this stem canker disease in Septoria-free zones is presently under investigation. Both standard artificial inoculation procedure and field test monitoring in the canker-conducive area allow efficient canker resistance screening of large populations. Since 1986, an inoculation method has been carried out for preliminary screening of clones. The method consists of placing mycelium plugs on fresh leaf scars on stump sprouts. Clone responses observed 3 months later are comparable to ratings of canker damage in field tests. A new selected population, developed for the southern Québec breeding region, is now under evaluation. After a preliminary screening in a nursery trial, a high-density farm-field test of 2,693 selected clones, representing 92 families and 20 hybrid types, was planted in 1997 in Saint-Ours, near Sorel, for Septoria evaluation. After 3 years, 70% of the

clones were infected by *S. musiva*. The hybrids MB *(P. maximowiczii* x *P. balsamifera*), MN *(P. maximowiczii* x *P. nigra*), DM *(P. deltoides* x *P. maximowiczii*), EM *(P.* x *euramericana* x *P. maximowiczii*), and IM *(P.* x *interamericana* x *P. maximowiczii*) had the highest ratio of resistant clones to total number of clones per hybrid. The ratio was 63% for the MB hybrid and varied from 39 to 44% for the others. The MT *(P. maximowiczii* x *P. trichocarpa*) hybrid was the most susceptible (7% resistant) followed by MI *(P. maximowiczii* x *P.* x *interamericana*), MM, and MJ *(P. maximowiczii* x *P.* x *jackii*). In 1999, after two growing seasons, 408 resistant clones were selected from the Saint-Ours trial for artificial inoculation according to standard procedure. Approximately 80% of the 408 clones were still resistant after Septoria inoculation. In addition to Aigeiros hybrids, the MB, MN, EM, IM, and DM hybrid types have a high potential for vigor and canker resistance in southern Québec. In the future, the breeding program will continue to be largely oriented towards selection for Septoria resistance.

The revised EU-directive on the marketing of forest reproductive material and the draft of the new OECD-Scheme on the certification of forest reproductive material with reference to transgenic poplars

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The Council Directive of the European Union (66/404 EEC) for the marketing of forest reproductive material has been amended and was put into force recently. This directive regulates the production and the marketing of forest reproductive material within the European Community. It contains a great number of revisions and new aspects, some of which are also relevant for poplars as far as they are covered by this Directive. The main new aspects can be summarised as follows:

- New categories have been added: they are “source identified” (which does not apply to poplars) and qualified, (which does apply to poplars), besides the category tested.
- Beside the clone, the following new types of basic material have been introduced: clonal mixture and parents of family.
- If the basic material consists of genetically modified organisms, the reproductive material derived from that basic material shall meet the requirements set out in the Directive 90/220 EEC on the deliberate release into the environment of genetically modified organisms, which requires among other things an environmental risk assessment. (The Directive 90/220 EEC has been amended also and is scheduled to be enforced at the end of the year 2000. It will greatly emphasise the environmental risk assessment.)
- In case of genetically modified reproductive material, certificates and labels must indicate that the reproductive material is genetically modified.

While the Directive 66/404 EEC is valid only in the European Community, the OECD-Scheme (1974) for the control of forest reproductive material moving in international trade is a scheme optional for all countries. This scheme has also been amended (but not adopted yet), and the draft version is congruent in main features with the revised EU-Directive. Thus international trade will be facilitated. All amended regulations will bring more bureaucracy for breeders, traders, and users, but also much more clarity and certainty of the rules. Breeders will profit from them because their products from advanced breeding methods can be marketed easily.

Expression and stability in transgenic aspen clones under field conditions at Großhansdorf

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In 1996 a field trial was established using eight transgenic lines derived from two aspen clones Brauna 11 (female) and W52 (male) of *Populus tremula* and one hybrid aspen clone Esch5 (female) of *P. tremula* x *tremuloide*s. Six transgenic lines contain the 35S-*rol*C-construct and two transgenic lines contain the rbcS-*rol*C-construct. The field trial is designed as a block model consisting of 4 replications x 8 plots (transgenic lines) x 8 plants per plot including controls. The *rol*C-construct affects several phenotypic traits such as small growth habit small leaves increased number of internodes, and early flushing with 35S-*rol*C, and normal growth habit and leaves, but light green colour of the leaves with rbcS-*rol*C. The 35S-promoter is a constitutive one, while the rbcS-promoter is light inducible. This system is used to analyse the expression of the phenotypic traits during 4 years and the stability/instability of the transgenes. First results show a normal variation of phenotypic traits within a line, but differences between lines in some cases. While most lines seem to be expressing stability, some reversions have been found in two lines, which occurred in different frequencies (6[line #1] resp. 26 [line #4] out of 32). Twigs or leaves had reverted to the wild-type character. Reverted parts of the plant found in the previous year remained in the reverted phase in the following year. Molecular analysis of all plants and especially of the reverted parts of the plant followed on different levels, using PCR, southern, and northern experiments. Preliminary results give evidence that the status of the inserted construct in reverted parts can be absent, inactive, or partly lost or inactive. The next step was to investigate the T-DNA structure and features of the flanking region to find reasons for instability. There is evidence for rearrangements at the insertion-region causing the gene silencing in line #1 by using inverse-PCR and sequencing techniques. This would explain the frequently observed reversions resulting in instability in that line due to intrachromosomal base-pairing leading to double-stranded loops of single-stranded DNA during unitotic cell divisions. In line #2, the reason for the observed instability is

unknown so far. Additional investigations deal with the status of mycorrhiza (types and degree of colonisation). Four types occur frequently, while 10 further types are rare. There was found a widely homogenous distribution among transgenic and control plants except for one type, which showed differences between transgenic lines. Furthermore, this model will be used to analyse a possible horizontal gene transfer from the host plant to the mycorrhiza-fungus.

Cottonwood leaf beetle in fiber farms: predicting emergence and development

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Within the industry of fibre farming, a key insect pest, the cottonwood leaf beetle (CLB) *Chrysomela scripta* F, is of concern. The CLB is considered to be the most widespread defoliator of *Populus* in the United States and can act as a limiting factor in the establishment of plantations or in the economic accumulation of biomass in the first few years of growth. In the south-eastern United States where *Populus* is intensively cultivated, one or more insecticide applications are applied annually in an attempt to control the CLB. Yet, guidelines for monitoring CLB populations at the landscape level have not been developed.

To assist in the timing of this monitoring effort, we assessed the developmental rate of the CLB in terms of degree-days. To do this, we compiled developmental rate estimates from our own work as well as from others. To calculate degree-days for the CLB population in Mississippi, USA, we used a lower developmental threshold (LDT) of 53°F or 11.8°C. During the 1999 field season in Mississippi, observations were made on the emergence of overwintered adults and the progression of stages from egg to first generation adult (preimaginal development) for testing our prediction system. Diapausing adults emerged after accumulating approximately 136 degree-days, from December 1998 to March 1999. The first egg masses appeared after 162 degree-days (March 18-25, 1999). First generation adults appeared after 443 degree-days (April 29, 1999). To determine the developmental time from egg to adult for the first generation in the field, we adjusted the degree-day estimates by subtracting degree-days accumulated prior to oviposition of egg masses. Total preimaginal development was determined to be 281 degree-days. Therefore, the generalisation can be made that first generation adults appeared approximately 281 degree-days after oviposition of egg masses. This model and associated data will be used to predict overwintering emergence and population development at the Mississippi site as well as at a fibre farm in Missouri during 2000. Results will be presented in the poster along with subsequent generation predictions.

Sphaerellopsis filum on Melampsora on Populus in North America

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Sphaerellopsis filum is thought to be a “nonspecific fungal hyperparasite of rust” that occurs on most of the thousands of rust fungi in temperate zones and the tropics alike. *Sphaerellopsis filum* is the subject of biocontrol efforts directed at leaf rust in intensive willow plantations in the UK, and yet how it obtains nutrients and causes senescence is unknown. By providing insight into whether *S. filum* obtains its nitrogen from *Melampsora* or from *Populu*s, nitrogen isotope ratios ($\delta^{15\,N}$ values) may allow us to confirm that *S. filum* is a hyperparasite rather than an opportunistic necrotrophic pathogen of *Populu*s. The specificity and omnipresence of *S. filum* are also at issue. The author has collected *S. filum* on *Melampsora* on *Populus* on the coastal plain in the south-eastern U.S., for the past 3 years. However, its occurrence elsewhere in North America on *Populus* is unrecorded and dubious. Even in western Kentucky and nearby states, *S. filum* is absent although other putative hyperparasites are present. Could it be that some populations of *Melampsora* are resistant to *S. filum* from *Populus deltoides* from the coastal plain? Could this explain its restricted distribution? This hypothesis is being tested with *Melampsora* isolates from across North America using a newly developed co-inoculation assay.

Effects of first-year weed control strategies on weed levels and tree growth in two hybrid poplar plantings in northern Minnesota

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Mechanical and chemical weed control treatments were compared in a 4 x 2 x 2 factorial experiment replicated three times on each of two sites. Pre-emergent herbicide comparisons were trifluralin, oxyfluorfen, linuron, and a trifluralin + imazaquin mix. Post-emergent strategies compared separately the effects of treatment within rows (herbicides) and treatment between rows (discing and herbicides). Each sub-sub-plot included 30 trees of each of three clones: DN34, DN182, and NM6. Weed height and cover were estimated every 2 weeks for each plot, and for the area around each tree in October, when tree height and diameter were measured.

A midseason weed measurement, around August 1, provided the best relationship between weed levels and growth. Comparisons suggest little effect of weeds until a threshold was reached, and then growth dropped off

geometrically. All of the pre-emergent herbicide treatments kept weeds below this threshold through mid-August. Following this, the weed levels increased in the linuron and trifluralin treatments. Both within-row and between-row treatments, separate or combined, kept weed levels well below the threshold throughout the season when used with any of the pre-emergent herbicides. Very few weeds grew into the trifluralin + imazaquin plots, but tree growth in these plots was severely reduced from apparent phytotoxicity. The benefits from the within-row treatment to tree growth varied; growth improved on one site, but results were mixed on the other site. The between-row treatments stunted tree growth significantly (but was not apparent in the field), apparently from soil compaction.

Stand development and biomass yield in an eight-year-old willow (Salix *spp.) clone trial*

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The future use of willow *(Salix* spp.) as a source of bioenergy in Sweden depends on a high and sustainable yield. Dense plantations of short-rotation forests are bound to undergo different stages of development as a result of varying intensity of competition for light both between individual stools and between shoots within individual stools. If competition is intense, there is an enhanced risk of stool mortality. The timing of harvest in relation to stand development, therefore, is of great importance to maintain a vital stand.

A field trial with 12 willow clones was established on a clay soil in central Sweden (59º N) in spring 1990. A double-row spacing system was used and 20,000 cuttings per hectare were planted manually. The trial contains four replications, each with 12 monoclonal 10 x 10 m subplots. Measurements of living standing biomass (i.e., stem diameter) were performed annually with non-destructive methods on individual stools from 1991 to 1997. A coarse estimation of dead biomass was performed in 1997. Annual assessments of survival were carried out from 1990 to 1997. The trial has been coppiced twice; the first time in winter 1993/94 and the second in winter 1997/98. On both occasions a commercial harvester was used.

The initial average stool survival after the establishment season differed among the clones and varied between 72% and 99%. During the subsequent 3 years in the first cutting cycle, almost no stool mortality was recorded and shoot mortality was low. At the end of the second cutting cycle, the average stool survival of the different clones varied between 53% and 88%. High stool mortality was observed from 1996 to 1997. During the first cutting cycle, increased annual production of living biomass was observed every year and the standing biomass in 1993 varied

between 25 and 38 t dry-matter per hectare (tDM/ha). During the second cutting cycle, the annual production peaked in the second year in all except two clones. In 1997, the standing living biomass of the different clones varied between 31 and 39 tDM/ha . Eight of the twelve clones had a higher production in the second cutting cycle. The average standing dead biomass for all clones was 8 tDM/ha in 1997.

The results show that during the first cutting cycle the competition between stools was low and stool survival was therefore high, mainly depending on cutting quality. In the later part of the second cutting cycle, both stool and shoot mortality increased as a result of competition. This mortality also affected biomass production through a decrease of annual increment at the end of the second cutting cycle. To maintain a high sustainable yield, high stool survival is important. The relatively high mortality between 1996 and 1997 indicates that the harvest was carried out too late. The expected increase of production during the second cutting cycle was verified by measuring and including standing dead biomass.

Genetic diversity and regeneration studies of Populus ilicifolia

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Populus ilicifolia (Eng.) Rouleau is a tree species endemic to Kenya. The species marks the southernmost natural distribution of the genus. It is distributed along the Ewaso Nyiro, Tana, and Athi Rivers, from latitudes 1^{o} N to 3^{o} S, longitudes 37^{o} E to 41^{o} E, and from sea level to about 1,200 m. The geographic range of the species is in arid and semi-arid areas of the country, where the mean annual rainfall ranges from 200 to 800 mm. Rainfall is bimodal with peaks in March - May and in October - December. The mean diurnal temperatures vary between 17^{o} o and 35^{o} C.

The species is typically riverine, but its existence is highly threatened by direct exploitation, agropastoral activities, and other development projects such as dam construction that take place along the rivers. The last survey conducted on the species indicated an immediate need to determine the genetic diversity, collect germplasm, and identify other matching sites for *ex-situ* conservation.

Isoenzyme studies conducted using samples from seven widely separated sites along the three main river systems indicate that there is low genetic diversity within and among populations. Within its natural range, the species regenerates poorly naturally. Studies conducted on propagation techniques indicate that with some improvement in growth conditions the species can be raised successfully both from seeds and cuttings. Mature seeds collected and sown within 1-2 days germinated well under hot and humid conditions. A rooting success of up to 60%

on stem cuttings was realised under hot glasshouse conditions. With identification of good matching sites, plantations can be established to conserve the species and to increase its economic use.

Genetic variability of physiological characters of black poplar clones and their importance for breeding

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This paper presents the results of research on physiological characters of rooted cuttings of eight black poplar clones (four *Populus* x *euramericana* and four *Populus deltoide*s) in three field experiments on different soil types (humofluvisol, fluvisol f. loamy, and fluvisol f. sandy). Physiological characters measured were net photosynthesis, dark respiration, and leaf area. At the end of the vegetation period, the main plant growth elements measured were diameter, height, and biomass. The results of the research on physiological processes of poplar clones showed a high interclonal variability of most elements and processes of species under study. Statistically significant differences between clones and insignificant differences between repetitions, medium and high coefficients of heritability in a broad sense, indicate that the majority of study characters are controlled by genetic factors that result in considerable specificity of some clones. The statistically significant interaction genotype x environment, in the greatest number of characters, indicates the different reactions of clones to the site, i.e., soil type. Also, the rank of the clones in three experiments was not the same, so the interaction clone x environment existed in all the characters under study.

The quotient of variance of genotype x environment and variance of genotype, for dark respiration, and rooted-cutting diameters and heights was higher than 0.5, and therefore the interaction genotype x environment must be considered during selection. A strong genetic correlation with the elements of growth and biomass was shown especially for leaf area. Further, primarily experimental research will be directed to define the variability of these characters within species and in later ontogenetic stages. The results indicate that it could be possible to introduce a desirable level of physiological processes to the hybrids by which the effects of hybridisation can be enhanced.

The insect pests on willows in Marmara Region in Turkey

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Willows have been cultivated on the borders of fields and on stream banks since ancient times. These trees have been used both as construction wood and fuel. As demand for wood has increased, willow plantations on large areas have been established as in poplar cultivation. In recent years, several experiments have been performed on willow cultivation.

In this study, the harmful insects that attack the native or exotic willows in the Marmara region were determined. Sixty-seven insect species that attack willows in this region were identified. These species belong to 28 different families and 5 orders. The ecological conditions that increase the effect of insect damages were also determined.

The potential of willow genetic improvement

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Willows *(Salix* L.) are very important forest species in China for various purposes. They are rich in species and gene resources, and they are easy to cross and vegetatively propagate. In nearly 40 years, remarkable progress has been made in the selection of excellent clones for timber production, osier clones for coppice as wicker work material, and ornamental trees. Willows are typical short-rotation species because of early fast growth. Their wood is white and has even structure. According to our study, willow wood would be of excellent for pulp. Although its wood is light and soft, it has relatively high mechanical intensity. In particular the impact toughness and the bend strength are fairly high, so it could be used as qualified pitwood. Our breeding practices illustrate that by developing interspecific/intraspecific hybridisation among the species of *Salix* and clone breeding, excellent clones could be selected for high quality pulpwood or pitwood.

The weeping varieties of *S. babylonica, S. matsudana,* and *S. alba* are often planted as ornamental trees, specially *S. babylonica,* which is much more important than the others in China. Five excellent clones with “golden weeping” branches have been successfully selected from the artificial hybrids of *S. babylonica* x *S. alba*. Five excellent “silver bud” clones have also been selected from shrub or bush artificial hybrids. Willow has wide adaptation. Its heterosis from hybridisation is obvious. The F1 progenies, of these artificial hybrids whose parents come from different provenance, would have strong heterosis and wider ecological adaptability. Willows have strong tolerance, such as high tolerance to dampness, and drought and moderate tolerance to salt. They also have the ability to absorb pollution substances. As a result, in willow genetic improvement programs from now on, fast-growing clonal selection should be put forward continually for intensive culture and industrial use. On the other hand, tolerance

should become the main genetic improvement goal in selecting those clones that could be extensively cultured and achieve a certain economical income. These clones will be useful in establishing various ecological forests, protecting plantations, conserving water controlling soil erosion, and in providing environmental afforestation and ornamental forests. The benefits of willow plantation shall finally be clear.

Parental line improvement and breeding of elite cottonwood hybrids in an industrial tree improvement program

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Boise Cascade Corporation (BCC) established intensively managed fibre farms in eastern Oregon and Washington (USA) in 1991, and currently operates 7,350 ha on five locations in the region. Plantations are maintained in a stress-free condition including irrigation, pest and weed control, and fertilisation. Rotation length is 6-7 years. The trees are utilised to provide high quality short fibre furnish to BCC's Wallula, Washington, Pulp and Paper Mill, where the chips are used in the manufacture of uncoated freesheet. The fibre farm cottonwood tree improvement program started in 1993. At the outset, trees were selected based solely on growth rate. More recently emphasis has been placed on wood properties such as wood density, pulp yield, lignin content, fibre length, and fibre dimensions. The breeding program is composed of both intraspecific breeding for parental line improvement and interspecific breeding for F1 hybrid generation. Parental line improvement starts with breeding within *Populus trichocarpa, P. deltoides,* and *P. nigra* according to a positive assortative mating scheme. Pure species progeny are evaluated for 2 years, and the top 1% based on diameter and height growth are selected for placement in a breeding archive. Some of these selections will flower at age 3, allowing additional intraspecific and interspecific crosses to be made. Production of elite F1 hybrids begins with interspecific crosses between primarily these same three taxa. Selections are made from the hybrid progeny at age 1 and 2, which are placed in a replicated clone test. Elite hybrids are selected for commercial deployment based on the evaluation of age 2 height and diameter growth, followed by wood and fibre quality determination. Clones selected for commercial deployment are then serially propagated to create sufficient plants for a stoolbed. Using this approach, new hybrid clones are established 6 years after the initial cross is made. Thus far, 5 new clones have been released for commercial deployment. To date, significant genetic improvement has been achieved in wood density and several fibre characteristics.

Nursery production of 1-0 bareroot poplar cuttings in Québec

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With the world-wide increase in demand for fibres, hybrid poplar is now recognised as an alternative source of wood supply. In 2001, the expected volume of poplar planting stock produced annually in Québec will be around 1.8 million plants and should exceed 2.5 million by 2005. Bareroot plants show improved initial height growth, quickly get out of reach of browsers, and are easily planted (30 cm depth) when sites are adequately prepared. Successful plantations could also be established with cuttings, using plastic mulch strips and protection against browsers. Although, in that case, site selection and preparation requirements are very high (plowing, discing, and cultivation to allow successful unrolling of the mulch). In addition to environmental concerns, the costs of plastic mulch and installation took us away from that scenario. As bareroot plants are used for poplar planting stock in Québec, operational production of 1-0 rooted cuttings was developed involving five provincial nurseries: Berthier, Grandes-Piles, Normandin, Saint-Modeste, and Trécesson. Both stoolbeds and cutting-donor plants are used as sources of cutting material. Stoolbeds are established in each nursery for 8 to 10 years. One-year-old sprouts are harvested in late fall, cut into cuttings, and stored for winter at -2ºC. Cutting donors grown for 1 or 2 seasons in nursery beds are also used as an alternative source of material. They could yield a second crop after being cut back in fall. Cutting donors allow a rapid build-up of new clones but require larger bed areas compared to stoolbeds. For the regular cutting production, 12- to 15-cm-long cuttings with a 5-15 mm diameter are mechanically planted in nursery beds in May, at the rate of four cuttings per metre and five rows per bed (1,5 m wide), for a total of 20 plants per bed metre. Cuttings are irrigated in the first weeks and later on if needed, according to soil moisture data. Basic fertilization (N-P-K-Mg- Ca) is applied at a rate varying from 25 to 75 kg N/ha/yr. Weed control is achieved through the use of herbicides combined with hand weeding. We use a mix of Dual® and Lorox® (pre-emergence), Fusilade® against grasses, and Gallery® 4 weeks after planting. No undercutting or wrenching are done, but vertical root pruning is done between the rows in the beginning of August to promote root development closer to the stem. Plants are lifted by machine (Fobro) late in the fall at a height of 80 to 200 cm. Plants are then processed indoors for grading, culling, root trimming, counting, packaging, labelling, and storage (-2ºC). Against all expectations, customers are pleased with the plant size and become rapidly accustomed to the logistics of poplar planting.

