INTERNATIONAL POPLAR COMMISSION

25th Session
Berlin, Germany, 13-16 September 2016

Poplars and Other Fast-Growing Trees - Renewable Resources for Future Green Economies

Abstracts of Submitted Papers and Posters

Forestry Policy and Resources Division
Forestry Department

Working Paper IPC/14
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The Abstracts of Submitted Papers and Posters do not reflect any official position of FAO but are to provide early release of information on on-going International Poplar Commission initiatives and its member country activities and programmes to stimulate dialogue between Poplar and Willow stakeholders around the globe.

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Comments and feedback are welcome.

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POPLARS AND OTHER FAST-GROWING TREES – RENEWABLE RESOURCES FOR FUTURE GREEN ECONOMIES

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Organized by

German Federal Ministry of Food and Agriculture (BMEL)
Food and Agriculture Organization of the United Nations (FAO)
ACKNOWLEDGEMENTS

The selection and compilation of these abstracts of submitted papers and posters are the product of an international team of dedicated experts willingly giving their time and expertise to evaluate, review and allocate more than 200 submitted abstracts for oral or visual presentations in plenary or concurrent sessions. It is encouraging to see the diversity of topics submitted by the authors of more than 30 countries from all regions of the world to the 25th Session of the International Poplar Commission.

The Scientific Committee was chaired by Mr. Georg von Wühlisch (Germany), and co-chaired by Mr. Martin Weih (Sweden). Ms. Michèle Millanès from the IPC-Secretariat in Rome supported the paper summary review process, and performed the compilation, editing and formatting of the abstracts in an accurate and orderly manner to produce this working paper.

The International Poplar Commission and its members would like to express their sincere thanks to all persons who contributed to the publication of this working paper.
FOREWORD

The 25th Session of the International Poplar Commission, hosted by Germany in Berlin, will bring together a number of international stakeholders, poplar scientists, researchers, growers, processors and traders to address topical issues related to the theme “Poplars and other fast-growing trees – Renewable resources for future green economies”.

The more than 200 paper abstracts from more than 30 industrialized and developing countries contained in this working paper demonstrate the increasing diversity in users and uses of poplar and willow culture, but also highlight the expanding knowledge and rapid development of new technical innovations (both growing and using) of poplars and willows around the globe.

In Germany the planting of poplars and willows in managed forests and the establishment of short-rotation plantations did not increase significantly in recent years. This is mainly due to the concept of continuous-cover forest management devoid of clear cuts and the low commercial value of poplar wood. On occasion, aspen and balsam poplar are introduced as pioneer species on calamity areas or for the afforestation of agricultural land. The most recent German National Forest Inventory assigned in total 147,000 ha to poplar stands (excluding short-rotation plantations), of which more than half (55%) is taken by aspen followed by European black poplar & hybrid varieties (26%).

As Germany is adamant to achieve the ambitious European Union goal of increasing its share of renewable energy sources by 2030 the production of wood fuel from poplar and willow plantations in the form of wood chips may develop in a profitable and feasible option for sustainable biomass production depending on the development of the oil price and supportive forest policy measures. In addition, short-rotation plantations are widely acknowledged to have positive environmental benefits for climate protection due to their high CO2 sequestration rate, their positive effects on soil regeneration, renewal of groundwater as well as on plant and animal biodiversity.

Except for the plenary sessions this Book of Abstracts is organized and structured according to the new proposed titles of the working parties of the International Poplar Commission:

1. Taxonomy, Nomenclature and Registration
2. Domestication and Conservation of Genetic Resources
3. Climate Change, Plant Health and Resilience to Threats and Crises
4. Sustainable Livelihoods, Land-use, Products and Bioenergy
5. Environmental and Ecosystem Services

No abstracts were submitted for working group 6 Policy, Communication and Outreach

We hope that this publication will help to facilitate fruitful discussions between stakeholders at the 25th IPC-Session and provide participants with author coordinates for follow-ups beyond the Session.

Finally, the IPC-Secretariat wishes for a fruitful Session in transferring poplar and willow knowledge and technology effectively between all participants regardless of national or socio-economic contexts.