Wood quality and utilisation perspectives of selected poplar clones for biomass energy in Hungary

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Both wood quality and biomass production are of interest in relation to the growing and utilisation of poplars, especially in countries, such as in Hungary, where timber and biomass resources are limited. The forest land is relatively small in area and most of the forests are situated on marginal sites, outside their ecological optimum. Quality of the overall timber resource is poor, and its utilisation for traditional wood products is influenced by the high incidence of wood defects, such as the percentage and characteristics of juvenile wood and the incidence of reaction wood. On the other hand, presently more than 90% of Hungary's energy demand is supplied by fossil fuel and nuclear sources and only about 3% is from bioenergy. Roughly 55% of the energy for consumption must be imported; meanwhile, the potential for solar energy in the region is quite high, far above the European average. In this presentation, some results and conclusions of long-term investigations of wood quality and the feasibility of energy plantations of selected poplar clones are discussed. Clonal differences of wood properties for the *Populus* x *euramericana* clones included in these studies are often statistically significant but very small and may be negligible from a practical point of view. Characteristics of juvenile wood and reaction wood have to be considered for specific utilisation scenarios. Silvicultural methods could affect wood quality, maybe more so than breeding and selection. Besides environmental benefits, high-yield poplar energy plantations may become economically feasible in Hungary with harvesting on a 3-to 4-year rotation. Thus, the potential energy yield of energy plantations is quite high, 240-310 GJ/ha/yr resulting in 700-1,250 GJ/ha at the time of the harvest, especially if the most suitable clones are selected.

Planting hybrid poplars in Armenia

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Armenia is a sparsely wooded country. About 98% of the forests are hard woods, (oak, beech, hornbeam, etc.) and only 2% are soft woods (pine, poplar, etc.). Due to the energy crisis since 1992, the forests of Armenia were damaged by the illegal harvests of about 30,000 ha. The suburban green forest mass of about 5,000 ha was cut down almost completely. To soften the after effects of the

energy crisis, re-establish the ecological balance, and fill the demand for softwood, AESA provided assistance for establishing 53 hybrid poplar clones in 1994.

In 1997 an experimental-industrial plantation was established in Armavir marz of Armenia, where 14 selected clones were used (50-194, 49-177, 50-197, DN-70, DN-1, 55-260, NM-6, etc.). Plantations were established in Armavir cut-over forest areas in 1997 (15 ha), 1998 (19 ha), 1999 (29 ha and 1 ha of nursery), and 25 ha of plantations are foreseen for year 2000. The plantations were established mainly by the spacing schemes 3.2 m, 3.3 m, and 3.4 m. The best dendrometric indices were displayed in Armavair by the clones 50-194, 55-260, 49-177, 184-411, and 50-197. About 10,000 ha of the damaged forest areas of Armenia could be used for growing hybrid poplars, thus improving the ecological conditions of the damaged areas on one hand and filling the demand for soft wood and firewood in Armenia on the other hand.

Aphids (Aphididae, Homoptera*) on poplars in Serbia*

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In the course of the last few years in poplar growing regions in Serbia, an increased presence of aphids as well as a higher number of aphid species were observed. The increased presence of aphids caused significantly more conspicuous consequences of aphid attack, such as chlorosis, leaf deformation, different forms of galls on the leaves, retarded shoot and plant development, and in extreme cases, plant death. The differences in aphid species' predilection for various poplar species and clones were observed. The most endangered clones were those of autochthonous black poplar and white poplar.

The represented aphid species were collected and determined by inspection. During our research and after Petrovi, the following aphid species were identified: *Chaitophorus longisetosus* Szel*., Chaitophorus populialbae* (B.d.F.*), Chaitophorus leucomelas* Koch*, Chaitophorus nassonowi* Mordv*., Chaitophorus populeti* (Panz.*), Chaitophorus tremulae, Pterocoma populeum* (Kalt.*), Pachypappa* spp*., Pemphigus bursarius* (L.*), Pemphigus immunis* (Buckt.*), Pemphigus phenax, Pemphigus populinigrae* (Schr.*), Pemphigus protospireae* Licht*., Pemphigus spyrotheca* Pass*., Phloeomyzus passerinii* (Sign.*), Pterocoma populeum* (Kalt.*), Thecabius lysimachiae.*

Along with the study of aphids, the following physiological parameters were analysed: transpiration, photosynthesis, stomata conductivity, and A and B chlorophyll contents in attacked and unattacked plants. The study results point to

significant differences between attacked and unattacked plants. The study will continue in further detailed research of aphid fauna on poplars, more detailed research of the relation between aphids and physiological parameters of the host plant, predilection of various aphid species for poplar species and clones, as well as potential control measures.

Intercropping of Lolium perenne *with* Populus deltoides *Marsh. of different ages: economic evaluation*

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To obtain low cost rations for cattle, economically successful perennial ryegrass intercropping will mainly depend on pasture productivity and its dry matter (DM) unitary cost. However, dry matter production decreases across time due to the effect of tree shadow. The objective of this research was to determine the cost of forage dry matter obtained from *Lolium perenne* sown intercropped with 3-, 5-, and 8-year-old poplar trees. The study was done in San José de la Mariquina (39^{o} 36$^{'}$ S.L.), Chile, on a volcanic ash soil with 1,700 mm of annual rainfall and average temperatures of 16.9^{o} C maximum and 1.7^{o}C minimum.

The experimental design used included poplar plots at a density of 277 trees ha^{-1} (6 x 6 m); ryegrass production was evaluated for 3-, 5-, and 8-year-old poplar trees. Cover index was 3.2 m, 4.5 m, and 5.8 m wide, respectively. The DM costs are expressed in U.S. dollars.

Twenty-five kilograms of *Lolium perenne* per hectare were sown in March 1999; the fertilisation was 50 kg N/ ha, 147 kgP_2O_5/ha and 96 kg K_2O/ha. After the first and second cut, 50 kg N/ha was added.

Annual dry matter accumulation reached 7,137; 6,234; and 1,851 kg/ha ($P<0.05$) for 3-, 5-, and 8-year-old poplar trees, respectively. Unitary costs were 0.014, 0.016, and 0.031 U.S. $/kg DM, respectively. The reference cost of the dry matter in a normal situation is 0.015 U.S. $/kg DM.

The results obtained indicate that ryegrass intercropping with 3- and 5-year-old poplar trees permitted the achievement of a satisfactory unitary cost of DM for cattle production. In these cases the cost of DM was similar to a normal pasture. However, for the 8-year-old trees, ryegrass production was severely affected and increased its unitary cost; therefore, it would not be economically feasible for cattle feeding.

Calcium accumulation in the wood of short-rotation cottonwood species: effects on pulp properties

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The utilisation of species of the *Populus* genus of forest trees, particularly aspen and cottonwoods, as the cornerstone for the development of short-rotation intensive culture (SRIC) sustainable plantation forestry in the Northern Hemisphere has been promoted recently for a number of reasons. The primary driving force behind the implementation of SRIC *Populus* plantations, however, is their potential to alleviate the shortfall in world fibre supplies projected for 2010. This threat has provided an impetus for the examination of alternative fibre sources. Many non-wood sources have been characterised, but the most logical and industrially expedient solution to the problem is likely to lie in fast-growth hardwood tree species. In the Southern Hemisphere (and some parts of Europe), eucalyptus species are the hardwood of choice, for their high growth rates, inherent adaptability, and excellent papermaking properties. In the Northern Hemisphere, poplars represent a similar opportunity, having high growth rates- up to $30m^3$/ha/yr, producing pulps of high natural brightness, and offering the potential for genetic improvement of wood quality traits. If *Populus* species plantations are to be commercially successful, therefore, it is critical that they produce marketable pulps with desirable papermaking properties.

A number of research groups have previously noted that certain poplar species have an inherent tendency to accumulate mineral deposits, particularly calcium salt crystals, in their wood. Evidence described in these papers suggests that these crystals do not represent abnormalities but rather are consistently present in some *Populus* lineages (particularly the sections *Aigeros* and *Tacamahac*a). The crystals were found to accumulate in the stem, branches, roots, and within vessels and fibres frequently occluding them completely. The present study confirms that certain poplar species, including some of the hybrid poplars examined here, are prone to localised calcium crystal accumulation within vessel elements. The study expands on this previous observation in two major respects. First, at least in the kraft process, these calcium deposits are carried through the pulping regime and appear as hard, localised “bumps” in handsheets made from the pulp. If carried through cleaning, screening, and bleaching, such surface deformations would adversely affect paper quality.

The implications of these observations for kraft pulping are apparent. The fact that the deformation-causing deposits are present even after extensive pulp beating is cause for concern. Surface deformations of the kind seen here may seriously affect the quality of such pulps produced from poplars of these species. In the standard handsheet testing undertaken in this study, the presence of the

deformations caused manifold problems when performing caliper tests (to determine apparent density and apparent specific volume) and roughness tests. Furthermore, calcium ions are known to cause a number of costly problems for pulp mills. Calcium ions introduced into pulping systems in wood can combine with carbonate, oxalate, and sulphate ions to form complexes that are capable of causing blockages at all pulping stages. Calcium oxalate scaling is one of the most trying problems experienced in modern bleach plants and can affect evaporators and pulp digesters. At lower pulping temperatures, resin and fatty acid soaps can precipitate with calcium ions, making it more difficult to wash the pulp free of those soaps. The results of this study may, therefore, be regarded as a caveat for the use of certain species of poplars in pulping – if poplars are harvested from calcium-rich soils, there may be problems during processing and papermaking due to the accumulation of calcium salts in those trees.

Analysis of repetitive DNA elements in Populus *species and their use in study of phylogenetic relationships*

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The genus *Populus* is made up of nearly 35 species classified into five sections. The major rationale for poplar plantations is their potential use in industry, agroforestry, landscaping, and as animal feed. In India, however, plantations are largely dominated by *Populus ciliata* and *Populus deltoide*s. *Populus ciliata* (also known as the Himalayan poplar) is endemic to the Himalayan belt and is important silviculturally because it serves as a nursery crop for regeneration of silver fir. *Populus deltoides,* on the other hand, is found in the plains and is grown both as a plantation and as an agroforestry species. A number of hybrids are being developed in the genus to obtain diverse planting material showing varied adaptability and improved tolerance to biotic and abiotic stresses.

A major prerequisite for such improvement programs is the development of marker systems that may be used for clonal/hybrid identification. Repetitive DNA elements that are known to constitute a major part of the nuclear genome are powerful tools to study phylogeny. Besides this, species-specific repetitive DNA elements have been used in a wide range of plant genera for germplasm characterisation. Keeping this in view and considering the limited knowledge on the genome organisation in the genus, the isolation of repetitive DNA elements from the genus was attempted. A total of 400 clones were screened for presence

of repeat sequences from a genomic library of *Populus deltoides* digested simultaneously with four blunt-end cutting enzymes. A number of repetitive elements were identified, and these belonged to two classes, namely tandem and dispersed repeats. Two tandemly organised repetitive sequences, namely the 145bp and the 110bp, were identified as these produced a classical ladder pattern with *Hae*III. The 145bp family is widespread across most species analysed except *P. euphratica*. The 110bp tandem repeat was organised as large clusters and was present in a number of species except *P. trichocarpa* and *P. euphratica*. One family of dispersed repeats identified was characterised in *P. deltoides*. This member was absent in a number of species such as *P. alba*, *P. davidiana*, *P. euphratica*, and *P. tomentosa*.

Repeated DNA elements are an ideal tool to study the phylogenetic relationship between species. We have observed that the repeat elements identified in *P. deltoides* that are widespread across the species are strikingly absent in *P. euphratica*. This clearly indicates that *P. euphratica* is a distant member of the genus and may belong to another genus. Our data employing the sequence comparison of the 5S rDNA spacer region also substantiates the genetically distant nature of *P. euphratica.* Another application of the repeat elements is in the analysis of wide hybrids. The 110bp and dispersed elements, which are prevalent in some species and absent in other species, have been utilised for screening of interspecific hybrids in this genus. The chromosomal localisation of these repeat elements by *in situ* hybridisation is in progress and will be discussed.

Insecticidal activity and expression of Bacillus thuringiensis *toxin gene in transgenic poplar* (Populus deltoides *Bartr. x* P. simonii *Carr)*

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Insect-resistant poplar *(Populus deltoides* Bartr. x *Populus simonii* Carr) plants have been produced by infecting leaf disks with *Agrobacterium tumefaciens* strain LBA4404 carrying a binary vector pFWZ10 containing an artificially modified *Bacillus thuringiensis* toxin gene *(Bt* gene) under a duplicated CaMV 35S promoter and omega enhancer, and *npt* II, a selected marker gene. Seventy kanamyacin (km)–resistant clones have been regenerated from the selected medium with km 60 mg/L. PCR analysis showed that 31 clones produced the same band as the *Bt* gene did. PCR-southern blotting showed there were 8 clones into whose genome the *Bt* gene has been inserted. Bioassays with the larvae of *Lymantria dispar* on the leaves of 31 PCR-analysed clones showed different levels of insecticidal activity compared with the control. Four clones

showed higher than 80% death rate of larvae fed with the leaves of the selected plants on the tenth day, except that six clones showed no insect resistance compared with the control, which may show gene silencing in the transgenic plants and will be analysed. The clones showing insect resistance have been moved to the field. Molecular and insect-resistance analysis of the field plants will be done in the future.

Selection of **Salix** *varieties for specific uses - phytoremediation of heavy metal contaminated land and nutrient rich wastewaters*

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A series of studies undertaken at WRC have employed willow and to a lesser extent, poplar, for the novel, sustainable, and cost-effective management of waste. These have included application of sewage biosolids, polishing of sewage effluent and industrial wastewaters rich in plant nutrients, onsite management of landfill leachates, and rehabilitation of heavy metal contaminated land. All these techniques place specific demands on the varieties used and hence fitness for purpose is an important criterion for variety selection. Equally, it may be possible to optimise the efficacy of the approach by selection of varieties that have pertinent traits, such as high heavy metal accumulation, high tolerance of saline soil solution, low nutrient use efficiency, and so on.

Salix *as a means of cost-effective, onsite management of landfill leachate*

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Landfill leachate management is an ongoing cost after a landfill has ceased to generate income. Leachate contains components beneficial to plant growth as well as those that may be toxic in excessive quantities. Onsite treatment by irrigation onto contained areas can eliminate the need for sewer discharge and thereby reduce aftercare costs. Liquor volumes are reduced through evapotranspiration, and soil chemical and physical processes combined with plant nutrient uptake can be effective at reducing the potential impact of the leachate on receiving waters.

Short-rotation forest plantations of willow and poplar have high evaporative potential and low management requirements and hence are an attractive crop for landfill leachate management. Systems are in operation in Sweden (willow) and

the U.S. (poplar). Studies in the UK are investigating more aggressive leachates with high ammonium-nitrate concentrations and high electrical conductivity. Two long-term trials were established in May 1998 following a successful pilot trial the previous August, aimed at determining the capacity of *Salix* to tolerate and assimilate leachate components.

Phytoremediation of heavy metal contaminated land using willow: practical reality or impossibility?

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Land on the urban fringe can be contaminated with heavy metals as a result of industrial activity, posing a risk both to human health and to the environment, restricting the use of such land and thereby its value. Remediation may be possible by chemical means, or by burial of the contaminated area, but this is expensive and is seldom undertaken for large areas suffering from low level contamination. The production of biomass fuel crops on such land can bring it into economic use, result in an aesthetic improvement, and potentially lead to long-term remediation through heavy metal removal in the harvested crop. The production of biomass fuel crops on degraded land has several advantages as a site remediation measure. Some, such as *Salix* and *Populu*s, are pioneer species and hence are adapted to the harsh growing conditions that typify derelict land. Establishment and management costs are low compared with chemical washing. The contamination is contained onsite unlike a conventional dig and cart approach. Energy conversion of the fuel offers a method for the concentration of metal contained in the biomass. Production of a low risk, non-food crop on otherwise unproductive land brings that land back into the local economy.

Poplar breeding and testing strategies to meet current trends in utilization

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The breeding and selection of poplar clones suited to fibre and biofuel feedstock production requires simultaneous attention to all elements of the production

system. Selection criteria need to be chosen wisely because they determine the characteristics, i.e., growth rate, pest resistance, rooting ability, wood quality, etc., of the resulting cultivars: characteristics that further determine whether any industrial production system can succeed biologically and economically. Too few criteria can leave some important traits unimproved, while too many criteria can frustrate a breeding program logistically, especially when traits are negatively correlated within the same population. Selection is further complicated because the ability to produce large populations of hybrids, coupled with the ability to practice clonal propagation, mean that some multistage selection strategy must be developed. Selection can be imposed among seedlings prior to propagation, among remaining clones in short-term tests, and, ultimately, among a few clones after large block yield testing. The choice of which selection criteria to impose at each stage, and at what intensity, determines the cost and probable success of any breeding effort. In addition, selection criteria may be subject to genotype x environment interactions, depending on the range of environments found within the zone of commercial deployment and on the kind of populations under test. We will discuss the effects of different breeding and testing strategies on the likely outcome of poplar improvement programs. We will also discuss reasons why the information needed to optimise breeding and testing strategies has remained mostly inadequate and suggest methods that might be used to obtain that information.

We will use, as a case study, data from the Regional Testing Program we have been conducting in Minnesota, Iowa, Wisconsin, and Michigan. Our objectives have been to: 1) identify highly productive, disease-resistant clonal selections and 2) understand any patterns of genotype x environment interactions within the Region that would, logically, govern commercial deployment of new clones. Clones were selected from breeding programs at Iowa State University, the University of Minnesota, and the USDA Forest Service for experiments established in 1995 and 1997. The 1995 test included 43 clones of *P. deltoide*s, 10 clones of *P. deltoides* x *P. maximowiczii* F1 hybrids, 2 clones of *P. deltoides* x *P. nigra* F1 hybrids (including the DN-34 [a.k.a. NC-5326, cv. Eugenii] control), 1 clone of *P. nigra* x *P. maximowiczii* (NM-6 control), and 4 clones of aspen hybrids. The 1997 test included 75 clones of *P. deltoide*s, 12 clones of *P. deltoides* x *P. maximowiczii* F1 hybrids, and the same commercial controls. We will report results of analyses of variance and principal component analyses of tree heights, diameters, estimated aboveground biomass, *Septoria* canker incidence, and *Melampsora* rust incidence that have demonstrated both significant genotype main effects and significant genotype x environment interactions. We will use these and other data to demonstrate how multiple selection criteria might be allocated among stages of testing, and how selection for wood quality might be superimposed on our existing program.

Growth and contaminant uptake by hybrid poplars and willows in response to application of municipal landfill leachate

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Phytoremediation is an emerging technology that is a cost-effective and environmentally sound approach for many municipal landfill cleanups. Two of the most common tree species used in phytoremediation are poplars *(Populus* sp*p*.) and willows *(Salix* sp*p*.); both exhibit rapid growth rates and ease of vegetative propagation. More information is needed on the proper choice of tree clones for phytoremediation because soils, climate, and contaminants vary with sites. In this study we examined the phytoremediation potential of 10 northern poplar and willow clones in response to applications of Rhinelander, WI municipal landfill leachate in a replicated factorial experiment.

Our objectives were to compare seasonal: 1) plant growth, 2) hydrological uptake, 3) volatile organic compound (VOC) removal, and 4) inorganic macro- and micro-ion removal for the 10 clones growing across four experimental treatments (i.e., with and without contaminated water, and with and without trees).

Trees were grown from cuttings in landfill soil in 600 litre plastic tanks, and watered weekly with applications of either municipal water (control), or leachate ground water (contaminated) during the 1999 growing season; other tanks were treated similarly without trees. VOC's of the influent and effluent were monitored periodically, leaves were collected in October, and plant components (i.e. stems and roots) harvested in December for micro- and macro-ion analysis. Our results showed that height and volume growth of the poplar and willow clones growing in contaminated water were not significantly different from the controls. There were growth differences among the clones 2 poplar and 2 willow clones performed the "best". Tanks with trees took up 3 times the quantity of water when compared to tanks without trees indicating significant hydrologic uptake. Contaminant VOC's from the Rhinelander landfill were removed at a rate similar to the evapotranspiration rate including 1,1 DCA, tetrahydrofuran, benzene, and vinyl chloride. Significant quantities of some trace metal ions were removed by the trees; e.g., boron and zinc were found in leaves of some clones at concentrations much higher than most northern plants. Moreover, there were significant differences among clones in leaf concentrations of macro-ions such as magnesium and calcium that often contribute to ion toxicity in receiving waters near landfills. Our overall results suggest that certain poplar and willow clones have much potential for successful phytoremediation at our Rhinelander landfill.

Productivity of the selected poplar clones in the river Sava floodplain

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The productivity of nine selected poplar clones was researched in the floodplain of the river Sava, on fluvisol with a fossil horizon. The test was established with three replicates with nine clones of which seven clones are *Populus deltoides* (cl. S6-20, 721, S6-36, 618, 450, 55/65, and 457) and two clones *Populus euramericana* (cl. I-214 and Ostia). The standard (normal) planting technique was applied, planting stock 1/1, spacing 4.25 x 4.25 m or 555 plants/ha. Nine years after test plantation establishment, 50% of the trees were felled by regular geometrical thinning, so that after thinning 278 trees/ha remained. At the time of thinning, wood volume amounted to between 68 m^3/ha (cl. S6-20) and 145.6 m^3/ha (cl. 457). After 9 years of test plantation development, at the time of thinning, clone 450 had the highest current increment with 30.3 m^3/ha and clone S6-20 with 17.7 m^3/ha had the lowest current increment.

At the end of the 20^{th} growing season, the total produced timber volume, with thinned wood volume, was between 356.8 m^3/ha for clone S6-20 and 461.5 m^3/ha for clone 450. In this period, current increment ranged between 14.9 m^3/ha (cl. 457) and 22.9 m^3/ha (cl. S6-36).

The culmination of current annual increment of all clones occurred during the ninth year, the year of thinning. After thinning, current increment had a more moderate course, which leads to the conclusion that clone reaction to the increased growing space was not significant and that the results of thinning were not significant. The results presented in the paper show that, in addition to the correct choice of plantation establishment technology and the correct clone selection, one of the most significant factors of successful plantation development is the maximum utilisation of soil potential.

Populus*–a Midsouth industrial research perspective*

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The focus of both *Populus* research and operational deployment in the Southern United States has been on eastern cottonwood *(Populus deltoides* Bartr.). Eastern cottonwood research efforts were the primary undertaking of the USDA Forest Service Southern Hardwoods Laboratory at Stoneville, MS. Research efforts included the fields of genetics, silviculture, biometrics, pathology, and

entomology, which were all aimed at providing growers with a product that was both cost-effective and high yielding. Both sawtimber and pulpwood industries quickly embraced this highly intensive new program. One significant problem was that the best sites for cottonwood production were either unprotected alluvial land or highly productive protected alluvial agricultural land.

Westvaco, like a number of pulp and paper companies, owns suitable cottonwood sites in the lower Mississippi River Valley. Westvaco began operational deployment of eastern cottonwood clones in the early 1970s based on the results of cottonwood clone tests established in the mid- 1960s by the Stoneville group. At that time, research at Westvaco's Central Forest Research Center was primarily focused on loblolly pine rather than cottonwood, and it was not until 1980 that the company became interested in developing an in-house hardwood plantation research effort. This new direction included a variety of species as well as eastern cottonwood. In the mid-1980s the research efforts at Westvaco's Central Forest Research Center, now located at Wickliffe, KY, began to focus on eastern cottonwood. Clonal testing efforts increased dramatically at the centre as a means of constructing a suitable breeding population. This effort was also supported by co-operative work between Westvaco and the University of Kentucky with the development of a Disease Resistant Eastern Cottonwood Breeding Population. In addition, a cooperative effort among Westvaco, the Forest Service, and Crown Zellerbach was initiated to investigate the performance of pure clonal blocks and clonal mixtures. In addition, we began investigating breeding techniques in anticipation of our next effort in cottonwood genetics. However, in 1989 our cottonwood research was discontinued as a moratorium was placed on the operational plantation program at the Central Center.

In 1995, Westvaco reinitiated its hardwood research efforts, but this time the effort was on a division-wide basis. The knowledge gained in the 1970s and 1980s was used as a starting point for the renewed program in eastern cottonwood. New facilities were constructed and research personnel were hired to push forward the new hardwood plantation initiative. The major difference was that this renewed hardwood effort included both uplands and fibre farm plantations. With these new areas came new challenges not only in the field of genetics, but also in physiology, silviculture, and biometrics. In addition, Westvaco broadened its biotechnology expertise of hardwoods. Although our *Populus* breeding efforts now include material for upland sites, our primary focus continues to be on alluvial and fibre farm sites of the mid-south. Testing includes control-pollinated progeny tests and various clonal trials. Selections from these trials are being fed into both our biotechnology and plantation productivity research programs as well as our operational deployment population.

Restoration of agricultural land in Italy using woody crop plantations

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The European Union foresees that a large amount of land will be withdrawn from agriculture and used for the production of non-food raw materials. The planned utilisation of this land includes afforestation and plantation of woody crops for biomass and timber production using fast-growing species of the *Salicaceae* family. The choice of the species to be planted could also be oriented toward the use of native poplars, allowing sustainable management of the plantations. The objective is to reduce the agricultural practices and the use of chemicals thanks to the trees' adaptability to the environment. A first type of plantation is aimed at the restoration of agricultural land using a 20-year rotation culture. Mixed plantations established with seedlings of some native *(Populus alba, Carpinus betulus, Alnus glutinos*a) and non-native species *(Robinia pseudoacacia*) are under observation for the use of permanent growth plots to evaluate ecological functionality and productive potential. The possible cultural operations will be discussed to define the criteria to be chosen for sustainable management of these plantations.

The second kind of plantation focuses on biomass production using a short-rotation culture. It will obtain subsidies from EU only if the plantation will be coppiced several times in a 20-year rotation. However, it is well known that commercial clones available in Italy were selected mainly for timber production. For this reason, we established in 1998 a poplar clonal trial to study and evaluate under short-rotation culture (spacing 3 x 2 m) the performance of some poplar species and hybrids in growth and adaptation to the main biotic and abiotic stresses. The trial included 12 clones of *P. alba,* 3 clones of *P. nigra* F1 , 1 clone of *P. deltoides* F1, 2 clones of *P. deltoides* x *P. nigra* F1 hybrids, 4 clones of *P. deltoides* x *P. trichocarpa* F1 hybrids, 10 clones of *P.* x *interamericana* x *P. nigra* F1 hybrids, 1 clone of *P. maximowiczii* x *P.* x *interamericana* F1 hybrid, 1 clone of *P. deltoides* x *P.* x *euramericana* F1 hybrid, and 6 commercial clones (I-214, Boccalari, Luisa Avanzo, San Martino, Beauprè, Villafranca) as control. *P. alba* clones were selected from a common garden study at the University of Tuscia, and the others were selected from the breeding program of a private company. We will report results of analysis of variance of tree heights, diameters, estimated aboveground biomass, and susceptibility to some pests *(Melampsora* spp., *Marsonnina brunnea*, *Venturia populina*) and insects *(Paranthrene tabaniformis*, *Melasoma populi*) that have demonstrated significant genotype main effects. The analysed data showed a very good adaptation of the white poplar clones towards rust and insects, confirming the potential of this species for further genetic improvement.

Host preference of poplar leaf beetle, Melasoma populi *(L.) on four different poplar species*

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This study was carried out during 1998 to 2000 at the Alborz research centre poplar nursery in Karadj, Iran. Poplar leaf beetle is considered a major pest of poplar species in Iran. Adult and larval instars attack young stands (1 to 5 years old) in poplar nurseries and native plantations. During severe infestation, adult and larvae can defoliate host trees. Our field studies, in 1999, showed that the damage rate caused by this insect varied among different poplar species and clones. On the basis of these field observations, a number of field experiments were prepared. The poplar species used in this study included *Populus nigra*, *P. alba*, *P. simonii,* and *P. euramericana.*

In the spring of 1999, a pair of newly emerged beetles were restricted to a 30-cm branch of each of the above poplar species by a lace tissue cage. These beetles were permitted to feed for a 20-day period, until they died. During this period, deposited egg clusters were collected daily and transferred to the laboratory. The eggs in each cluster were counted and registered. Total leaf area fed by each pair of beetles in their tissue cages was calculated by a digital planimeter. Analyses of variance of total fed leaf area showed a significant difference ($p < 0.001$) among these four poplar species. *Populus nigra* and *P. euramericana* were preferred compared to *P. simonii* and *P. alba*. Analyses of variance on total deposited eggs in each species show that *P. nigra* and *P. euramericana* were preferred hosts for ovipositing compared to *P. simonii* and *P. alba*. The average weight of newly emerged beetles that had completed their immature instars in *P. nigra* and *P. euramericana* clones was higher than that of beetles associated with *P. alba* or *P. simonii.*

Cross protection of transgenic and non-transgenic poplar (Populus nigra *L.) clones in field tests for insect tolerance*

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Poplar plantations all around the world frequently experience infestation by leaf-eating insects. Considerable damage is caused by *Apochemia cinerarius* Erscheff, *Lymantria dispar* L., and *Orthosia incerta* Hufnagel. Their pupae survive

in the soil thus ensuring cycles of infestation. To face the problem, we have produced transgenic *Populus nigra* L. plants by infecting leaves with *Agrobacterium tumefaciens* carrying a *Bacillus thuringiensis (B*t)-toxin gene under a duplicated CaMV 35S promoter. After molecular analysis, bioassays on insecticide activity in the laboratory, and greenhouse evaluation, selected transgenic plants are now being evaluated in a field trial in China. A plantation was established in 1994 in Manas (Xinjiang Ulygur Autonomous Region, China) which includes 14 *B*t-poplar clones selected for insect tolerance and good silvicultural traits. Control non-transgenic plants were added at random positions in the experimental plot. The plants have now reached sexual maturity.

During peaks of *A. cinerarius* infection, we observed that: (a) leaves of *B*t-poplar plants resist insect attack, (b) leaves of non-transgenic control plants, or of transgenic plants that had low insect resistance, present within the transgenic cultivation, were equally protected, (c) the number of pupae in the soil was far below the danger level. The explanation of this is that the insecticide activity of *B*t-poplar trees reduces larval density in the soil, thus protecting all plants in the plantation. Events of somaclonal variation were recorded in the primary poplar transformants. Variation included changes in leaf morphology. Morphological and molecular analysis based on random amplification of genomic DNA sequences (RAPD analysis), showed that both DNA and leaf changes are retained after clonal propagation and growth to maturity in the Manas plantation.

Morphological investigation on aspen (Populus tremula *L.) growing naturally in Turkey*

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Forest resources in Turkey are not sufficient to meet the demand for wood. Therefore, it is necessary to find new alternatives to increase wood production. By means of poplar plantations, it is possible to produce abundant wood within 12 to 15 years. In this study, inner and outer morphologies of naturally growing aspen were investigated. The results obtained may be summarised as follows: vessel member number (mm^2) in spring and summer woods at different altitudes. Springwood vessels are larger than those of summer wood. The dimension of vessel decreases systematically toward sea level. A super positioned perforation table exists. In the radial direction, vessel groupings contain 2 to 8 vessels or a maximum of 3 to 10 vessels. Rays are “Uniserite” and “Homocellular” in aspen, and their length varies between 0.656 mm and 2.0 mm. Aspen wood should be utilised in papermaking.

Practical problems of poplar growing in Turkey

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Forests of Turkey are not enough to meet the country's wood needs. The wood deficit started in 1982 and will reach 15 billion m^3/yr in 2000 according to predictions. To enhance wood production, new possibilities for expanding wood production must be found. It is possible only poplar growing can supply necessary wood products in the next 12-15 years. Poplar has been grown for a long time in Turkey. Lands of poplar growing have been expanding quickly in Turkey. According to the inventory study done in "Poplar Growing Project" by the Turkish government and FAO before 1968, annual poplar wood production of Turkey was approximately 600,000 m^3/yr. Today 3.5 billion m^3/yr of poplar wood are produced. Poplar growing studies have been conducted since 1957. Today, there are some problems of poplar growing; poplar growing research must be continued. Exotic clones using production in the world must be grown. Hybridisation studies of indigenous and exotic trees must be continued. New lands must be found for growing poplars.

A Free Air CO2 Enrichment experiment on a short-rotation, intensive poplar plantation: growth dynamics and leaf area over a 2-year period

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Awareness has been growing recently that trees and forests not only passively undergo global climatic changes, but also are driving actors that determine the course of climatic changes. As this active role is being emphasised more and more, the scientific community aims to assess and quantify the contribution of forests in the global climate change issue. The increase of atmospheric CO2 concentration is a crucial point in this matter, and many techniques have been adopted to study the behaviour of trees under elevated CO2 concentration conditions. FACE (Free Air Carbon Dioxide Enrichment) technique is turning out to be the most efficient one in the recent years since it allows the study of the forest ecosystem without altering microclimatic conditions and without limiting the dimensions of the plants. This technique has been applied in an experiment on short-rotation, intensive poplar plantations called POPFACE funded by the European Community and participated in by different European research groups.

A poplar plantation of about 10 ha was established in spring 1999 in an agricultural region of central Italy, and six experimental areas–three with elevated CO2 (550 ppm) and three with ambient CO2 were selected inside the plantation. Three different genotypes of *P. alba, P. nigra,* and *P.* x *euramericana* are being used to study the effect of elevated CO2 at different levels from leaf physiology to whole canopy activity, from roots and mychorrhizae to interactions of plants with fungi and insects.

During the first growing season, the validity of the FACE facility was tested and preliminary data on tree growth and physiology were collected. An increase in growth parameters was observed in all species and seemed to be rather significant for the *P. nigra* genotype. Particularly, the number of sylleptic branches and the volume index of the main stem were stimulated by elevated CO2 , together with total leaf area per plant; therefore, total aboveground biomass increased under the elevated CO2 treatment, resulting in an increase in carbon sequestration capacity by plants. In the second growing season, the further expansion of tree crowns and canopy leaf area is causing the onset of a strong, inter-individual competition for light and other resources that will interact with the growth and physiology of the different poplar genotypes growing under ambient versus elevated CO2 . The experimental results of the second year and a comparison with first-year results will be discussed to provide clues to the potential contribution of agroforestry in a future world of elevated CO2.

Development of Land Suitability Maps for Hybrid Poplars

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In planning for poplar production as with any crop it is important to consider climate, soil, landscape, market, production, social and economic factors before making any decision to grow poplars commercially. Land suitability is defined as the fitness of land for a specified kind of land use. Poplars have specific growing requirements and growers need to know which areas are suitable for economic poplar production. The classification was based on an assessment of land qualities which affect poplar growth. These qualities include biophysical features of soil, topography and climate. The assessment of suitability does not take into account hazards such as fire, pests or diseases, nor does it consider socio-economic factors. This paper evaluates the suitability of landscapes for hybrid poplar production. Our objectives were to identify landscape areas that are potentially suitable for hybrid poplar production in plantations and to develop a hybrid poplar suitability mapping systems that can be adapted at both provincial and regional scales.

The criteria supplied for hybrid poplar development required the evaluation of climatic growth factors including growing season precipitation, annual precipitation, and annual moisture deficits. Soil and landscape factors considered included depth to water table, soil texture, salinity, pH, sodicity or SAR rating, A-

horizon depth, slope percentage, slope length and flooding. Criteria for specific ecoregions were also initially considered. Using growth data of hybrid poplar collected from 100 sites selected over a wide geographic area, three suitability classes were established; Excellent or the most suitable areas for poplar growth, Good - while still suitable for poplar production, conditions were less favourable than the top class, and Poor - soil, landscape and or climate conditions are not favourable for strong growth of hybrid poplars.

Using Global Information Systems (GIS) we generated suitability maps at both regional and provincial scales. The provincial map considers growing season precipitation and dominant surface texture and utilised the Soil Landscapes of Canada Database (1:1 million scale). A more detailed regional map was derived from the 1:100,000 soil attribute database. Two methods were used to create regional and provincial maps. The first utilised the method of most limiting factor in which the most limiting factor affecting growth determined the growth potential for the area, While this method was simple to apply it does not recognise the importance of each growth factor being rated. Therefore, a second method of creating a final rating based on the relative importance of each the factors was applied

Provincial ratings reflect the dominant effect of climate in determining the most suitable location for the growth of hybrid poplars. Thus climate was considered 60 % of the total suitability while soils are considered as 40%. Regional ratings reflect a more detailed mapping of soil conditions thus a greater emphasis of portraying differences in soils and landscapes in the final poplar suitability ratings. Climate ratings were adjusted depending on the location in the region and reflect the provincial rating of the area. For the regional area used in the study, the climate rating on the provincial map was considered excellent, therefore the regional area receives the top climatic rating in the provincial rating as well. In regional studies, soils receive 70% of the total suitability rating, while climate receives 30 %.

Using GIS technology we were able to accurately map hybrid poplar suitability at the provincial and regional levels. The maps can be used by researchers, landowners and foresters to identify areas suitable for commercial production of hybrid poplars on agricultural land.

The role of plantations in the world's future timber supply

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High yield industrial forest plantations have existed in many regions of the globe for about four decades. This presentation will examine some of our experiences with forest plantations over that time. Additionally, the past and potential impacts

of plantation forestry on the U.S. and global timber supply will be examined. Prospects domestically and abroad will be addressed. Finally, likely future innovations in plantation forestry, including biotechnology, will be examined.

The harmful Lepidoptera *species of poplar in Izmit and Sakarya Regions in Turkey*

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As a fast growing and easily processible raw material, poplar is an important tree species that offers the possibility of meeting the growing demand for wood raw material in Turkey. The main purpose of poplar cultivation is to obtain a great amount of wood material with high technical properties in a short time. The aim of this study is to examine the types and life cycles of the harmful *Lepidoptera* species of poplar plantations around Izmit and Adapazari provinces. First, all available literature was reviewed to obtain knowledge about the species that exist in this environment. Secondly, planned periodical surveys of the biology and damage of these insects were carried out. The adults collected from fields and obtained in the laboratory were identified by the help of experts. Their morphologies, biological stages, and their damages on poplars were also examined. As a result of this study, 21 harmful *Lepidoptera* species, which belong to 9 families, living on poplar around Izmit and Adapazari provinces were determined and are listed below: Family Phylocnistidae, *Phylocnistis suffusella* Zeller; Family Tortricidae, *Archips rosana* (Linnaeus) and *Gypsonoma dealbana* (Frölich); Family Aegeriidae, *Aegeria apiformis* Clerck and *Paranthrene tabaniformis* (Rott.); Family Noctuidae, *Apatele psi* (Linnaeus), *Catocala elocata* (Esper), *Nycteola asiatica* (Krulikovskii), and *Scoliopteryx libatrix* (Linnaeus); Family Lymantriidae, *Leucoma salicis* (Linnaeus), *Lymantria dispar* (Linnaeus), and *Orgya antiqua* (Linnaeus); Family Arctiidae, *Hyphantria cunea* (Drury), and *Phragmatobia fuliginosa* (Linnaeus); Family Notodontidae, *Cerura vinula* (Linnaeus), *Pheosia tremula* Clerck, *Pygaera anastomosis* (Linnaeus), *Pygaera curtula* (Linnaeus); Family Lasiocampidae, *Malacosoma neustria* (Linnaeus); Family Sphingidae, *Smerinthus populi* (Linnaeus).

Poplar in agroforestry: a case study of its ecological benefits, site productivity, and economics

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Poplars are the major tree component of the traditional agroforestry system throughout the south temperate central area of China, which includes all or portions of Jiangsu, Anhui, Zhejiang, Hubei, Henan, Shandong, and Shanxi provinces, an area of roughly 600,000 km^2. However, lack of experimental data or basic information on interplanting is a serious gap in our knowledge, and consequently, a stable, optimal poplar-crop interplantation pattern is hard to achieve. To develop such a pattern that is economically viable, environmentally sound, technically workable, and socially compatible, some new poplar-crop interplanting patterns were designed and established using the principle of edge effects in 1992. Six spacing were designed in the experiment with narrow-wide spacing pattern, i.e., I: (3x3) x 20 m, II: (3x3) x 30 m, III: (3x3) x 40 m, IV: (4x4) x 20 m, V: (4x4) x 30 m, and VI: (4x4) x 40 m, and the block arrangement was made at random. Based on a 7-year investigation, this paper mainly tests the difference of these new patterns on temporal and spatial variations in microclimate in various phenological phases of winter wheat, variations in wheat yield and wheat quality, biomass productivity, and light-use efficiency. An economic assessment and the potential viability of these new patterns are also discussed in the paper. These preliminary results can provide some basic principles for developing optimal poplar-crop interplantation patterns in the plain areas of China.

Genetic evaluation of poplar clones introduced from different organizations in the nursery and field under Punjab (India) conditions

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The Forest Research Institute of Dehra Dun (India) began introducing *Populus* species/clones as early as 1950. These species/clones were distributed in many agroclimatic regions to test their adaptability and growth performance. Clones G-3 and G-48 (Australian origin) of *P. deltoides* have been widely adopted by farmers of the north-western parts of India under agroforestry systems. In Punjab, systematic introduction of *P. deltoides* clones began in 1987. Since then, about 300 different clones originating in Australia, the United States, the United Kingdom, Italy, West Germany, and India have been introduced for evaluation and further selection. All of these clones are being maintained in germplasm at Punjab Agricultural University, Ludhiana. These clones were introduced in 11 groups, and each group was/is being tested consecutively for 3 years in the nursery. Some clones showed remarkable growth, significantly better than the control (G-3). Such clones were put under five field testing trials in different agroclimatic regions of Punjab. Periodical observations on tree height, diameter, and susceptibility to insect pests were recorded. On the basis of growth

performance and resistance to insect pests, the Research Evaluation Committee (REC) of Punjab Agricultural University recommended the commercial cultivation of seven clones (PL-1 to OL-7; four for the central plain region, two for the semi-arid region, and one for both regions) in Punjab. Some other clones even outperformed these in other testing trials. These are expected to be recommended for commercial cultivation by the REC of the University. There were clone x site interactions. Some clones outperformed on specific sites, and others showed genetic stability and their performance was very good on all sites. The results of the study have been discussed in the light of genetic superiority, genetic stability, and genotype x site interactions.

Faunistic studies on the Lepidoptera *species found in Cankiri forest nursery in Turkey*

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This study was done to determine the order *Lepidoptera* species in Cankiri Forest Nursery between May and September 1999. This area is 97 ha and its altitude is 760 m. *Populus* x *euramerican*a, *Robinia pseudoacacia* L., *Acer negundo* L., *Fraxinus excelsior* L., *Elaeagnus angustifolia* L., *Pinus nigra* Arn., *Cedrus libani* A. Rich., *Ailanthus altissima* (Mill.) Swingle, and *Morus alba* L. have been growing in this nursery. *Populus euramericana*, *Salix* sp., *Thuja orientalis* L., and *Quercus* sp. have been growing as natural flora in the same area. Pennsylvania type light trap was used for catching the pests and determining their flight period. Adult insects were obtained from the larvae on the infested plants. The relationship between host plants and the *Lepidoptera* species was established.