Walter Kollert
Secretary
International Poplar Commission
FAO Forestry Department
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TRENDS AND PERSPECTIVES IN POPLAR AND WILLOW CULTIVATION – A GLOBAL SYNTHESIS OF NATIONAL PROGRESS REPORTS

Jim Carle

The member countries of the International Poplar Commission (IPC) report every four years on the occasion of full sessions about national and global trends and perspectives in poplar and willow cultivation. This global synthesis report was compiled from the available national reports of member countries; it highlights status, innovations, issues and trends in regards to cultivation, management and utilization of poplars and willows growing in indigenous or planted forests, agroforestry production systems and as distinctive landscape components for protective and productive purposes. Another purpose is to draw the attention of policy makers, scientists, and producers to the rich diversity of expertise, knowledge and leadership that is documented in the various country reports. The narrative part of the synthesis report provides the policy, legal, institutional and technical dimensions of poplar and willow culture and is complemented by statistics on poplar and willow resources by function, wood removals, forest products and trends and a comprehensive listing of scientific reference documents published during 2012 – 2015 by member countries. These documents are also made available on the FAO website: http://www.fao.org/forestry/ipc/en/.

Key words: Poplars, willows, indigenous forests, planted forests, agroforestry, global trends.

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ADVANCES IN A WILLOW (Salix spp) BREEDING PROGRAMME IN ARGENTINA FOR DIFFERENT WOOD APPLICATIONS

Teresa Cerrillo1, Jorgelina Grande2, Silvia Monteoliva3,4, Virginia Lúquez3,4, Araceli García5, Celina Braccini5, Patricia Fernandez1,4, Esteban Thomas6, Ivana Amico7, Ignacio Fosco8, Fabio Achinelli3,9, Edgardo Casaubón1 and Raúl Villaverde10

Willows are cultivated in Argentina for different applications, mainly pulp and paper industry and particleboard, and, secondarily, for saw-timber. With the aim to improve the clonal offer, a breeding programme is being developed by INTA in collaboration with other official institutions and private agreements. The strategy is based on inter- and intra-specific hybridisation and selection, considering: growth, adaptability, resistance to pests and diseases, stem form and wood quality. A broad series of trials to test the material are located in different areas of the country, the most in the Paraná Delta, the main core of willow production in the country; other tests are established in Patagonia region and Salado River Basin. In addition to the industrial use of its wood, new willow genotypes are being explored for other applications, as forestry-livestock systems, biomass production and environmental strategies.

Evaluations of a series of screening and yield trials in the Delta area have led to select six new clones in 2012, and three more in 2016. Clonal identification by genetic markers were carried out for all genotypes. Six of these genotypes were originated from controlled crossings (S. matsudana x S. aba and S. matsudana x S. nigra), and three from open-pollination (individuals of S. alba, S. nigra and S. matsudana). In yield trials of six years old, localized in average site qualities of the Delta region, the new clones showed a mean volume of 22.8m³.ha⁻¹.yr⁻¹, which was 45.3% better than the mean of the older traditional clones. The three top clones of the nine selected clones yielded 33.2m³.ha⁻¹.yr⁻¹, 28.7m³.ha⁻¹.yr⁻¹ and 26.5m³.ha⁻¹.yr⁻¹. Regarding wood traits, six of the nine new improved clones showed outstanding characteristics (basic density, fiber length, whiteness of the wood; and tear strength, tensile strength and scattering of the pulp) and suitability for sawing. The genotypes selected have different degrees of flooding tolerance, in consequence specific clones could be recommended according to the risk of flooding of each area.

Key words: Willows, improvement, clones, wood.

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BIO-ENERGY FROM POPLAR BIOMASS UNDER SHORT ROTATIONS: FULL GREENHOUSE GAS BALANCE, ENERGY BALANCE AND ENVIRONMENTAL LIFE CYCLE ANALYSIS

Reinhart Ceulemans¹ (+ POPFULL Research Team)

Three questions need to be addressed before the efficacy of short-rotation biomass for energy and for carbon mitigation can be conclusively assessed: (i) Is bio-energy from woody biomass energy efficient? (ii) Does bio-energy effectively mitigate greenhouse gas (GHG) emissions? (iii) Is bio-energy from woody biomass economically profitable?