In this study 582 moths were identified representing 58 species and 14 families. Moths in the families Arctiidae (9), Geometridae (8), Noctuidae (11), Notodontidae (6), and Sphingidae (9) were captured most frequently. The 58 species were determined in the forest nursery where 25 of them were found to be important or potentially important pests in the forest area. The most important 25 pest species are *Arctia caja* L., *Eilema* sp. (Arctiidae), *Cossus cossus* L., (Cossidae), *Elicrinia cardiaria* Hbn. (Geometridae), *Malacosoma neustrium* L., *Phyllodesma tremulifolia* Hübner (Lasiocampidae), *Euproctis chrysorrhoea* L., *Leucoma salicis* L., (Lymantriidae), *Agronicta megacedphala* F., *Dysgonia algira* L., *Earias chlorana* L. (Noctuidae), *Cerura bifida* L., *C. vinula* L., *Pterosoma palpinum* L., *Notodonta ziczac* L., *Pygaera curtula* L. (Notodontidae), *Saturnia pyri* Schiff. (Saturnidae), *Paranthrene tabaniformis* (Rott.) (Sesiidae), *Hyloicus pinastri* L., *Laothoe populi* L., *Smerinthus kindermanni* Lederer, *S. ocellatus* L. (Sphingidae), *Thaumetopoa pityocampa* (Schiff.) (Thaumetopoeidae),*Gypsonoma dealbana* (Fröl.), and *Tortrix viridana* L. (Tortricidae).

The other 33 species were found to be harmful on orchards, herbs, and annual plants. They were *Diaphora mendica* L., *Epatalmis casearea* Goeze., *Epicallia villica* L., *Lithosia quadra* L., *Phragmatobia fuliginosa* L., *Phrogmatobia placida* Frivaldsky, *Tyria jacobaeae* L. (Arctiidae), *Ethemia bipunctella* F. (Ethemiidae), *Acidaria decorata* [D-S], *Aplocera plagiata* L ., *Calothyanis amata* L., *Opisthograptis luteolata* L., *Rhodostrophia tabidoria* Zeller, *Semiothisa clathrata* L., *Timandra amata* L. (Geometridae), *Malacosoma castrensis* L. (Lasiocampidae), *Dysgonia torrida* (Guenee), *Emmeria trabealis* Scop, *Hyles euphorbia* L., *H. nicaea* Prunner, *Noctua orbona* Hufn., *N. pronuba* L., *Polyphaenis subsericata* H-S, *Triphaena fimbria* L. (Noctuidae), *Phoesia tremula* L. (Notodontidae), *Crambus craterellus* Scop, *C. pinellus* L. (Pyralidae), *Agrius convolvuli* L., *Deilophila suellus* Stgr., *Hyles hippophoes* Esp., *Macroglossum stellatarum* L., *Rethera komarovi* Christeph. (Sphingidae), and *Hedya nubiferana* Hw. (Tortricidae) dir.

This study found that *Phyllodesma tremulifolia*, *Leucoma salici*s, *Cerura bifida*, *Cerura vinula*, *Pterosoma palpinum, Paranthrene tabaniformis, Leucoma populi, Smerinthus ocellatu*s, and *Gypsonoma dealbana* are the important species in the poplar nursery, but *Arctia caja, Cossus cossus, Malacosoma neustrium, Euproctis chrysorrhoea, Hyloicus pinastri, Tortrix viridan*a, and *Thaumetopoa pityocampa* are the most harmful species in our forest ecosystem.

Response to salinity in Populus

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Salinization of soils is a phenomenon that has increased significantly in many parts of the world, proving to be a limiting factor for agricultural and forestry productions in many arid and semi-arid regions. Many areas in Spain, both large and small, are affected in an important way, like the Ebro and Guadalquivir basin. Rusticity and plasticity of white poplar determine a wide geographic distribution in Spain and justify its potential use in ecologically difficult areas where aridity, height, temperatures, or salinity are problems. This work covers, under greenhouse conditions, the response to salt (7 and 14 dS/m) of different clones of *P. alba*, which belong to a CIFOR collection of this genus with different origins within the territory. Also included are two hybrids from the crossing *P. deltoides* x *P. alba* in which the male parent is from south-east Spain; *P. euphratica* and four clones of *P. euramericana* (I-214, IMC, Triplo, and Flevo). We considered different parameters (agronomic and physiological) to facilitate the detection of genetic variability in tolerance to salt in poplar, such as percent of survival, height increase, and rate of net photosynthesis.

When the evaluation of tolerance was carried out following the criterion of survival, three *P. alba* clones (of the same family) showed survival levels of 100% without symptoms, compared to others of the same species that showed sensitivity. *P. euphratica* and the clones from *P.* x *euramericana* showed tolerant and sensitive behaviour, respectively, using this evaluation criterion. When the parameter observed was increased in height, we noticed a significant height reduction in relation to the controls, with the exception of *P. euphratica* at the lower dose, although the height loss was, in percentage terms, less in those considered tolerant to the survival parameter. The rate of photosynthesis was not seen to be negatively affected for any clone/dose combination 24 hours after the start of the experiment. However, in the middle of the experiment, when poplars had been exposed to salt for a month, it was possible to detect differences in the rate of photosynthesis in clones considered tolerant were clones similar to the controls and clones considered sensitive were significantly different from the controls. At the end of the experiment (2 months of salt) in every case, including *P. eupratica*, the rate of photosynthesis was reduced significantly, regardless of survival percentage and height increases. The majority of the clones used in this work showed behaviour that is typical of non-halophytic plants in comparison with *P. eupratica*, which is considered tolerant to difficult conditions, including salinity. However, the variation observed in relations to survival among autochthonous clones of *P. alba* and hybrids of *P. deltoides* x *P. alba* demonstrated variability within the species that can be used in both the selection of adaptive characters, such as tolerance to salt, and in the possible reforestation of areas affected by this problems.

From gene isolation to genetic modification in Poplar: the use of a poplar floral homeotic gene for genetic engineering of reproductive sterility

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Genetic engineering of sterility provides a means to greatly reduce transgene spread into the environment. One means of engineering sterility involves the use of a floral-specific gene's regulatory region (promoter) to direct the expression of a cytotoxin to developing floral organ primoridia, preventing the development of flowers. Based on several years of field trials with several dozen lines of transgenic poplars, we found that heterologous floral promoters caused reduced growth when fused to the barnase or DTA cytotoxins. We have therefore searched for floral genes from poplar whose promoters direct strongly floral-specific expression. We isolated a number of floral homeotic genes homologous to the well-known Arabidopsis genes LEAFY, AGAMOUS, APETALA1, and APETALA3 from *Populus trichocarpa* (black cottonwood). One of these genes, PTD, which is highly homologous to the Arabidopsis gene APETALA3 and the

Antirrhinum gene DEFICIENS, had expression specifically confined to floral tissues based on gel-blot and *in situ* expression analysis, suggesting that its promoter would be useful for engineering of cytotoxin-based sterility. To test this hypothesis, the PTD promoter was used to direct expression of a reporter gene and cytotoxin in transgenic Arabidopsis, tobacco, and early-flowering poplar (poplar co-expressing 35S::LFY). The reporter was specifically expressed in a subset of floral tissues in each plant type, suggesting that the PTD promoter would be useful in diverse species. In Arabidopsis, 63 of 69 PTD::DTA lines failed to flower or display arrested petal and stamen development and were self-sterile. Petals, stamens, and carpels were ablated in all 18 PTD::DTA lines of tobacco that flowered. In 35S::LFY transformed poplar, the frequency of flowering decreased from 90% (18 of 20 lines) in plants containing 35S::LFY alone to 10% (1 of 10 lines) when PTD::DTA was also present. Results will be presented on the phenotypes observed, and the remaining challenges for using this gene in constructs intended to provide stable, long-term sterility in poplar.

Beneficial reuse of landfill leachate with hybrid poplar

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The use of hybrid poplar is increasing for application in plant-based wastewater reuse systems. In the system described, a hybrid poplar plantation received primary treated landfill leachate as applied by microspray irrigation. The site is located in McMinnville, Oregon, USA and has been operated with leachate application for seven growing seasons, beginning in 1993. In every year of operation, monitoring of nutrient and metals concentrations in leachate, groundwater, soil pore water, bulk soil, and leaf tissue has been conducted to aid in irrigation management. The primary environmental objective of site management has been to avoid any degradation of groundwater quality as a result of leachate constituents percolating out of the root zone and towards underlying groundwater. Because the leachate contains high concentrations of ammonia, nitrogen transport in the soil, plant, and groundwater system is of particular concern. Monitoring results indicate that there has been no degradation of groundwater during operation of the leachate reuse system. Nitrogen (N) concentrations in soil have increased over time in the upper root zone but have been attenuated before being leached out of the influence of tree roots. Although soil pH has remained fairly constant over time (6.4 +/- 0.72), soil cation exchange capacity (CEC) has decreased from 31.4 meq/kg in 1993 to 14.9 meq/ kg in 1999. This trend may indicate a gradual saturation of exchange sites over time. In 1997, an additional leachate pretreatment process, breakpoint chlorination, was implemented to reduce N concentrations so that a greater volume of leachate could be applied to the fixed capacity poplar tree reuse system. This process introduced a significant quantity of sodium (Na) and chloride (Cl) into the plant-soil system. Although no impact to groundwater was detected, Na, Cl, and

total dissolved solids (TDS) concentrations in soil pore water did increase substantially in 1997, 1998, and 1999 as compared to previous irrigation seasons. In general, the poplar tree system was effective in the sequestration of leachate constituents, and the objective of beneficially reusing the wastewater while preventing any negative groundwater quality impact was achieved. However, long-term operation of this site should address the issues of decreasing CEC and increasing Cl, Na, and TDS.

Testing and analysis of afforestation techniques of poplar with medium-depth planting (MDP) in Korqin sandy lands

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Comparing the survival rate and growth increment between the Medium-Depth Planting (MDP) and traditional planting methods, it is noted that significant differences in survival and increments exist between the two methods. Research shows that the Medium-Depth Planting technique is suitable for Korqin Sandy Lands. Comparison trials on different planting times, different stock types, and different treatments have been established. The results show that 2-year-old stock is better than 1-year-old stock; if planting in spring, stock must be buried underground during the previous winter.

First results on growth of ten poplar clones in an experimental planting for biomass production in northern Greece

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This paper presents the first results on growth, measured as diameter at breast high (dbh), of ten 1-year-old poplar clones, established in an experimental planting at spacing 1.0 x 1.0 m in the forest nursery of Strymonas. The clones were planted as cuttings. The 10 tested clones were the following: a) Italian clones: I-74/76, I-77/74, I-81/74, I-102/74, Belloto, Tiepolo, CIMA, I-214, I-45/51, and b) Greek clone: He-X/3. The aim of this work is to study the biomass production (fresh/dry matter, tonnes/ha) at age 3-4 years (rotation period).

The results of the first growth period (1997) showed that diameter growth (dbh) differed significantly between clones. Data analysis proved that clone I-45/51 had the highest diameter growth (2.4 ± 0.40 cm i.e. mean ± standard error) and clone I-214 had the lowest growth (1.8 ± 0.35 cm). The growth of the other poplar

clones ranged between these two values (CIMA: 2.3 ± 0.28 cm, I-74/76: 2.2 ± 0.34 cm, He-X/3: 2.2 ± 0.34 cm, Tiepolo: 2.2 ± 0.37 cm, I-81/74: 2.2 ± 0.31 cm, Belloto: 2.1 ± 0.31 cm, I-77/74: 2.1 ± 0.32 cm, I-102/ 74: 1.9 ± 0.30 cm). Results also demonstrated clone I-214 which is widely used in poplar plantations is less productive in narrow spacing (1.0 x 1.0 m) compared to other clones. Furthermore, since diameter growth is correlated well with biomass production, it is implied that the growth of dbh can predict the production of biomass of the tested poplar clones.

Spread of the watermark disease Brenneria salicis *in arborescent willows*

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The watermark disease caused by the bacterium *Brenneria salicis* (formerly *Erwinia salici*s) is of significant concern wherever arborescent willows are grown or occur naturally. A research program was set up in order to discover a suitable identification and detection method for *B. salici*s. We derived primers from the nucleotide sequence of the 16S rRNA gene of *B. salicis* for the development of a PCR to detect this pathogen. One set of primers, Es1a-Es4b, directed the amplification of a 553-bp fragment from *B. salicis* genomic DNA as well as *B. salicis* cells. The minimum number of cells that could be detected from the vascular fluid of willows was 20 CFU/ml. The PCR assays proved to be very sensitive and reliable in detecting *B. salicis* in willow plant material. In the willow selection and breeding program at the Institute for Forestry and Game Management (IFG), emphasis is placed on the establishment of a gene bank and on the selection of clones resistant to diseases, especially to watermark disease, and with a high growth potential. Through the years, a collection was built, containing about 800 indigenous tree-forming willow clones, 80% of them belonging to the white willow species *(Salix alb*a), crack willow species *(Salix fragili*s), and their interspecific hybrids. During recent years, the basic collection was screened using the PCR-based detection method for *B. salici*s. Up to 78% of the nursery trees were contaminated with the bacteria, without showing external disease symptoms. First results will be presented.

An actual situation of poplar resistance to Melampsora larici-populina in Belgium

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Poplar breeding in Belgium was initiated in 1948 by Swedish Match to develop fast-growing clones for match production. Since then, several vigorous hybrids have been selected by crossing *P. deltoides* Marsh. with the endogenous *P. nigra* L.*[*P. x *euramericana* (Dode) Guinier] or with *P. trichocarpa* Torrey & Gray*[P.* x *interamericana*]. The basis for this breeding program is a collection of several hundred clones of *P. nigra*, *P. deltoides*, and *P. trichocarpa.*

Since 1980, the resistance of most of the commercialised clones to *Melampsora larici-populina* has broken down. This has led to the identification of five main pathotypes of the rust species. However, several poplar clones, belonging to different species and hybrids, have remained tolerant to the different pathotypes. This paper presents an actual situation of poplar resistance to *M. larici-populina* and discusses future strategies for poplar resistance breeding.

Growth and yield of 7-year-old hybrid poplar at three planting densities

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Potlatch Corporation's hybrid poplar program at Boardman, Oregon, USA is testing various clones for potential fibre supply and the production of solid wood products. Clones are being tested using a randomised design with four replicated plots per clone in the clonal test, and three replicated plots per clone in the spacing test. Each replicate is physically arranged as seven plots deep and six plots wide. Each plot has 49 trees of the clone assigned to that plot, planted at 7 x 7 trees. All plots were hand-planted in 1993 and have received the same cultural treatments. Cuttings in the clonal tests were planted at 10 x 8 foot spacing, and cuttings in the spacing tests were planting at 10 x 8, 10 x 10, and 10 x 12 foot spacing. Water and nutrients were supplied during the past 7 growing seasons using a drip irrigation system. This study will report growth and yield differences for a 7-year-old DxN clone grown at three planting densities (363, 436 and 544 trees/acre).

In January 2000, 7-year-old trees were destructively sampled on the clonal and spacing test sites using stem analysis techniques. Data analyses will be completed by mid-April 2000. We will report our growth and yield results on the three spacings at the IPC 2000 conference in September 2000.

Genetically modified poplars: state-of-the-art and perspectives on the public controversy

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From a biological viewpoint, poplars are the ideal species with which to introduce genetically modified (GM) trees into forest plantations. Based on transformability and the availability of genes that confer traits valued by growers, GM trees could now be in commercial use. A number of laboratories have demonstrated normal growth and morphology of transgenic poplars in field trials of commercial clones, and the genes used—herbicide resistance, insect resistance, and modified wood chemistry—could each be of substantial economic value. However, questions remain about potential impacts of genetically engineered poplars; and economic, political, and social factors have converged to push the timeline for deployment in most countries back several years. Most significant is the strong political reaction in much of the developed world against GM food crops. They are effectively banned in many parts of Europe, and public outcry is growing in the USA and other countries. In all places, the dissent has been led by environmental and consumer activist organisations that believe that food and environmental safety issues have not been adequately addressed. Some groups, however, are against GM in any form for ethical or political reasons.

Distortion of scientific information has been a key tool of activists against GM crops. On a number of occasions preliminary results have been blown far out of proportion to their scientific meaning. A key element of concern derives from the control of GM crops by a few large, multinational companies that clearly are using them in a very aggressive manner in their businesses. The combination of a novel technology that produces food and environmental safety concerns, and that stands to restructure economic power in global agriculture, has created a great deal of unease over the adequacy of government controls. The GM controversy has engaged forestry, mainly prompted by a report issued by the Worldwide Fund for Nature in 1999 (http://www.panda.org/resources/publications/forest/gm-overview.html). The report reiterates a number of scientific challenges for use of GM crops, well known to practitioners for many years. But it also suggests, without evidence, that dangerous releases are happening, and that a moratorium on field trials is therefore needed. The main consequence of the report has been to further polarise discussions of GM trees, bringing the kind of disorder that has plagued Europe to bear on the public discussion about GM trees within the global forestry community.

To go forward with transgenic poplars in the developed world, we believe that companies doing research and considering deployment will need to be more transparent and co-operative than they have been in the past. If the public is to consider these new kinds of trees entering the environment on a large scale, they will need to be informed fully and given a chance to comment, and will likely need to be convinced that there will be broad economic benefits that go beyond those that accrue to a select few multinational companies. Second, more research on potential environmental effects and means to mitigate them, and eventual

monitoring of plantations, will be needed. Most critical will be avenues to reduce the spread of genes via sexual reproduction because “biopollution” is likely to be the most important, and most recalcitrant, environmental and public concern. Finally, more field research is needed to assess the long-term stability of transgenic traits in the face of environmental variation, particularly for biosafety-related traits like sterility, and to estimate the frequency with which somaclonal variation might have latent effects on clonal yield and adaptability.

Identification of RAPD molecular markers for resistance against Alternaria alternata in Populus

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In the present study a three-generation *Populus deltoides*(R)x*P. cathayana*(S) hybrid poplar pedigree, comprising F and F progenies, was used to investigate the genetic control of resistance to *Alternaria alternata* (Ala). The susceptibility of parents, F and F to Ala was tested in both the greenhouse and the field. The results suggested that the resistance may be determined by a single recessive gene for *P. deltoides*. To identify the markers linked to Ala resistance, using RAPD markers, in combination with bulked segregant analysis, we analysed approximately 4200 selectively amplified DNA fragments using 400 primers and identified two markers linked to this resistance gene. The results are the basis for molecular marker assisted selection and early identification of disease resistance varieties.

Study of agro-forestry system poplar (Populus *x* euramericana *cv. I-488) and crops: crop’s planting space to the trees. VI Region, Chile*

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To maximise the use of soil in a forest of poplars to develop agro-forestry poplar-crops, the effect of the crop’s planting space to the trees was evaluated through the productivity of the crops and growth of the poplars. In the clone I-488 in the first and second year of the plantation, established at a density of 278 trees/ ha (6 x 6 m), crops planted three distances from the poplars (0.5, 0.75, and 1.0 m) were studied. The crops included annual species like onion, tomato, sweet corn, corn, green beans, dry beans, potato, and wheat were studied. The productivity of the crops was evaluated by yield and leaf area; in poplars, diameter at breast

height (dbh) and at the base of the first branch, and total height and height to first branch were measured. For the agro-forestry system, the incidence of photosynthetic active radiation (PAR), effect on soil fertility, variation of the environmental and soil temperature (30 cm depth), and fluctuations of the water table were evaluated.

The results indicated that the crop yield was not affected when varying the distance to the tree. However inside the agro-forestry system, the smallest planting space produced a significantly greater yield of each species. Regarding tree growth in the first year a significant and positive effect on dbh was observed in crops of onion, potato, and green beans in some distances; however, in the second year, significant differences were not obtained. In relation to PAR, during the first year, the trees did not interfere with incident light on the crops; in the second year, the effect was observed only from spring season when the incident PAR decreased by between 10 and 50%. The antecedents indicate that at least during the first 2 years of plantation, it is possible to establish poplars with associated crops to 0.50 m, maximising the use of soil without affecting the growth of the trees.

Coppice effects on willow and hybrid poplar stem attributes and biomass production

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Coppice short-rotation intensive culture systems (SRIC) are being established over large areas in different parts of the world to produce pulpwood, fuel, bioproducts, or firewood. Once the root system is established, the aboveground portion of the trees are cut back to produce vigorous growth through a flush of multiple stems. Coppice systems are known to exhibit superior biomass production potential. This is primarily attributed to efficient photosynthate transport between root and shoot, rapid occupation of land through high leaf area deployment, early bud break and late leaf senescence, resulting in a more efficient use of the growing season. Willows *(Salix* spp.) and hybrid poplars *(Populus* spp.) have excellent coppicing ability. Differences between them may be expected in coppicing potential and in post-coppice growth patterns, including biomass production. Although several studies have analysed the phenomenon of coppicing and the associated biomass production potential in willow and hybrid poplars, little has been reported on their differential response to coppicing. In addition, it is of practical interest to study the changes in stem morphology through which post-coppice growth vigour is expressed. A coppice rotation system selection trial of 38 poplar and willow clones was established in central New York State (NY) in 1997. In December 1997, at the end of the first growing

season, the trees were cutback at 2-5 cm off the ground to promote coppice regrowth. A suite of tree dimension variables (diameter, height, and number of stems), and stool biomass was monitored in 1997 and 1998. This paper presents an analysis of the effect of coppicing on individual stem dimensions, number of stems, and stool biomass production for willow and hybrid poplar clones and identifies the specific attributes that best explain the variation in post-coppice biomass production rates.

Study of new hybrid clones of the white poplar

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Poplar is one of the rapidly growing tree species that are being adopted widely in the world. To culture and select the species that can adapt well in the arid and semi-arid areas in northwestern China, by using conventional breeding methods, *Populus alba*, *P. tomentosa*, and *Populus bolleana* were crossed and produced 150,000 hybrid seedlings. After primary selection, seven better hybrids were expanded to seven clones thereafter.

To depict the growing patterns of the seven clones, the properties of annual growth for every clone were simulated by the logistic equation (Y= k/(1+eA+Bt)) to determine the maximum points of growth rate per day and the fast-growing period. Also, genetic parameters such as the hereditary and genetic variation coefficient of height, diameter and timber volume were estimated, and the results showed that the genetic correlation coefficient among the three parameters was highly significant. To study drought-resistant features, 13 properties related to drought resistance such as stem water potential productivity of transpiration, dry weight per unit area of leaves, the anatomical structure of leaves, PV parameters, leaf water holding ability, and so on, were used to comprehensively evaluate their anti-drought ability by means of standardisation of data range. According to the results, the order of drought resistance was arranged. At the same time, an investigation was made on cold-resistant and anti-pest features of the seven clones to ensure that the very clones we hope to select will also have better adaptability to the environment. In addition, the rooting characters of the seven clones were studied, and the results indicated that there are highly significant differences in the earliest date of rooting, number of main roots, sum of the lengths of main roots, and number of lateral roots in the seven clones.

Taking into consideration all the indexes above (including growth, rooting character, and resistance to adversity), three clones of 96-06, 96-03, 96-07 among the seven clones show better adaptability to an arid environment on the basis of calculation by the AHP (Analytical Hierarchy) method. They are worthy of being popularised and can give some help to develop western China.

Tissue culture studies on triploids of Chinese white poplar

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The triploids of Chinese white poplar are new poplar varieties that have been widely utilised in north-west China in recent years due to all their good qualities, such as fast-growth, stem pattern, good adaptability, superior timber, resistance to disease and pests, etc. The wood volume of the triploids of Chinese white poplar is as much as two or three times that of common Chinese white poplar *(Populus tomentosa*) in only 8 years. Effective *in vitro* multiplication methods were developed for Chinese white poplar due to the recalcitrant response of its cuttings in rooting and to facilitate commercial production. *In vitro* terminal and auxiliary buds were stimulated on modified MS medium, which seemed to be most adequate for mass production of healthy shoots including 0.3-1.0 mg/litre BA, 0.05-0.1 mg/litre NAA and 0-0.5 mg/litre GA3. Each terminal and auxiliary bud produced more than 10-20 shoots with a length of 3.0 to 8.0 cm within 4 weeks. Calli were induced from leaf and stem explants under dark on modified MS medium with 0.5-1.2 mg/litre 2,4-D and 0.3- 0.5 mg/litre BA or KT 2 weeks later. Shoot differentiation was significant after calli cultures were transferred to modified MS medium containing 0.5 to 1.5 mg/litre BA and 0.05~0.1mg/litre NAA after one month. An average of 10 shoots were derived from each calli within 5 weeks. Multiplied shoots were subcultured on modified MS medium with lower concentration plant growth regulators every 20 days. *In vitro* shoots were successfully rooted on 1/2 modified MS medium with 0-0.1 mg/litre NAA. Those plantlets with a system of strong roots were successfully transplanted to soil and grew vigorously.

A composite linkage map for Populus *based on RAPD, AFLP, and microsatellite markers*

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A composite linkage map for *Populus* was constructed using random amplified polymorphic DNA, amplified fragment length polymorphism and microsatellite markers from a pseudo-backcross progeny population of *P. deltoides* and *P. nigr*a. A traditional strategy for genetic mapping in outcrossing species, such as forest trees, is based on two-way pseudo-testcross configurations of the markers

(testcross markers) heterozygous in one parent and null in the other. By using the markers segregated in both parents (intercross markers) as bridges, the two parent-specific genetic maps can be aligned. In this study, we detected a number of non-parental hetero-duplex markers resulting from the PCR amplification of two DNA segments that have a high degree of homology to one another but differ in their nucleotide sequences. These hetero-duplex markers detected served as bridges to generate an integrated map that includes 19 major linkage groups equal to the *Populus* haploid chromosome number and 24 minor groups. The 19 major linkage groups cover a total of 2,600 cm, with an average spacing between two markers of 10.5 cm. The map developed in this study provides a first step in producing a highly saturated linkage map of the *Populus* genome.

The results of the first selection clone trial (hybrid poplar) established in the Mediterranean Region of Turkey

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This study evaluates the performance of 40 hybrid poplar clones in the first selection clone trial established in the Mediterranean region of Turkey. Evaluations were carried out according to growth (height, diameter), survival, and stem quality (bole straightness) values of the clones at the sixth year of the trial, in 1999. All clones tested in this trial were created as a result of artificial crossing work carried out at Casale Monferrato Poplar Research Institute in Italy during 1983-1984, and then introduced to Turkey. In the crossing work, individuals of *Populus deltoides* Marsh. (Oklahoma, Texas, Tennessee, Illinois, and Iowa) were used as female and polycross of *Populus nigra* L. as male partners. The objective of this study is to determine the fast-growing and resistant (to the biotic and abiotic agencies) clones for use in poplar plantations in the region to help meet rapidly increasing demands for wood for local and industrial uses. The experimental site is located in Ceyhan Nursery in the Cukurova plain of the Mediterranean region of Turkey. The experimental design was a randomised complete block with five replications. Forty clones were laid out in row plots represented by four saplings.

According to the results of analysis of variance carried out in 1999, there were significant differences among the clone means in survival (F = 1.628*), diameter growth (F = 5.141***), height growth (F = 2.587***), and bole straightness (F = 3.549***). The top seven fastest growing clones, which have been selected for the second selection clone trial, have 16% higher diameter growth than the site mean. These seven clones have also shown 9% higher height growth, 22% better bole straightness, and 3% higher survival rate over the site mean. In the establishment of the second selection clone trial, *P*. x *euramericana* I–214, which is the most widely used clone at poplar plantations in Turkey, will be included as a control clone.

Poplar breeding in Russia

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Poplar breeding in Russia has its history and achievements. Most widespread in Russia are *Populus tremula* L. (~19 M ha) and *P. suaveolens* Fisch. (~1 M ha). Other poplars that have economic significance *(P. alba* L., *P. nigra* L., *P. laurifolia* Ldb. a.o) grow in river valleys in natural conditions. The first poplar selected in natural forests in the middle of the 19th century was *P. tremula* L. It was selected for its early opening of buds (P. t. f. *praecox*) and late opening of buds (P. t. f. *tardifolia*). Some plants of euramericana hybrids of black poplars were introduced in the country. Many of hybrids were created by home breeders and multiplied in different regions of Russia in 1937–1970. After the organisation of the Central Institute of Forest Genetics and Breeding (1971), the principal investigations of poplar breeding were carried out in the central part of European Russia. The main directions of research were: productivity of stem wood and biomass; quality of stem and wood; resistance to frost, diseases, and pests; environment protection, plant verdure, and some others. There was research on the selection of the best forms and natural hybrids in natural stands, artificial hybridisation, and introduction of best clones from different parts of the Soviet Union and abroad. All these clones, forms, hybrids, and cultivars were collected *ex situ*, and many of them were tested on special plantations in different parts of Russia.

The most impressive results were found in testing plantations in the central forest-steppe zone (Semiluksky populetum near Voronezh), which was created by the author in 1974 with cuttings on an area of 4.5 ha. The type of growing conditions is D2 , soil–tchernozem; the original area per tree was 20 m^2 . The 24 ramets of each clone were planted in four repetitions with randomised spacing. Eighty clones were tested from different sections of poplars:

1. White poplars and their hybrids with pyramidal crown;
2. White poplars and their hybrids with spreading crown;
3. Black poplars and their hybrids with pyramidal crown;
4. Black poplars and their hybrids with spreading crown;
5. Balsam poplars and their hybrids.

The best clones at age 21years in section 1 had 71 m^3/ha; in section 2 – 237 m^3/ha; in section 3 – 448 m^3/ha; in section 4 – 769 m^3/ha; and in section 5 – 378 m^3/ha. The superiority of the best clones compared to the control was 70% – 250% in different sections. On that and another plantation disease and pest resistance and quality woods were investigated. This research provides an opportunity to determine the potential of the productivity increase of different poplars clones and to use them in poplar plantations of Russia.

Sustainable development of poplar genetic resources in Turkey

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Turkey is a significant country in the world for its largely varying climatic and topographic conditions, resulting in wide diversity of forest tree species and ecosystems. But, genetic resources and natural habitats of forest tree species have been continuously impaired in the country. The loss of these resources and the degradation of the land have affected not only the national economy but also the welfare of the people. Therefore, active steps must be taken to conserve and utilise this valuable heritage. In recent years, extensive efforts have been given to conservation, management, and utilisation of existing forest genetic resources in Turkey by the Ministry of Forestry. Great emphasis has also been given to the genetic resources to be used in the establishment of industrial plantations with poplars and fast-growing forest tree species. Conservation and utilisation of genetic resources of poplars have been carried out by the Poplar and Fast Growing Forest Trees Research Institute in Izmit with the co-operation of related departments of the Ministry of Forestry. Planning has been made for *in situ* and *ex situ* conservation of autochthonous poplars *(Populus nigra*, *P. alba*, *P. tremula*, and *P. euphratica*), but the highest priority has been given to *ex situ* conservation of black poplars *(Populus nigra* L.), eastern cottonwood *(Populus deltoides* Bartr.), and their hybrids *(*P. x *euramericana*). A collection with 1,100 clones of these three species was established at Izmit nursery stoolbeds in 1996. Various clone banks and clone trials have also been established in different climatic regions with P. x *euramericana*, *P. deltoides*, and *P. nigra* clones. An *ex situ* conservation program for *P. nigra* has been in progress under the framework of the European Forest Genetic Resources Program (EUFORGEN).

Intensive culture of poplars is becoming increasingly important as a source of wood and fibre. Therefore, breeding strategies have been developed and implemented to measure, capture, recombine, and exploit the genetic variation of poplars in many countries. Commercial plantations of poplars have considerable economic importance in Turkey for industrial wood production. To release the much more productive hybrid clones for improving the quantity and quality of wood harvested from these plantations, classical breeding programs with *P. deltoides* and native species *P. nigra* are in progress. The results of a comparative study implemented in the Marmara Region with 26 *P. deltoides* clones representing different site conditions in the USA and *P*. x *euramerican* clone I-214, showed that some of the clones from the southern USA, produced higher amounts of wood than I-214 did, at the end of a 12-year period of rotation (mai/ha: the best clone of *P. deltoides* = 45.2 m^3, I-214 = 28.8 m^3). Similar results have been obtained from other trials with different clones in the Marmara Region. *P. deltoides* clones have shown considerably high volume increment in an 11-to

12-year rotation period (mai: 25-45m^3/ha). In accordance with these results, breeding programs have been concentrated on interspecific and intraspecific crossings of *P. deltoides* and *P. nigra*. About 500 hybrid clones obtained from these crossings have been tested at the clone trials. Some of these clones are promising based on the research study of selection and biotechnological improvement of poplars for the paper industry.

Global climate change, carbon sequestration and short-rotation woody crops production: where is the U.S.A?

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The 1997 Kyoto Protocol put forth a set of prescriptions and policy implications designed to reduce current and future levels of atmospheric carbon to a level based on 1990 estimates of individual national carbon emissions. The signatory nations agreed to work toward these goals through reduced emissions of six greenhouse gases and a net positive terrestrial carbon exchange. The legally binding framework, the complexity of the accounting system and the lack of displacement credits, along with domestic politics, contributed to the U.S. decision not to become a signatory nation. However, in recognition of the potential problems associated with elevated CO2 in the atmosphere, the current administration with the support of Congress has funded the Bioenergy Initiative with the goal of increasing the use of bio-based products and bioenergy by 3-fold (over base year 2000) by the year 2010 and 10-fold by 2020. This increase translates to 7.86 Quads by 2010 and 26.2 Quads by 2020, or ca. 7.5% of the total national energy equivalents by 2010 and 22.2% by 2020. There are numerous petroleum-based commodity chemicals, e.g., polylactic acid, furfural, succinic acid, etc., that could be manufactured from biomass. Yet, the world-wide demand for most of these chemicals is individually low, and thus, the largest ultimate contributor to the Bioenergy Initiative goals will be energy. The quantity of bio-based products or energy production created by 2010 will depend upon the cost of the feedstock. At $50 per dry delivered ton, there are ca. 5.55 Quads of net energy equivalents available for use toward the Bioenergy Initiative goals. Most of this resource comes from agricultural, forestry and mill wastes and residuals. Energy crops represent only 1.1 Quads of this new production. To increase energy crop contributions to the 2010 goal and to be able to achieve the 2020 goal, energy crop productivity must increase and production costs must be reduced.

Basic biological research, logistic improvements and policy changes will be needed to substantially increase the economic supply potential from energy crops in 2010. Production economics, i.e., net present value, of short rotation woody silvicultural systems is impacted most extensively by improvements in yield. Silvicultural enhancements such as irrigation and fertilisation do increase

yields but at an added economic and energy consumptive cost. Alternatively, more effective weed control and optimised spacing have lower costs and energy consumption associated with their implementation. Optimisation of rotation lengths, spacing and equipment choice will have positive effects on production economics. Likewise, traditional selection for improved growth rates, pest resistance and higher feedstock density result in net positive energy and yield benefits. Optimising the product, co-product and by-product mix through genetic manipulations of individual SRWC plantations could result in positive energy and economic budgets, but the specific improvements will need to be product and site dependent. Fundamentally changing the production system, i.e., changing tree form and silvicultural requirements of energy crops, has the greatest potential for reducing the costs associated with SRWC production. Finally, agricultural and energy policies will need to be changed to allow successful competitive establishment of energy crops as an element in an integrated carbon management strategy.

An experiment on selection of the most convenient spacings in the production of Populus nigra *(Gazi) saplings*

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The quality of poplar saplings has an important and inescapable place in poplar development programs and in the promotion of these programs. The poplar cultivation programs cover a set of activities such as nursery soil preparation, selection of good quality material, interrow cultivation, pruning, fertilisation, application of parasites, etc. Therefore, to obtain successful results in every stage of nursery activities, special attention should be paid to each of these aspects. Spacing creates an area for the plant to live, grow, and obtain water and minerals from soil. So the selection of the spacing has a special weight in nursery techniques. The machines that are run between rows are important factors affecting the width of the rows. Determination of planting spacing in poplar nurseries was taken from one of the research topics and an experiment was established. The objective of the experiment was to obtain information about the most suitable spacing in the poplar nursery. The experimental design was randomised complete blocks with three replications. The experiment was established in the Ankara Forest Nursery.

Treatments were:
1- Spacing between rows 1.50 m and 1.80 m
2- Spacing in rows 0.20 m, 0.30 m, 0.40 m, 0.50 m, and 0.60 m

At the end of first and second growth periods, diameter and height growth were measured and assessed with the analysis of variance.

The results of *Populus nigra* (Gazi) obtained are outlined. At the end of the vegetation period, it was seen that different spacing are significantly effective on diameter and height growth on both parcels of 1.50 m and 1.80 m. At the end of second vegetation period, the treatments were effective only on diameter growth in the parcels of 1.80 m. According to the results of analysis of variance and Duncan tests, it was seen that the most suitable spacing on diameter growth were 1.80 m x 0.80 m and 1.80 m x 0.70 m spacing given area of 0.90 m^2 and 0.75 m^2 per plant. Although no significant results were obtained in the plots of 1.50 m, the best diameter growth was determined in the treatments of 1.50 m x 0.60 m and 1.50 m x 0.50 m. In comparing plots of 1.80 m and 1.50 m, better diameter and height growth were obtained in the treatments of 1.80 m x 0.70 m and 1.80 m x 0.70 m.

Investigation into the prevention of disease caused by Cytospora chrysosperma *(Pers.) Fr. in poplar in Turkey*

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Cytospora chrysosperma (Pers.) Fr. is one of the most important fungi that causes losses among poplar plantations in our country. This fungus causes bark necrosis on poplars. Samples were collected from the diseased poplar areas, and the *Cytospora* fungus was isolated. The causal fungus was cultured on PDA (potato dextrose agar) at 22-24º C with a 12-hour photoperiod for 7 days. The isolate 7 (Çerke, near Ankara) was selected as the most virulent one and stored in a refrigerator to be tested as inoculum. Eight 1- and 2-year-old poplar clones were used to determine the susceptibility response to *Cytospora* according to the Split Plot Design with five replicates on November 19, 1996 and on April 24, 1997. The inoculations were made by puncturing the bark (1.3 m height from ground) with a cork-borer 10 mm in diameter, substituting a culture disc 6 mm in diameter in place of the removed disc, replacing the bark disc on the culture, and then covering it. The cellophane tape was removed 1 month later. Necrotic lesions were measured and dried saplings were counted. The results were evaluated according to analysis of variance. As a result, 77/10, Samsun, and 67/1 were found to be susceptible clones. I-214, Anadolu, and 64/13 were found to be the most resistant ones. Two-year-old saplings planted and inoculated in the spring were the least affected ones. Most of the spring inoculation wounds were overgrown by new callus, but cankers and dieback developed in the saplings inoculated in the fall.

Cytospora was more harmful in poplar plantations than in nurseries. To determine the effects of the factors on *Cytospora* canker experiments were

conducted in Izmit, Torbali, Ipsala, Konya, Isparta, and Altintas, in 1993 for the project "Investigations on Yield Researches of Common black poplar (Gazi)". The observations on *Cytospora* canker were recorded during 5 years. The characteristics of soil type and climate were determined. As a result, most of the damages were observed in the first year of planting and decreased in the second and successive years. A positive correlation between *Cytospora* canker and the proportion of clay and lime was found. The fungus damage increased as the days of winter injuries increased and it decreased with rain effectiveness.

Assessing soil organic matter changes in short-rotation intensive culture systems using soil microbial biomass carbon

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During the past decade, the focus of research in short-rotation forestry (SRF) systems has shifted from feasibility and biomass production to environmental sustainability and productivity. Beneficial attributes associated with SRF (i.e., carbon sequestration in aboveground biomass and soil, conservation of fossil fuels) could reduce atmospheric CO2 enrichment and associated negative impacts on global climate change.

While research has amply demonstrated the capability of SRF for high aboveground carbon sequestration, the capability of SRF to sequester soil carbon needs to be demonstrated. Soil carbon is sequestered in SRF as soil organic matter (SOM), litter and tree roots. The SOM pool contributes significantly to soil fertility. Changes in the SOM pool under SRF management could affect soil fertility, productivity, and system sustainability. Research is needed to determine the long-term effects (either positive or negative) on SOM. Such an effort requires a sensitive and accurate index to monitor SOM changes over time.

There is ample evidence that SOM is composed of a variety of fractions or pools differing in decomposition rates. In a broad sense, two pools are recognised: a labile or actively cycling fraction and a stable or recalcitrant fraction. We hypothesised that changes in SOM in SRF will be reflected in the labile fraction because of the relatively high turnover rate. Soil microbial biomass (SMB) represents a labile SOM fraction, responds rapidly to conditions that alter SOM levels and is a sensitive and accurate indicator of changes in SOM levels. Soil microbial biomass carbon may indicate potential microbial activity and SOM dynamics. This paper presents our assessment of SOM changes using SMB carbon in willow *(Sali*x) and hybrid poplar *(Populu*s) short-rotation intensive culture plantations established in 1995 on three different sites in New York State and sampled in 1997 and 1999.

Genetic pollution and mating systems in an artifical stand of black poplar (Populus nigra *L.)*

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The massive introduction of a small number of *P*. x *euramericana* clones and *P. nigra* varieties is often supposed to be one principal reason for the reduction of genetic diversity in the species *Populus nigr*a, although very few scientific data are available on this topic. In this study, flower phenology, seed production, and contribution of parent trees in the offspring was observed in a mature ex situ stand of black poplar in the framework of the FAIR-project "Genetic diversity in river populations of European black poplar for evaluation of biodiversity, conservation strategies, nature development, and genetic improvement" (Fair5-PL97- 3386). One of the objectives of the project is to provide management tools for both conservation and restoration of wild river populations of black poplar. Flower phenology was observed twice a week during two successive springs (1999 and 2000) in a mature *ex situ* stand (planted in 1965) containing several male and female trees of *Populus nigr*a. The stand was surrounded by poplars of the species *Populus trichocarpa* and *Populus deltoides.* This gave us the opportunity to study the contribution of foreign genes in the offspring of *Populus nigra*. We observed the start, duration, and end of flowering period of each male and female clone, and the beginning, duration, and end of seed release. Seeds were collected in bulk under the mature *P. nigra* trees and grown in the greenhouse. We also collected seeds on three females. Viability of seeds and seedlings were assessed and morphological characteristics of the young seedlings were noticed. Isozyme analysis was used to study the introgression of foreign genes in the offspring.

Considerable variation in time of flushing between black poplar clones was observed. *P. nigra* cv. Italica flushed before the other black poplars observed; this indicates that there might be no danger for introgression from this cultivar in indigenous black poplars in Belgium. Generally *P.* x *euramericana* flushed before P. *nigra*, although there was a lot of variation in flushing time in both species; introgression of foreign genes in *P. nigra* could not be excluded from this point of view. Although different efforts, like climbing into trees, were made, the quantity of seeds that could be harvested on the females was very low. The difficulties that we experienced in harvesting seeds on the females could be due to some compatibility problems in the mating system within the species *P. nigra* in this *ex situ* stand. Seeds harvested in bulk produced only 50% seedlings with morphological characteristics of (pure) *P. nigra*. Isozyme data (available in July 2000) will give us more information about the number of foreign genes in the offspring of the black poplar stand.

Isozyme polymorphism in the Belgian and Hungarian Populus nigra *gene bank and the EUFORGEN* Populus nigra *core collection*

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The European black poplar, *Populus nigra* L., is a common pioneer tree in riparian forests, ranging from central and southern Europe to central Asia and north Africa. The genetic diversity of the species is thought to be threatened in a number of ways. Two of the most important reasons are: (i) the reduction of perturbed areas due to regularisation of river flows, which decreased the regeneration of trees all over Western Europe; and (ii) the massive introduction of a small number of *P.* x *euramericana* clones and *P. nigra* varieties likely to intercross with wild *P. nigra* trees, which may lead to a reduction in the genetic diversity of offspring. In this study, gene diversity and differentiation of gene banks of *Populus* are measured by means of allozyme variation in the framework of the FAIR-project "Genetic diversity in river populations of European black poplar for evaluation of biodiversity, conservation strategies, nature development, and genetic improvement" (Fair5-PL97-3386). One of the objectives of the project is to describe the genetic diversity within *ex situ* collections and within and between natural populations in order to evaluate the current state of conservation in Europe.

Forty individuals of the *P. nigra* gene bank of the Hungarian Forest Research Institute Erdeszeti Tidomanyos Intelet (Sarvar, Hungary), 163 of the Belgian *Populus nigra* gene bank (Institute for Forestry and Game Management, Geraardsbergen), and 25 clones of the EUFORGEN Core collection were sampled. The EUFORGEN Core collection is a *P. nigra* collection of 42 clones representing the whole *P. nigra* distribution area in Europe. Seven enzyme stainings were considered revealing 10 loci (IDH-A, PGM, PGI-B, LAP, MDH-A/B, MDH-C, MDH-D, SKDH-A, and MNR) of which 6 were polymorphic (IDH-A, MDH-A/B, MDH-D, SKDH-A, PGM, PGI-B). PGM, PGI-B, LAP, and SKDH-A were useful for identifying species-specific alleles and genotypes of *Populus* x *euramerican*a.

The highest genetic diversity was observed in the Hungarian Gene Bank (H=0.11) although the relative sample size was small (N=44). Compared with the estimated genetic diversity for the species *P. nigra* (H=0.18), and considering the sample size, the Hungarian *ex situ* collection represents a great genetic diversity. The relative high value for H for the Hungarian Gene Bank can be explained by the absence of many rare alleles in the gene bank and an even distribution of the other alleles. The measure of genetic diversity H is described as a measure of evenness, which means that a sample with one frequently occurring allele and

three occasionally observed (rare) alleles (a total of four) is less diverse than a sample with four alleles that occur with about the same frequency. The genetic diversity for the Core Collection (H=0.094) is rather small, taking into account the great differences in geographical origin of the genotypes. For the Belgium gene bank (H= 0.038), low genetic diversity was observed, probably due to the long and existing absence of natural populations and the vegetative propagation and multiplication by man of the relict individuals. A first screening of morphological characteristics clearly indicates a great diversity within the Belgian gene bank. This diversity could not be assessed with this isozyme study, the use of other molecular markers will probably give more information on genetic diversity.

The influence of polyclonal poplar management on veneer and plywood quality

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To overcome the massive infections of rust diseases and pests, the trend toward polyclonal poplar management is rightly receiving growing interest. The advantages from an ecological point of view have been undoubtedly established, but little has been known about the impact on the industrial processing of clone-mixed poplar packs. In this respect, different clones from *Populus deltoides* x *Populus nigra* (Serotina), *P. trichocarpa* x *P. deltoides* (Beaupré, Hoogvorst, Hazendans, 69038/1, and 70045/1) and *P. deltoides* x *(P. trichocarpa* x *P. maximowiczii*) were considered together to evaluate the processed end products. The study aimed at investigating the technical and esthetic value of the rotary-peeled veneers of the different clones, the reaction of the veneer to a uniform drying regime, the technical properties of plywood industrially manufactured with the veneers and liquid phenol-formaldehyde resin, and their mutual variation in quality. All stems could be peeled until a core of 10-cm diameter. The clone Serotina from *P. deltoides* x *P. nigra* can be considered as the one with the highest yield, significantly higher than the other two hybrids. *P. trichocarpa* x *P. deltoide*s, for its part, had significantly higher yield than the hybrid *P. deltoides* x *(P. trichocarpa* x *P. maximowiczi*i), but shows a lot of internal significant differences among the clones.

Drying is a very delicate step in the production of veneer for plywood. An inadequate drying regime can make the veneer brittle. The overall conclusion can be made that Beaupré produces the largest amount of veneer, with sufficient technical quality and with a high proportion of aesthetically valued white veneer. Also, Hoogvorst scores well on technical criteria, but gives only a minority of white quality A (face veneer). So do Hazendans and 70045/1, evaluated as a clone with average veneer technical quality. It was found that these veneers are brittle, probably due to a non-adapted drying regime, in spite of the positive descriptive comments during the peeling process itself. The clone 69038/1 shows

more than 50% of white A quality veneer, which is somewhat brittle. Also, the clones from *Populus deltoides* x *(trichocarpa* x *maximowiczii*) produce 50% faultless white veneer, out of only a moderate production of A/B quality (cross-band veneer). The reference clone Serotina, appreciated for its good technical quality A/B veneer, cannot deliver the desirable white colour. Three-point bending tests on plywood of the different clones will be performed in the near future and results will be presented.

Poplar products and market survey in Belgium, FAIR6 CT98-4193 - PAMUCEAF - poplars: a multiple-use crop for European arable farmers – Task 2

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The aim of this investigation, incorporated into the European project PAMUCEAF, is to identify existing markets for poplar products within the EU states, to study the size of these markets, and to identify novel or underexploited poplar products that might be economically produced on surplus agricultural land. The size of the poplar market as raw material, in terms of current production types, market supply, and prices paid to growers, the industry's quality requirements, and views of the future on profitability, problems, and market trends, were analysed by means of a questionnaire. This was addressed to 50 poplar producers in Belgium. An extension of the results to other European countries is expected in the near future. Additionally, a similar questionnaire was set up for the poplar processing industries, to study the size of the markets with poplar based end products and to estimate actual and potential demand for poplars to produce these end products. The questionnaire handled topics such as company specifications, supply of raw material, and requirements for wood processing, size of the market of the end products, and future views. Seventeen poplar processing companies in Belgium answered the questionnaires; more answers are expected from other European countries.

From the data gathered by the two questionnaires, a wood stream of poplar can be designed for different EU countries, and mutual links can be deduced. An exploratory poplar wood survey for Belgium is illustrated in the poster. It gives an overview from poplar stands, through the poplar processing industry to poplar end product supply, considering the national market as well as the import and export market. From the results, it can be noted that the processed poplar wood mainly comes from the country itself (65%), while 35% of the poplar wood is imported from Germany, the Netherlands, and France. The division into the different poplar-processing sectors will vary from country to country. In Belgium, emphasis is on the processing of sawn timber for packaging material as pallets and cases (70%), and the production of veneer for plywood and packaging (23%)

also plays an important role. Besides, the end products mainly remain on the national market. Only 29% are exported to the Netherlands, France, UK, and Germany.

We will use these and other data to demonstrate what the existing supply of poplar means for a country, and what the coupled industry entails. Taking into account existing and potential poplar area and productivity, together with distance limitations, the potential for new industries in countries with a low portion of poplar areas can be regarded. At the same time, potential demand for poplars to produce defined products and their likely value can be estimated. Additionally, modelling this wood stream can let us vary parameters e.g., an increasing (e.g., Ireland, UK, Sweden) or decreasing wood supply, or increasing wood demand worldwide.

Response of hybrid poplar clones to fertilisation applied at planting on a Vancouver Island site

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Four clones of *Populus trichocarpa* x *P. deltoides* were fertilised at planting, either by banding along the row or by placing fertiliser beside the cuttings. The fertiliser (18:40:0 + 0.5% Cu, 0.5% Zn) was applied at 0, 100, and 200 kg N and P/ha in the banded treatment and 0, 22.5 g, and 45 g N and P per cutting (equivalent to 0, 25, and 50 kg/ha) in the placement treatment. The six treatments were split to accommodate four clones and randomised in eight blocks. All clones responded strongly to N fertiliser under the cultural conditions that included a weed- free site. Placement treatment increased stem volume 2.7-fold more than banding treatments after 2 years, and was 11-fold more effective in terms of fertiliser cost. N and P uptakes were increased by fertilization in the first two growing seasons, although only leaf N concentration was increased in the first year.

Increasing productivity in British Columbia cottonwood plantations through nutrient addition: inorganic and organic fertilization research and operational programs

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Culture of cottonwoods and their hybrids in the Pacific Northwest and British Columbia has grown and undergone important changes in recent years - from management on longer rotations to current practices of intensive management on reduced rotations and short rotations for wood and fibre markets, respectively. Through clone selection and stand management practices, including fertilisation, managers have been able to significantly increase plantation productivity. Research conducted in British Columbia has explored fertiliser formulations, placement, and timing of both inorganic and organic fertilisers.

Organic residuals, in particular bio-solids from municipal wastewater treatment plants and primary and secondary sludge from pulp mills and combinations thereof, have been applied to poplar plantations to increase productivity. Research conducted on the use of these residuals as plantation fertiliser has focused on nutrient dynamics, nitrogen supply, and the effect on the trees and the environment. The beneficial use of organic residuals as fertilisers provides a recycling opportunity for municipalities and associated industries, while providing nutrients and organic matter to increase tree growth. The values associated with these plantations include the production of fibre or wood products plus the environmental benefits inherent in providing an alternative to traditional methods of residuals disposal (landfill, incineration). They can also provide values associated with site rehabilitation, habitat enhancement, and non-point source pollution abatement. Concurrent with research leading to operational poplar fertilisation programs has been the development of successful and cost-effective technologies for the application of fertilisers. This presentation will provide an overview of inorganic and organic fertilisation of hybrid poplar in British Columbia. The opportunity for increasing plantations and plantation productivity will be discussed with emphasis on socio-economic and land management issues and practices in British Columbia.

Towards a growth model for poplar: relation between soil properties and growth of poplar

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The productivity of poplar clones can vary strongly according to site conditions. A detailed study of the interaction between site and productivity of two Belgian clones Ghoy and Beaupré has been carried out. For the clone Ghoy the study was done on a country scale; the clone Beaupré was studied on a European scale. Sixteen experimental plantations of the clone Ghoy, aged between 15 and 20 years and distributed over the main poplar regions in Belgium, were characterised for growth (annual girth and height growth). Out of these

parameters, a site index, height at indefinite age, was calculated. For each plot, the soil profile and root distribution was described and each horizon was characterised for chemical status (pH, EC, N, P, K, Ca, Mg, Fe) and physical soil properties (structure, O.M., CaCO3, texture, saturated hydraulic conductivity, bulk density, soil moisture retention curve).

Twenty-five experimental plots of the clone Beaupré distributed over the north-western part of Europe have been studied in a similar way in the context of the E.U.-AAIR-project 'Poplar for farmers.' A site-index based on height at age 7 was used as a measure of growth performance, due to the limited age of the available plots. Besides the parameters used in the Ghoy study, climatic factors were included in the analysis. Multivariate analysis (multiple regression analysis and principal component analysis) was used to relate the site index and the climatic data (only Beaupré) and the soil chemical and physical properties. To fulfil the requirements of biometric analysis, the soil horizons were grouped into a top layer (with 80% of the total root biomass) and a sub-horizon (from the lower boundary of the rooted layer down to the reduction horizon). Only those parameters that showed no mutual correlation ($r < 0.70$) were taken into account.

The analysis of the data for the clone Ghoy revealed that for the top layer the electric conductivity and N-content could explain 76% of the total variation in site-index. For the sub-horizon the chemical characteristics were not significant. A combination of physical factors (thickness of the horizon, O.M., structure, bulk density, sum of clay and silt fraction, useful pore space, or saturated hydraulic conductivity) explains 80% of the total variation. The analysis of the data of the clone Beaupré shows comparable results. The climatic data contribute to the explanation of the variation in site index, as the investigated plots cover a wider range of climatic conditions. The results are discussed and related to the water supply. Some examples of validation of the developed models are given. Finally, the possibility of using the models as a decision tool is discussed.

Willows: an underestimated resource for environment and society

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From a global perspective and compared to poplar cultivation, willow cultivation has been the stepchild of the use of the *Salicacea*e. The cultivation of willows for a large number of different purposes traditionally has been carried out at a small scale, mainly in the Northern Hemisphere.

However, the number of species in the genus *Salix* exceeds the number of *Populus* species by one order of magnitude, and the geographical distribution

and physiognomic range of willow species is larger than that of poplars. Only recently an effort has been made to exploit the large biological variation within the genus *Salix* by means of breeding and selection programs and by means of new planting and management schemes.

During only one century, the major constraint to the availability of forest products has shifted from physical limitations via economic hindrances to ecological constraints. Therefore, the huge potential of environmental assets of willow cultivation is expected to boost willow cultivation during the next century, and a rapid development of all aspects of willow cultivation is envisaged.

Many of the lessons learned during the large-scale cultivation of poplars, can be transferred directly to the field of willow growing. These include the design of production systems in relation to the targeted products and services, purpose-directed management, logistics, and breeding and selection methods and goals.

Further exploitation of willow in its potential position in between forestry and agriculture, as recipient of organic nutrient surplus from urbanised and intensively used agricultural areas and as a buffer between productive land and water courses, will lead to a sustainable short rotation forestry that meets our needs during this century.

The challenge of durable resistance to pests and diseases in forest trees: the biologist's point of view

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Most active tree breeding programs over the world take into account resistance to pests and diseases. Breeders do not search anymore for total immunity or complete absence of any damage, but select for reasonable tolerance - natural attacks leading to non-significant reduction of growth. The response of a tree to pests and diseases is determined by three major parameters:

- the genetic information carried by the tree (variability and genetic inheritance of the response)
- the genetic information carried by the aggressor (variability, level and homogeneity of attacks or infection)
- the environmental conditions where interactions occur.

Tree geneticists have largely studied these interactions from the host point of view, stating that most interactions are complex mechanisms, controlled by many loci with probably epistatic effects. You can refer to Bastien (1999) to see how breeding has evolved from variation among populations to the use of screening

techniques and recently of biochemical/molecular markers. Construction of durable resistance (pyramiding major and minor resistance genes) will very likely use these new tools. The next step for breeders will be to find a balance between improved genetic basis of their artificial plantations and enough variability of these genotypes to face present and potentially new aggressors (strains, races, introduced parasites, insect populations…).

Geneticists cannot construct such long lasting resistance without taking into account the genetic variability of the aggressor. In that sense, interactions between geneticists/breeders and pathologists/entomologists must be of top priority! The story of poplars and rusts (overcoming of complete resistance) in Europe is a good example: links between these disciplines are even stronger as emergence of new races of *Melampsora larici populina* has been favoured (and revealed!) by the selection and large-scale plantations of resistant hybrids!

Finally, the role of factors in the environment--where the plantations are finally established--have to be studied and characterised (humidity, temperature, wind, presence of alternate host…). Furthermore, we must understand the biology of both organisms (tree: phenology and leaf duration, leaf area density, leaf orientation and inclination angle, internal leaf structure for hardwoods… parasite: biological cycles, range and dissemination patterns, variability in pathogenicity and populations). And because several major pathogens can affect the same tree genus, it is sometimes necessary to find complex solutions like interspecific hybrids including indigenous and exotic parentage. In conclusion, even though we can assume that resistance to pests and diseases in forest trees is genetically inherited, we have to take into account the whole interaction combining the biology of the host and the aggressor and their genetic characteristics within the complex natural environment of the forest tree stand. The key for the future will be to manage in time and space the host genotypes to maintain reasonable variability.

Presentation of the new poplar selection program by the French scientific consortium AFOCEL* / Cemagref / *INRA

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France has structured research forces on poplar by combining expertise of three research institutes: AFOCEL, *Cemagre*f, and INRA. This scientific consortium 'GIS Peuplier' will be in charge of a program of poplar clonal selection, within the technical structure of the Experimental Nursery of Guéméné Penfao (conducted by the Forestry Department of the Ministry of Agriculture and Fisheries). Its first task will be to test the new clones or cultivars originating from foreign poplar

institutes (mainly from Belgium, Italy, and the Netherlands) under French climatic and soil conditions. Its second task will be to create and select new interspecific hybrids.

We present in this paper the different selection steps of this second task. First step: from the 1,500 progenies produced every year by controlled pollination (50 families x 30 progenies), an initial nursery test (six randomised complete blocks, single tree plots) will be established for 2 years to screen rapidly and accurately for general resistance to rusts (the host *Larix* spp. will be mixed with poplar in order to have an equal frequency of the different rust races). Second step: the 500 remaining clones will be tested in a nursery trial of 4 years of growth (10 blocks) to obtain a good estimation of potential of growth and to provide wood disks in which wood quality traits can be measured (colour, basic density, tension wood, etc.) These 500 clones will also be tested for their tolerance to rust, in an experimental trial of 2 years of growth where half of the trial (8 blocks) will be chemically treated against rust. Third step: the 50 remaining clones will then be field-tested (high density trial – 1,000 trees/ha and two-large scale trials – 200 trees/ha), to finally select 5 clones for establishing certification tests (17 years after the initial controlled pollination). In parallel, these 50 remaining clones will be studied in further nursery trials for other threatening diseases *(Xanthomonas populi*, *Marssonina brunnea*). Plant material will be based on a collection of genotypes of *Populus deltoides* and *P. trichocarpa* originating from provenance and clonal tests from INRA and from the French collection of *Populus nigra*. F1 or F2 /BC types of crosses will be discussed.

Alternative methods of site preparation for willow and poplar biomass crops in the northeastern United States

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The proper application of well-designed site preparation techniques is essential to the biological and economic success of willow and poplar biomass crops. Fall site preparation, the currently recommended practice, includes late summer application of contact herbicides, followed by plowing and disking in the fall. A final cultivation is conducted the following spring, immediately prior to planting. While effective, this approach creates the potential for significant soil erosion during the winter and establishment year. It also limits crop management options the year prior to planting biomass crops. Previous no-till trials with hybrid poplar have produced variable results. However, research in the orchard industry has

shown that properly managed ground covers can reduce erosion potential without having a detrimental effect on tree growth and production.

This study was designed to assess the impact of different methods of site preparation on survival and growth of high density (approximately 15,000 plants/ha), short-rotation willow and poplar biomass crops. Six treatments were applied including: 1) the currently recommended fall site preparation, 2) strip tillage applied in the spring, 3) fall tillage followed with a winter rye cover crop, 4) spring tillage, 5) no-tillage, and 6) no weed control.

The test site had been out of annual crop production for several years and was dominated by perennial weeds. All treatments were hand planted with one willow (SV1) and one poplar clone (NM6). No-tillage and fall treatments were also planted with a modified Froebbesta mechanical planter to test its effect on survival and growth of both clones.

First year survival was excellent for hand-planted willow (91.8±105%) and poplar (92.8±1.3%). For both clones, the no weed control treatment produced significantly less biomass compared to the average of all the tillage treatments (willow $p=0.015$, poplar $p<0.0001$). The no-tillage treatment had significantly lower biomass production for both species compared to the tillage treatments ($p=0.013$ for willow, $p=0.01$ for poplar). For willow, the fall cover crop treatment produced the greatest biomass, followed by the spring tillage treatment, and the fall tillage treatment. For poplar, the spring tillage treatment had the highest biomass production followed closely by the cover crop treatment. Planting method did not have a significant effect on survival or first year biomass production for either site preparation treatment or clone.

Incorporating cover crops into fall site preparation or waiting until the spring to conduct mechanical tillage can address soil erosion concerns without adversely affecting the establishment of willow and poplar biomass crops. However, challenges related to spring access may limit the utility of site preparation at that time, further supporting the potential of fall cover crops. The necessity of good weed control during establishment, regardless of the site preparation method, is reinforced by this trial.

Effect of cutting storage conditions on the survival and early growth of four willow clones

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Planting vigorous cuttings that quickly develop shoots and roots is essential to the biological and economic success of willow biomass crops. Current recommendations are that cuttings should be removed from cold storage 2-4

days before planting. Maintaining this short period is complicated by unpredictable field access in the spring due to wet field conditions, restricted availability of specialised planting equipment, and delivery schedules for planting stock. The following two questions were addressed by this study:

1. How long can cuttings be left out of cold storage before being planted and still maintain high sprouting and rooting ability, and rapid early growth rates?
2. Once cuttings have been removed from cold storage, how does returning them to different cold storage facilities (+2^{o} C, -4^{o} C, or –20^{o} C) affect their sprouting and rooting ability and early growth?

Cuttings of four willow clones (S301, SA2, SH3, and SV1) were removed from a -4^{o} C freezer and stored for 23, 16, 12, 9, and 2 days in their original containers in a greenhouse. Additional cuttings of each clone were removed from the freezer and stored for 2, 5, and 9 days before being returned to a cooler (+2^{o} C), a -4^{o} C freezer, or a -20^{o} C chest freezer for 7 days. All cuttings were then planted in a greenhouse and left for 3 weeks before being harvested.

Leaving the cuttings out for up to 23 days did not affect sprouting or rooting ability. After 3 weeks, 90% of all the clones for all treatments had produced roots and >83% had produced shoots. Three of the clones had a significant positive linear trend (∞=0.05) between aboveground biomass and days left out after 3 weeks of growth. These results suggest that cuttings can be left out of the -4^{o} C freezer for longer than the recommended period of 2-4 days before being planted.

Returning cuttings to a -20^{o} C freezer after being left out for 5 to 9 days reduced the proportion of cuttings with roots or shoots, and shoot biomass of all clones. Once cuttings have been out of cold storage, they should not be placed in a -20^{o} C freezer. Shoot development was slowed for clones SA2, SV1, and S301, and root development was slowed for SA2, SV1, and SH3 by returning them to either +2^{o} C or -4^{o} C cold storage after being out for 5-9 days. Returning cuttings to either a +2^{o} C cooler or a -4^{o} C freezer had no effect on the proportion of cuttings with roots or shoot biomass at the time of harvest. Returning cuttings to storage at +2^{o} C or -4^{o} C may extend the period of time that cutting viability can be maintained after being removed from -4^{o} C and thawed.

Biodiversity and forest management in **Populus** *dominated forests of North America*

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Populus dominated forests are largely restricted to the Hudsonian zone of North America. Their dominance in these forests is maintained by extensive forest fires and other natural disturbances. Commercial exploitation for timber of these forests is comparatively recent, but the rapid growth of poplars and their hybrids make them attractive material for use in both intensive and extensive forest management practices. Comparatively little is known about the reaction of arthropod communities to forest management. Nevertheless, arthropods are integral parts of these systems and their continued functioning. A co-ordinated series of studies has been implemented to investigate the effects of harvesting to different intensities on the arthropod communities in four cover types representing a successional gradient in which *Populus* species dominate the pioneer vegetation. By comparing the development of communities in these stands to those in stands regenerated by burning, the experiment aims to test the feasibility of Ecosystem Management Emulating Natural Disturbance (EMEND). The EMEND experiment focuses on monitoring the responses of select taxa representing a variety of trophic functions such as herbivores (Lepidoptera), epigaeic beetles (Carabidae and Staphilinidae), spiders (Araenidae), saproxylic beetles (especially Scolytidae and Cerambycidae) and parasitoids (Hymenoptera) to the various treatments. Thus far, pretreatment inventories have been completed and can be compared with the early post-treatment responses.

Breeding and conservation of poplars in Ukraine

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Poplars *(Populus* sp. L.) and their fast-growing hybrids are a promising source of pulpwood and other wood materials. In Ukraine, where only about 15% of the territory is covered by forests, these species have been used in breeding programs for a long time. Three poplar species are native in Ukraine: *Populus nigra* L., *P. alba* L., and *P. tremula* L.

P. nigra and *P. alba* occur as scattered individual trees or small groups of trees over the whole territory of Ukraine, excluding high mountain regions. There are pure and mixed stands of black and white poplars located along the rivers on plains. Pure and mixed stands of aspen are situated mostly in the northern part of the country.

Ukraine does not have specific legislation for the protection of poplar stands. Some of the poplar stands are included in protected forest communities (water-protective forests, etc.). The main poplar stands are in managed forests.

A big program on poplar breeding was carried out in the 1950s-1960s under the supervision of Prof. Natalia Starova. In 1959 a breeding system composed of 10 breeding centres and 17 variety-testing points was organised. This system covered almost all the climatic zones of Ukraine. Its tasks were:

1) to find, choose, propagate, and test native productive resistant forms of poplar species and their spontaneous hybrids;
2) to obtain, test, and propagate productive artificial hybrids.

According to the first task, about 250 superior trees were chosen. The main activity was concentrated in the second task. More than 460 crossings were made during the 10-year period and more than 600 thousand hybrids were obtained, from which about 900 of the best trees were chosen. These trees were tested in preliminary trials and more than 40 varieties were chosen. Some of these clones have been included in the State Register of certified varieties of plants of Ukraine; the rest are being tested.

At the same time, investigations of flowering and fructification were carried out. Development of flower buds, stamens, pistils and ovules, micro- and megasporogenesis, male and female gametophytes, pollination, fertilisation, and fructification were investigated. Inheritance and early diagnostics of sex were also studied.

In the last 10-15 years systematic surveys of poplar stands have been made by collaborators of our Institute. More than 8.2 thousand ha of the stands have been inspected. Pure natural *Populus nigra* and *P. alba* stands are rare in Ukraine, but there are relatively considerable areas of pure and mixed natural *P. tremula* stands. A number of superior trees were chosen during surveying. These trees were propagated vegetatively in stoolbeds and clonal archives, and some were propagated generatively by seeds in collection plantations.

Uptake and accumulation of radio-caesium in **Salix** *plantations on contaminated agricultural soils*

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The accident at the Chernobyl nuclear power plant in 1986 led to a significant increase of radionuclide content in certain parts of Sweden. In agricultural areas, farmers are looking for alternative crops on contaminated soils. Biomass plantations for energy are potential candidates for such soils provided that the cycling of radionuclides can be controlled. However, little is known about the behaviour of caesium in energy forest production systems. For this reason the uptake and distribution of Cs-137 in *Salix viminalis* were studied. Selected clones were grown on caesium-contaminated sandy soils under field conditions. The ground deposition of Cs-137 in 1986 within the research area was 170 kBg/m. In

1994, when the study started, the ground deposition was 141 kBg/m. The experimental plots were fertilised with 60 kg N/ha, and 0 and 42 kg K/ha, respectively, during 2 years. The experiment was carried out for 4 years. Samples of different plant parts were collected every year during active growth and dormancy. The results showed that roots and leaves had higher Cs-137 concentration than stems and cuttings. The fine roots (0-1 mm) had the highest Cs-137 concentration of all the plant organs. The transfer factor (TFg) of Cs-137 varied between 0.001 and 0.0028. There is a seasonal variation of Cs-137 concentration in the leaves and stems of Salix plants. No significant differences in caesium uptake were found in this study between the K treatments. From this experiment we conclude that *Salix* is a fast-growing woody species that can accumulate radio caesium from contaminated agricultural soil. The potential to cultivate *Salix* on contaminated agricultural soil is considered to be promising.

Purification of tonoplast from Populus euphratica *and its H + - pumping activity under salt stress*

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Through differential centrifugation and sucrose density gradient centrifugation, tonoplast vesicles were isolated from suspension-cultured *Populus euphratica* cells broken by mortar and pestle, blender, or ultra-sonic homogenizer. The sensitivities of ATPase to NO3, VO43, and NaN3, as well as proton pumping activities of membrane-bound pyrophosphatases, demonstrated that tonoplast vesicles are distributed mainly on the interface of 0~25% of sucrose. The effect of various cell-breaking methods on H^+ -ATPase activities and the orientation of H^+ -ATPase in the vesicles and activities of ATPase were analysed. It was found that the tonoplast vesicles purified from cells broken by blender were intact, possessed a higher ratio of right-side-out vesicles, and had a higher enzyme activity.

Study on willow tolerance to water stress

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The survival time (ST), of cuttings and the correlation among ST, rooting, shooting, and cutting characters were studied based on culturing tested cuttings in water. The cuttings were from 55 clones of *S. babylonica*, *S. alba*, interspecific hybrids of *S. matsudana* x *S. alba*, *S. matsudana* x *S. babylonica*, *S. babylonica* x *S. alba*, *(S. babylonica* x *S. alba*) x *S. matsudana*, *(S. matsudana* x *Chosenia*

arbutifolia) x *S. matsudana*, and intraspecific hybrids of *S. matsudana*. The average values of ST ranged from 33 days to 64.6 days. The ST differences were significant among hybrids as well as clones. The cuttings of *S. babylonica* had the longest ST; those of *S. alba* had the shortest one, and the other hybrids fell in between. The ST Heritability in broad sense h2 =0.615, and the genetic variation coefficient (GVC)=7.203%. The correlative analysis revealed that ST has significant correlation with dry weight of new shoots, dry weight of roots, total number of roots, and rate of dry weight and fresh weight of cuttings. Their genetic correlation coefficients varied from 0.308 to 0.445.

Study on restraint cause of 1-69 etc. to eggs hatching of Anoplophra glabripennis

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Anoplophra glabripennis (Motsch.) is one of main borers which damage Poplar in North China. In addition to Poplar, the hosts of this beetle can be other species such as willow, elm, maple, birch, pear, cherry and mulberry. In east China, *A. glabripennis* is reported on *Populus euramericana* (Dode) Guineir, P.nigra L. var, *italica* (Moench) Kochne, *P. dakuanensis* Hsu, P. balizhuang before 1970s. After 1980s, these species were replaced by *P. euramericana* (Dode) Guineir cv. I-214', *P.deltoides* Bartr. cv. 'Lux' (1-69/55), *P. euramericana* (Dode) Guineir cv. San Martino '1-72/58' and *P. deltoides* Bartr. cv. 'Zhonglin46'etc. gradually in Shandong Province. At present, these species covers about 90% of total timber-harvesting forest that is about 10,000 ha in this province. The ability of resistance about these species to *A. glabripennis* is significantly improved. Restraint cause of 1-69/55, 'Zhonglin46' etc. to eggs hatching of this beetle is reviewed by authors in this paper.

In the past three years, we captured 150 couples of this beetle and put them ('one male and one female' or 'one male and two female') on the trunk of 1-69/55, Zhonglin46 etc. within the diameter of 5-10cm, covering with cylindrical, transparent box simultaneously. As a result, we obtained more than 1000 egg's nicks. The rate of oviposition in these nicks is more than 98%. In the initial period of oviposition, eggs of beetles lactescence, look smooth and fully and develop normally. 2-3 days after egg's nick forming, lots of sap begin to flow continuously, leaving a trace of 100cm long eggs in the niches cut in the bark are always in the state of saturation. Normal development of eggs is inhibited by extremely saturated condition; eggs become wizened with colour change into yellow, brown or black. Finally they fail to hatch. The recovering time of egg's nick is later. Callus pressure to eggs was not observed. Callus begin to grow in 15 days after

egg's nicks form, in the 20th day, the internal diameter of egg's nicks is 1.572.57cm on average, in the 40th day or so, they recover completely.

Under the intensive farming condition, the clone of I-69, Zhonglin46 etc. can produce strong physiological resistance to wounds of trunk, lots of sap from wounded areas inhibit the development of this beetle's eggs.

Ecological clone characterisation for increased biomass production

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Short-rotation forestry for biomass production in Sweden has mainly focused on the use of willow *(Salix* spp.). Willows constitute a relatively new crop, and the potential for growth improvement is large. Thus, new clones have the potential to grow much faster than the reference clone L78183, which still is the most common one used in Swedish short-rotation coppice. Prior to any extensive field trial, the characterisation of promising plant material in terms of growth rate under different water/irrigation and nutrient/fertilisation regimes is urgently needed both by willow breeders and farmers.

A methodology of short-term characterisation was developed and tested on two clones: L78183 and SW910007 Tora. The method was based on outdoor growth studies using potted plants, which were grown from cuttings and exposed to various environmental conditions in a full-factorial design. The current study lasted for 8 weeks during the 1999 growing season, and the environmental conditions simulated three fertilisation, two irrigation, and two temperature regimes. The analysis of plant growth included the methods of functional growth analysis, and the calculation of nitrogen (N) use efficiency *(sensu* N productivity) and water use efficiency (^{13}C method).

The results of the comparison between the willow clones L78183 (reference clone) and Tora showed a 25% higher shoot dry weight growth of Tora than L78183 at high fertilisation and irrigation, whereas the ranking was reversed at low fertilisation and water stress. Tora increased growth rate largely through increased N concentration, and L78183 increased growth rate through increased N use efficiency. Water stress strongly decreased the root N uptake rate of Tora but not L78183. In addition, water-stressed plants of Tora showed significantly lower water-use efficiency than L78183. During autumn, Tora resorbed more N from leaves than L78183, which decreased the annual N turnover rate of Tora compared to L78183.

In brief, the reference clone L78183 is characterised by a relatively high growth potential on less fertile soils and/or under less intensive management, insensitivity to water stress, and high N productivity but also high N turnover rate. In contrast, Tora might have a high growth potential on fertile soils and/or under intensive management, but is relatively sensitive to water stress. Tora is a strong nutrient accumulator under fertile conditions and showed small N losses by leaf abscission and low N turnover rate. Consequently, Tora might be more suitable for vegetation filter purposes than the reference clone L78183.

The results are in general accordance with field observations on older plants, because Tora has been found to be superior under conditions favourable for growth but more sensitive to water stress. The ecological characterisation used here revealed much relevant information about the growth performance of the tested clones within a relatively short experimental period. In conclusion, this method is regarded as a promising tool for any screening of plant material to be used for biomass production, such as clones of *Salix* and *Populu*s.

Diversity and potential of poplar species in China – a promising enrichment for international breeding activities

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Problems of traditional poplar cultivation

The genus *Populus* is composed of many species with an impressive variety of growth characteristics. Site requirements and growth behaviour indicate considerable differentiation within a widespread range. Nevertheless, this abundant natural offer has been utilised only partially to promote poplar breeding and cultivation. Following an old tradition, more or less inflexible production systems are mainly keyed to a few high yielding P. x *euramericana* and P. x *interamericana* clones in most countries. Consequently, considerable economic failures have to be accepted again and again as a result of serious calamities.

Species diversity of poplars in China

China ranks among the countries characterised by an exceptionally multifarious indigenous flora. Based on ample genetic variation, poplar species were able to settle in divergent habitats and to conserve survival ability and reproduction over long periods because of adaptation processes. The diversity is concentrated, above all in the subtropical mountain regions of south-west China. Comprehensive studies of the genus *Populus* in the southern and eastern mountain chains of the Qinghai-Tibet- Plateau turned out to be particularly impressive; 3 sections, 17 species, and 15 varieties have been recorded and taxonomically classified there. They grow in altitudes between 1,500 m and 4,300

m above sea level. Many of these poplar sources stand out for remarkable site adaptation even on harsh conditions and for fast and vigorous growth.

Essential characters of promising species

Species expected to be suitable for international breeding and cultivation in the near future are presented in a general view. The necessarily subjective selection is based on the state of available knowledge mainly about site requirements, ecological importance, growth characteristics, regeneration ability, silvicultural behaviour, yield estimation, and wood utilisation. In particular, the following species are characterised in the paper in an abridged version: *P. cathayana, P. davidiana, P. euphratica, P. simonii, P. szechuanica, P. ussuriensis,* and *P. yunnanensi*s.

Advisable breeding priorities

The potential of poplars in China is regarded to be instrumental in enlarging and stimulating poplar breeding activities world-wide. Measures to be specified in the paper are considered important and could be materialised on the basis of a close and confident co-operation with Chinese colleagues and institutes relevant to the subject and the IPC.

A maximum likelihood-based method for mining major genes affecting quantitative character

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Traditional quantitative genetic approaches can only estimate aggregate genetic effects or variances for quantitatively inherited traits. Current developments of statistical and computational techniques have enabled us to analyse quantitative genetic variation at the individual gene level. The characterisation of important genes responsible for the phenotype of a quantitative trait has tremendous potential for increasing the efficiency of genetic improvement for economically important characters. In this paper, we present a maximum likelihood-based analytical approach to detecting a major gene of large effect on the phenotype of a quantitative trait in a progeny population derived from a mating design. Our analysis is based on a mixture genetic model specifying both major gene and background polygenic inheritance. The likelihood of the data is formulated by combining the information about population frequencies of the genotypes for the major gene and their phenotypic distribution densities. An iterative procedure based on EM algorithms is implemented to obtain maximum likelihood estimates for a number of population and quantitative genetic parameters at the gene level. This approach is employed for an example derived from a factorial mating design of an aspen species. The results from our model suggests that there exists an over-dominant gene affecting stem volume growth in the aspen progeny

population. It is concluded that further molecular genetic research toward mapping single genes has a high probability of success.

Study on poplar cankers in Shandong Province

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Advances in poplar canker research in Shandong province are reviewed by the authors in this paper. The paper includes types of cankers, damages, physiological characteristics, and pathogenicity of three main pathogens, disease occurrence and epidemic regularity, resistance detection of poplar, and canker integrated control technology. It also points out existing problems in the study at present and the future research direction.

Eight species of canker pathogens have been found on poplar in Shandong: the main pathogens attacking poplar cankers include *Dothiorella gregaria*, *Cytospora chrysosperma*, and *Dothichiza populea*. Other pathogens are often mixtures occurring together with the above three pathogens. Poplar species and bark water content are some important factors affecting disease occurrence and epidemics. There is a close correlation among poplar resistance, bark water content, isozyme activity, and phenol compounds. We suggest techniques of integrated control poplar canker, such as strict selection of resistant varieties, seedling quarantine, stronger management of plantations, and suitable fungicidal control. The molecular biochemistry mechanism of tree resistance and the hereditary basis will be important aspects of poplar canker resistance in the future.

Studies on variation and selection of wood properties in triploid clones of Populus tomentosa *Carr.*

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Wood property is very important character for industrial wood. The wood density and some physical wood properties of ten triploid clones of *Populus tomentosa* Carr. were examined. From two clonal test plantations and the variations of these wood property parameters among clones, vertical direction and radial direction were analyzed. There were significant differences between clones and vertical direction for these properties. The average value of wood basic density was 0.398g/cm at eight years old. The average values of growth ring density, early

wood density, late wood density, max-growth ring density and mm-growth ring density were 0.444g/cm^3, 0.428g/cm^3 511 g/cm^3, 0.604g/cm^3 and 0.322g/cm^3 respectively. Clonal repeatability of wood basic density and growth ring density, early wood density, late wood density of air dry timber were 0.63, 0.89, 0.92 and 0.86. respectively. Clonal repeatability of other physical properties of wood modulus of rupture, modulus elasticity, compression strength, hardness of cross section, radial section and tangent section, volume shrink, radial shrink, tangent shrink of bake dry wood and air dry wood, specific heat coefficients, thermal conductivities and warm-transfer coefficients were 0.62, 0.90, 0.70, 0.51, 0.71, 0.80, 0.67, 0.84, 0.68, 0.59, 0.77 and 0.62 respectively. All of these wood properties were under moderate and strong genetic controls. Wood basic density and growth ring density were unstably ascending of radial direction within tree, the variation pattern was not identical of vertical direction within tree. Faint positive correlation existed between wood density and growth traits (tree height, tree volume), weaker genetic correlation existed between wood density and other physical properties of wood.

On the basis of the studies, five superior clones were selected for veneer bolt-directive cultivation finally by PCA method for wood properties and cluster analysis with the result of glue bonding strength.

Breeding of P. simonii *in northern China*

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Populus simonii is one of the most important native tree species in northern China. Its distribution in China and its biological and physiological traits are discussed. Conservation of its genetic resources and interspecies and intraspecies artificial cross breeding with *P. deltoides* and *P. nigra* by a Belgian-funded and FAO-executed forestry project (GCP/CPR/009/BEL) is reported.

Selection and application of poplar varieties resistant to Anoplophora glabripennis *Motsch*

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Anoplophora glabripennis Motsch, a destructive borer of forest trees, caused great damage in China, which attracted attention from all over the world. A series of poplar varieties resistant to *Anoplophora glabripennis* Motsch were selected in

north China from 1969 to 2000. Satisfactory results in controlling the pest were obtained after introducing these varieties into more than 100 representative areas over a range of 4 million square kilometres.

A new technique was developed in the selection and application of resistant varieties. Scions from resistant varieties were grafted to susceptible stumps, and the resistant scions grew to 4.5 m high with diameters of 3 cm in the first year and 8 m high with diameters of about 5 cm in the second year. After 25 years, these resistant poplar trees reached 25 m in height and 56 cm in diameter. A macroscopic model was developed in which the resistant, tolerant, and susceptible poplar varieties were interplanted to control the spread of the pest. In a model area of 1,200 ha, the poplar trees damaged by *A. glabripennis* decreased from 98.7 to 3.8%.

Insect resistance of poplar species in East Asia

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Major achievements in insect resistance of poplar species during the past 4 years in East Asia are reviewed. New results were obtained by research on insect resistance mechanisms in chemical, anatomical, and nutritional characteristics with emphasis on secondary metabolites, bioassay, and insect physiology. By using molecular markers and genetic linkage maps, traditional breeding has achieved new development. In the field of biotechnology, quite an amount of work related to transgenic plants has been conducted, such as genomic analysis, field testing, safety evaluation, male sterility, the search for new resistance genes, and commercialisation.

1. Improving resistance to *Cerambycidae* by traditional breeding method in China.

Based on the obvious advantage of hybrid vigour, clones of poplar from artificial plantations with *P. deltoides* cv. Lux as the female tree and *P. deltoides* cv. Harvard as the male tree were selected. Controlled crossing was conducted in a greenhouse in 1983. After natural insect damage in test plantations, pest-resistant and tolerant clones were selected from the above crossing combination in 1990 and 1995, respectively. They were *P. deltoides* cv. Nankangi, *P. deltoides* cv. Nankang2, and *P. deltoides* cv. Nankang3. These species are resistant and tolerant to *Anoplophora glabripennis* and *Botocera horsfieldi*. Over 10 years of growth in plantations proved that these three clones were stable in tolerance to *Cerambycidae* borers.

2. Quantitative Trait Loci (QTL) of resistance to *Ceramibycidae* in China.

The F2 was produced in 1992. F2 trunks were artificially inoculated with adults of *Anoplophora glabripenni*s. Resistant clones were generated. This result further proved that the characteristics of resistance to *Cerambycidae* not only included obvious hybrid vigour but also can be inherited. One of F1 , *P. deltoides* cv. Nankangi (C-135) was chosen to backcross with its male parent, *P. deltoides* cv. Harvard for studying the relationship between genotype and phenotype of pest resistance in 1996. The genetic map for this backcross population was constructed by using Amplified Fragment Length Polymorphism (AFLP) marks. Artificial inoculation with adults of *Anoplophora glabripennis* on trunks of poplar backcross population was done, and chemical compounds from barks of the poplar backcross population were extracted for phenotypes of pest resistance. The relationship between genotype and phenotype of pest resistance was used in QTL.

3. Improve insect resistance of poplar species by genetic engineering.
P. nigra, *P. deltoide*s, *P. euramericana*, and *P. tomentosa* have been produced in China since 1990. Based on damaged leaf rate of transgenic plants and number of insect pupa in the soil, insect resistance of transgenic *P. nigra* to *Apochima cinerariys* and *Orthosia incerta* was evaluated in the field in Manas Forest Station, Xinjiang Uyger Autonomous Region, China. Compared to 80-90% damaged leaf rate of *P. nigra* and *P. euramericana* cv. Robusta in manmade plantations, the damaged leaf rate of transgenic plants mixing with non-transgenic plants was below 20%. *P. nigra-GM* has demonstrated substantial insect resistance and applicable value in the field. Some clones of *P. nigra-GM* were approved to be released to the environment by the Chinese Agricultural Genetic Engineering Safety Community of the Chinese Agriculture Ministry in 1997 and 1999. By transferring the Ta-Barase gene (male sterility gene), the Lcl gene *(Bacillus subtili*s) for resistance to *Cerambycidae*, the double Bt gene and proteinase inhibitor (PI) gene into poplar species, different kinds of transgenic plants have been obtained.

Studies on immunological analysis and expression of Bt (Bacillus thuringiensis*) toxin protein in transgenic poplar*

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In this paper, the spore/crystal complex was prepared from *Bacillus thuringiensis* var. *kurstaki* HD-1, HD-73 and genetically engineered strain 3O4A(b) in 171 K EM+ during sporulation as crystalline inclusions that are released along with spores. The parasporal crystal was isolated from the spore crystal/complex by liquid two phase method. CryIA, CryIA(b), and CryIA(c) were precipitated from parasporal crystal on PI4.4. The 130-140 kDa molecular weight protein was separated with sodium dodecyl sulfate polyacrylamide gel (SDS-PAGE) electrophoresis. Five kinds of polyclonal antibodies were acquired using the

above protein as antigens. The double diffusion titer of anti-CryIA, Anti-CryIA(c), CryIA(b), anti-CryIA(c)-130, and anti-CryIA(b)-130 were 1/32, 1/16, 1/16, 1/8, 1/8, respectively. ELISA titer of the five antisera were >l/10^5, >1/l0^5, >1/10^5, >l/10^4, >l/l0^4 A double sandwich ELISA was set up by the biotin-avidin-system, of which the detection sensitivity was l ng/ml. Another double sandwich ELISA was set up by HRP labelled antibody, of which the detection sensitivity was 10 ng/ml.

Four monoclonal antibodies (A4F5F11, B4E6C7, B4E6D8, and B4F5G11) were produced using CryIA insecticidal crystal protein to immune BALA/C mouse. A double sandwich ELISA coated with anti-CryIA(c) polyclonal antibody was established with B4E6D8 as sandwich antibody, of which the detection sensitivity was less than 1 ng/ml. The toxin content in leaves of Bt cotton was detected using the above three kinds of ELISA methods; the results were the same with bioassay and other methods. Bt toxin protein in leaves of three Bt-poplar varieties, *Populus nigra* 12,153,192 was measured using the double sandwich ELISA with monoclona1 and polyclonal antibodies to CryIA(c); the results were similar with other methods. Bt toxin content in leaves of Bt-poplar were positively correlated to corrected mortality for *Apocheimia cinerarius* Erscholf and *Lymantria dispar* Linneas. Bt toxin content in fresh weight of leaves differed with leaf age, but in soluble protein was stable. Compared with the control poplar, the contents of soluble protein in Bt-poplar were lower. All the contents of auxin (IAA), cytokinins (Z+ZR) and gibberillins (GAs) were decreased, but abscisic acid (ABA) content was increased, which might be related to the small leaves and slow growth of Bt-poplar plants.

Analysis of genetic and environmental effects on hybrid poplar rooting in Central and Northern Minnesota, USA

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We studied genetic and environmental effects on adventitious root initiation and growth because rooting is biologically prerequisite to the establishment of hybrid poplar plantations. Six clones from two pedigrees (pure *Populus deltoides* "cottonwoods" and *P. deltoides* x *P. maximowiczii* hybrids) were tested at two sites (Alexandria and Fertile, Minnesota, USA) and three planting dates (mid-May, late-May, mid-June, 1999). The experimental design was randomised complete blocks with two replications of five cuttings per clone. Individual trees were harvested 2 weeks after planting. Lateral roots, callus roots, callus, shoots, and leaves were dissected from each cutting and oven dried to determine dry weight (mg) of each component. Above-ground and below-ground temperatures (^oF) were recorded at 5-minute intervals throughout the experiment. Analyses of variance indicated that the most important factors influencing root initiation and growth were pedigree and clone-within-pedigree main effects, and the pedigree x planting date interaction.

Pedigrees differed for total root dry weight per cutting and mean number of roots per cutting ($p<0.0001$, $p<0.0001$, respectively). Overall, root dry weight of the hybrids was almost double that of the cottonwoods (25.37 mg, 13.95 mg, respectively). Likewise, root number was twice as much for the hybrids as for the cottonwoods (6, 3, respectively). The pedigree x planting date interaction was significant ($p<0.0001$) for root dry weight. Root dry weight of the hybrids was greater than for the cottonwoods at the earliest planting date (31.78 mg, 6.66 mg, respectively). Root number was also higher for the hybrids than for the cottonwoods for planting date 1 (8, 2, respectively). However, root dry weight and root number decreased for the hybrids and increased for the cottonwoods with later planting dates. Root dry weight of the hybrids was lower than that of the cottonwoods at the end of the experiment (20.23 mg, 24.46 mg, respectively) despite a slight root number advantage for the hybrids over the cottonwoods (4, 3, respectively).

Below-ground growing degree days (GDD) increased with planting date (104.7, 252.8, 283.1, respectively). However, attempts to relate root initiation and growth to soil temperature or air temperature met with uncertain results. Thus, neither linear nor curvilinear regressions of root dry weight on above-ground or below-ground GDD were significant for either pedigree. But the relationship between root initiation and growth to soil temperature or air temperature was stronger for the cottonwoods than for the hybrids ($r^2 = 0.6808$, $r^2 = 0.5897$, respectively). Our current hypothesis is that the relationship between root dry weight and temperature is curvilinear and of different shape for the cottonwoods and hybrids we have tested. We believe a more extensive experiment with increased sampling of dates and clones would be needed to adequately test our hypothesis.

Effects of early years nitrogen fertilization on the growth of poplar plantation in Turkey

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The demand for wood is increasing as the population increases in Turkey. The existing stand volume of our natural forests is not able to respond to this demand. But the wood produced from poplar cultivation will help fill this gap to a certain degree. The annual poplar wood production is 3.5-4.0 million/m^3 now, and fertilisation is one of the measures to be taken to increase this production. In this study the response of fertilisation effects applied in early years in two different sites on two different clones has been investigated. One experiment in Edirne (41^o 40' North latitude, 26^o 34' East longitude) nursery was established with the *P. euramericana* I-214 clone and the other experiment in Beypazari-Kirbasi (39^o 51' North latitude 31^o 41' East longitude) nursery was established with the *P.*

nigra Gazi (TR-56/52) clone. A randomised block design with three replications and five treatments was used. To increase the nitrogen level in the soil to 0.07%, 0.10%, and 0.15%, three different fertiliser doses were applied. In one of the remaining two treatments, farm manure was applied in planting holes, and the other treatment was a control (without fertiliser). The fertilisers were given in the first, third, and fifth growing seasons, and no fertilisers were applied in the second and fourth growing season. Height and diameter measurements were taken at the end of every growing season.

According to the statistical analyses of height and diameter measurements taken in two experiment areas, no significant difference was found in annual and cumulative increments at the end of 5 years. In the Edirne nursery, wide spacing (5.0 x 5.0 m) and well-aerated sandy loam textured soil have led to good root development. The success of fertilisation was lower in such soils, which causes surface water loss, but the good root system increased the usefulness of nutrient elements in water table and deep soils. Potassium and calcium richness of the soil caused the antagonistic relation between cations, and as a result, the uptake of NH4 by plants might be limited in the Beypazari-Kirbasi nursery. The lime richness of the soil also caused the loss of fertiliser. This situation is impeding the usefulness of fertiliser to the plants. According to 5 years of results, fertilisation with three doses of ammonium sulphate has not affected the height and diameter growth of the two clones used in Edirne and Beypazari plantation conditions.

Breeding of new willow varieties for saline-alkali soil plantations

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A large area of saline-alkali soil exists on Songlen Plain, in north-eastern China. It is very difficult to plant trees in these regions. To solve this problem, we have begun to do crossbreeding work with different willow species. The main species include *Salix babylonica* L., *Salix alba* L., *Salix chaenomeloides* var. *chaenomeloide*s, *Salix matsudana*, etc. During the past 14 years, we have done comparison trials in the nursery, comparison trials in plantations, and tests of cuttings grown in water with different saline-alkali concentrations.

The results of the trials in the nursery showed that the best clones were 85-96, 85-70, and 85-67; the height/diameter increments of 2-year-old trees of these clones were separately 408.57 cm/1.97 cm, 426.67 cm/1.77 cm, and 356.09 cm/1.48 cm (1992-1994, EC(5): 0.166-0.587 ms/cm, pH value: 8.3, depth: 0-20 cm). The results of the trials in plantations showed that the best clones were 85-68, 85-96, and 85-64; the height/diameter increments and survival rate were separately 120.85 cm/0.86 cm, 119.3 cm/0.62 cm, and 110.75 cm/0.82 cm, and 91.7%, 75.0%, and 91.7%. The growth characteristics of these clones was

significantly higher than that of the standard varieties (1996-1997, EC(5): 0.128-0.244 ms/cm, pH value: 8.0-8.5, depth: 0-40 cm).

The results of the tests of cuttings grown in solution showed that the best clones were 85-70, 85-67, 85- 36, and 85-96. The average length and number of the roots of these clones were 3.0 cm, 1.5 cm, 1.4 cm, and 1.6 cm and 4, 4, 5, and 2 in 0.4% salty solution pH-value: 9.2, Na2 CO3:NaHCO3 =2:1). All clones had the best growing character in 0.05-0.1% solution compared with water and another salty solution (2000.1-2).

Chromosome doubling and triploid breeding of Populus tomentosa *Carr. and its hybrid*

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Polyploid breeding is a breeding technology that was developed in the 1930s. Most researchers reported that polyploids usually have gigantism in their morphological organs. Polyploidy plants have a very high economic effect in production, especially the triploids, which have even greater economic value. A natural triploid of European aspen *(Populus tremula*) was discovered by Nilsson-Ehle and Muentzing in Sweden in 1936. Since then, other triploids in tree species have been cultured in some countries. The breeding efforts for tree polyploids were late in China. There is no report of discovery of natural polyploids in the major reforesting tree species, except for a few economic tree species. There were few studies on inducing polyploid in tree species artificially. For triploid breeding, it is very difficult to get tetraploid and unreduced 2n pollens as the parent materials in tree species. Production of triploid trees was thus restricted. Inducing chromosome unreduced pollen in a short period becomes the key to culture of triploid trees. A study on chromosome doubling and triploid breeding of Chinese white poplar *(Populus tomentosa* Carr.) and its hybrid *(P. tomentosa* x *P. bolleana*) has been carried out since 1984 at Beijing Forestry University. Big pollen grains were obtained when male flower buds were treated with various concentrations of colchicine and applied in different ways. It was identified that the big pollen grains induced by colchicine were unreduced 2n pollen by measuring the DNA relative content with cytofluorimetry technology. The results show that the suitable concentration of colchicine ranged from 0.1% to 0.5% and injection was the best treatment. The yield of 2n pollen grain was higher in lower temperatures. The 2n pollen grains had reliable vitality and could be used for triploid breeding by pollinating. So far in the field more than 30 clones with superior performance in yield and resistance have been obtained and 6 clones are now used widely as new varieties for plantations in northern China.

Genetic improvement of poplar in China

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China is replete with rich natural resources of the genus *Populu*s. The work of directional genetic improvement is mainly aimed at developing genetically improved poplar cultivars used in industrial woody plantations and protective stands in China. We summarised the major results and advances on genetic improvements of the *Tacamachaca* and *Aigeiros* Sections of several national key 5-year projects undertaken by breeding researchers of the Chinese Academy of Forestry.

1. Reforming strategy on genetic improvements of parent materials. Based on research, the variation of provenances, families, and individuals to the great genetic heterogeneity within species, the breeding strategy, from random hybridisation to selection, was transformed into a model, from selection to hybridisation to selection. The genotype variations between and within populations were used in parent selection for increasing predictability of breeding. Overall breeding strategy was changed and the study of genetic improvements of parent materials was strengthened during the late 1980's to the early 1990's.

2. Collection and evaluation of poplar germplasm in China. From the late 1980s to the early 1990s, we pursued the study of exotic and native germplasm of *P. cathayanas* Rehd., *P. ussuriensis* Kom., in China and created new cultivars with frost- and wet-tolerance to develop poplar industrial wood plantations of poplar. Genetic variations of morphology including branching and leafing were analysed using samples from provenances of *P. cathayanas* Rehd. and *P. ussuriensis* Kom. Genetic structure and differentiation in *P. ussuriensis* Kom., and phylogenetic relationship in *P. ussuriensis* Kom. and its relatives were confirmed by RAPD markers. In the 1980s, 331 clones of Section *Aigeiro*s, consisting of 52 clones of *P. deltoides* Bartr., 56 clones of *P. euramericana*, and 6 clones of *P. nigra*, were introduced from 17 foreign countries, and the first gene pool of Section *Aigeiros* in China was established in Changqing County, Shandong Province. The several characters in clones of Section *Aigeiros* have been measured and studied for 10 years.

3. Match crossing of poplar species and relationships between parent and progeny. In 1992 the poplar breeders of CAF undertook the hybridization between Sections *Aigeiros* and *Tacamahac*a; the clone *P. deltoides* Bartr. Cl. 55/65 female and the individuals of *P. cathayanas* Rehd. male were selected from different provenances.

4. Insights of heterosis and new cultivars obtained by selection and breeding. Using heterosis, we directionally developed new cultivars, while clonal

selection was made in F1 hybrid. We presented the analysis of age effect on wood characters using 13 clones of *P.* x *euramericana* Cl. N2136 and the selection for a number of traits either simultaneously or in sequence. We made more than 100 cross combinations and thought that three of them were suited for industrial wood plantations in different regions of China and would be stressed.

5. Results of breeding integrated in biotechnology such as salt-tolerant somatic mutants of *Populus* x *xiaozhuanica*, molecular linkage map of *P. deltoides* Marsh. x *P. cathayana* Rehd. and associations between quantitative traits and molecular markers. We obtained the somaclonal variants of *P.* x Popularis-39 through the establishment of NaCl-tolerant pressure cell culture to produce calli and control the conditions of adventitious bud and root induction. The somaclonal variants, tolerant to 0.3-0.35% NaCl, were propagated into more than 400 plants, which were tested in the field with NaCl. At the same time, we detected variants by RAPD markers.

Molecular evolutionary relationships in the Populus *genus*

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With approximately 30 species, the *Populus* genus is one of the most important forest tree species for evolutionary studies. *Populus* is widely distributed in the Northern Hemisphere. Based on morphological, ecological, and reproductive features, *Populus* has been classified into six different sections: *Abaso*, *Turanga, Leucoides, Aigeiros, Tacamahaca*, and *Populu*s. However, many ambiguities still remain about the origins of variation and the evolutionary relationships of the species within the genus. In this study, an attempt was made to unravel the phylogenetic relationships of the *Populus* species using molecular differences. A number of microsatellite markers from the chloroplast genomes were developed from 300 individuals representing 29 previously recognised species. We use these molecular data to generate phylogenies, compare these results to classic taxonomic studies, and provide a framework for future studies of life history strategies and biogeography across the genus.

The biomass of intensive and extensive cultured poplar plantations

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Biomass and its allocation in all kinds of organs (branch, stem, leaf, and root) was studied in intensive and extensive cultured poplar *(Populus simonii* x *P. pyramidalis* cv. Chifengensis 36) plantations in Liaoning province, China. The relationship between growth factors (height, diameter at breast height) and biomass was established. The biomass in different organs of the sample trees and its vertical distribution were also studied. Combing the volume data, the dynamic relations of stem biomass and total biomass were established also. The results showed that the effects of cultivation measures on the production of biomass were significant in the two plantations; the value of biomass and its distribution in all kinds of organs were higher in intensive cultured plantations than that in extensive cultured ones. So, intensive culture measures should be taken in managing poplar plantations in the studied area; the suitable age for cutting is about 13 years according to the dynamics of stem biomass and total biomass.

Growth and yield of intensive and extensive cultured poplar plantations

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The relationship between growth factors (height, diameter at breast height, and volume) and stand age were simulated by using the Richards equation in intensive and extensive poplar *Populus simonii* x *P. pyramidalis* cv. Chifengensis 36) plantations in Liaoning province, China. The results showed that the trees of the intensive culture plantation grew faster and matured earlier than that of the extensive culture plantation. The growth factors in the intensive plantation were all higher than those in the extensive one; the maximum of annual volume yield appeared at 8 years in the intensive plantation, but at 11 years in the extensive plantation. According to the annual volume yield and the mean volume yield, the age of quantitative maturity in two plantations was decided. In the former it was 12 years; in the latter it was 14 years. By using the parameters from the Richards equation, combined with the stand age, the growth prediction in 20 years was calculated. The optimum age of cutting in the two plantations was 13 years and 15 years, respectively. In conclusion, the effects of cultivation measures on the growth and yield of two plantations were significant. So, intensive culture measures can accelerate the growth of plantations and make quantitative maturity early, which shortens the rotation.

The vertical distribution and seasonal dynamic of leaf area in poplar plantations

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The vertical distribution and seasonal dynamic of leaf area were studied in intensive and extensive culture poplar *Populus simonii* x *P. pyramidalis* cv. Chifengensis 36) plantations in Liaoning province, China. The results showed that the cumulative leaf area index (CLAI) of intensive culture trees was obviously higher than that of extensive culture trees during the growing season. Seen from the seasonal dynamic of leaf area, the leaves of intensive trees sprout relatively early and drop late compared with the extensive ones; that means the intensive cultured plantation has a relative longer growing season than the extensive cultured one. The higher leaf area and longer growing season contributed to the higher productivity in the former. The seasonal change of leaf area in different crown layers in two stands and the vertical distribution of CLAI in two plantations during the growing season were also studied. The maximum CLAI appeared in July in the intensive culture plantation, and in August in the extensive cultured one. The minimum CLAI appeared in October in both plantations. Models were established, and the vertical distribution of CLAI in the two plantations can be accurately simulated by the relative models according to the observation date. Even in a uniform plantation, leaf area differed in different individuals. The leaf area appeared to have a positive relation to diameter at breast height (dbh), which means the trees with large dbh had a higher value of leaf area. These studies laid a foundation for further study of the light distribution in the canopy and the photosynthetic productivity in the plantations.

Investigation on the methods of biomass production from poplar plantations

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In this study, twelve biomass production methods were compared. Two different clones were tested (*P. deltoides* Samsun and I-214) in this trial. Two replications and twelve treatments were applied. Planting materials were planted in 1998. The treatments were: 1) Samsun clone, 20 cm height cuttings; 2) Samsun clone, 35 cm height cuttings; 3) Samsun clone, 50 cm height cuttings; 4) Samsun clone, 65 cm height cuttings; 5*)* Samsun clone, one year old rootness saplings; 6) Samsun clone, two years old saplings; 7) I-214 clone, 20 cm height cuttings; 8) I-214 clone, 35cm height cuttings, 9) I-214 clone, 50 cm height cuttings, 10) 1-214

clone, 65 cm height cuttings; 11) I-214 clone, one year old rootness saplings, 12) I-214 clone, two years old saplings.

According to the first two year results, survival rates, height and diameter values and unit times at the end of second year pruning opera/ion were determined.

No significant differences have been observed in the comparison rates.

According to the analysis of variance the highest diameter and height values have been found in the treatment of 5 and 6.

Unit costs were measured and recorded for all treatments.

Responses of Salix borealis *and* S. caprea *to simulated herbivory in polluted and clean habitats*

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Willows are able to tolerate high pollution loads and become a dominant group in polluted habitats, which makes them suitable candidates for the rehabilitation of areas deteriorated by emissions. However, willows are damaged by a number of insect herbivores, some of which may completely defoliate their hosts. I compared the effect of simulated herbivory on the growth, reproduction, developmental stability, and quality for herbivores of two willow species, *Salix borealis* (Fries.) Nasar. and *S. caprea* L., growing at different distances from two nickel-copper smelters.

In clean sites, defoliation of both willow species adversely affected sexual reproduction and increased formation of shoots from dormant buds, but did not change either shoot growth or leaf size. Compensatory responses to leaf clipping in polluted habitats were reduced for both willow species, but this effect was stronger for *S. borealis*, as reflected by a decrease in shoot growth and fruit production and an increase in leaf fluctuating asymmetry (FA), which is a non-specific indicator of stress. In polluted sites, leaf clipping did not affect activation of dormant buds, although in clean sites it was a common compensatory response to herbivory in both species. This may be explained by weakened apical dominance in polluted habitats due to both direct damage by gaseous pollutants and lower competition for light. Lower compensatory abilities of willows growing under pollution impact may also result from damage caused by pollutants and pollution-induced environmental changes (i. e., stronger winds, thinner snow cover, harder frosts). These factors activated compensatory responses in *S. borealis*, as indicated by regrowth from dormant buds, enhanced shoot growth, and increased reproduction in polluted sites. As a result, no resources are available for compensation of additional damage caused by herbivory in plants growing on low-nutritive polluted soils. Summer defoliation of

S. borealis resulted in the development of Delayed Inducible Resistance (DIR), which caused a decrease in both leaf damage of field growing individuals and foliar quality for herbivores in the laboratory bioassays. However, in polluted sites, DIR was not expressed. In contrast, amelioration of willow quality induced by bud removal was stronger in polluted sites. Both effects together with lower compensatory abilities may contribute to the high herbivore damage of willows growing in polluted habitats.