To provide answers to these three questions, we monitored an operational, large-scale (18 ha) short-rotation coppice (SRC) plantation for the production of bio-energy from the establishment of the plantation to the production of green electricity and/or heat. The high-density plantation in East-Flanders (Belgium) is managed in two-year rotation cycles and uses poplar (Populus) as the planted crop species. Eddy covariance techniques monitor net fluxes of all GHG’s between the plantation and the atmosphere. For the energy accounting, the global warming contribution and the energy efficiency assessment, we used life cycle analysis (LCA) over the two rotations from the cultivation of the plantation to the conversion of the harvested chips into electricity and/or heat. The collected information on the GHG’s and the energy inputs of the two-year rotations was used toward predictions and simulations of the net reduction of fossil GHG emissions of SRC. During two rotations, the SRC plantation supplied woodchips – ca. 10 tons of dry mass ha⁻¹ yr⁻¹ – for decentralized bio-energy operators in Belgium.

In answer to the first question the SRC bio-energy production yielded nine times more energy than was put in. With regard to the second question, the SRC plantation was a net carbon sink, i.e. absorbed more carbon from the atmosphere than was produced. But the non-CO₂ GHG (methane and nitrous oxide) represented an overall net emission to the atmosphere. Although the plantation was a small net producer of GHG, the electricity and green heat from bio-energy reduced greenhouse gas emissions by 78% as compared to electricity from fossil fuel generators in the EU. In answer to the third question, we showed that the bio-energy culture was economically not viable. The total cost of producing bio-energy was five times higher than the benefit of the renewable energy produced.

Key words: POPFULL, energy balance, energy efficiency, greenhouse gas balance.

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ROLE OF THE PRIVATE SECTOR IN PROMOTING THE CULTURE OF POPLAR AND OTHER FAST-GROWING TREE SPECIES IN INDIA

Ramesh Chand Dhiman

India is among a few densely populated countries where land resources are under intense biotic pressure to meet its forest based domestic and industrial needs. Forests cover an area of 76.46 million hectares largely under the control of state governments. Tree plantation activities have been mainly state-driven with public money. The country has a paradigm shift in production forestry post enunciation of Indian Forest Policy 1988 which stressed that the government forests be preserved for ecological and environmental services and the wood-based industry needs to develop synergies with farmers to grow raw material.

Presently, the country has a wood demand of 123 million m$^3$ out of which government forests are able to supply hardly 3 million m$^3$. The major share of wood for industrial and domestic use is now supplied from trees grown on the small farm holdings integrated with traditionally grown agriculture crops by millions of farmers. The deficit in wood and wood-related products is met with from imports draining the foreign exchange equivalent to Indian Rs. 42000 crores (1 crore=10 million). Wood-based industry has proactively developed synergic partnerships with farmers to grow wood for industrial and domestic needs.

The role of the private sector in this endeavor is in the form of research and development of site matched productive clones, develop cultural technologies related therewith, produce and supply planting stock, provide technical support system in management of plantations and procure wood for industrial wood processing. The private sector promote these plantations under their social corporate responsibility or supply planting stock at subsidized rates to ensure the sustainable wood availability for wood-based industries. An estimated area of 5 million hectares is under commercial agroforests planted with species of fast-grown genera viz., *Eucalyptus* (2 million ha), *Populus* (0.3 million ha), *Casuarina* (0.5 million ha), *Acacia* (0.7 million ha), and others (1.50 million ha). These agroforests produce around 100 million m$^3$ wood, 150 million tones firewood, generate around 4000 million man-days employment, sequester around 60 million tons carbon in trees, increase green cover by 2.84% (70% crown density) and ameliorate and sustain agriculture production with addition of around 15 million tons organic matter annually.

There are numerous other multiplier effects of these plantations in the form of self-employment in nursery production and trade; filed planting and management; harvesting and transportation of wood; rural development through infrastructure developments for such activities, value addition in even firewood billeting, development of vibrant wood marketing system etc. The presentation includes case studies of poplar and eucalyptus culture supported by the private sector.

**Key words:** Private sector, agroforests, poplar, eucalypts.

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POPLARS AND OTHER FAST-GROWING TREES - RENEWABLE RESOURCES FOR FUTURE GREEN ECONOMIES

Matthias Dieter

The consumption of wood-based products has slightly increased, in particular the consumption of wood-based panels. Their rise exceeds that of industrial round-wood production in absolute values (indication for the significance of wood processing residues and post-consumer wood). Focussing on the respective global top 20 consumer of semi-finished wood products, considerable changes have happened during the last decade. In almost all product markets big typical industrialized countries (as e.g. USA, Japan and several bigger European countries) are characterized by shrinking consumption. Evolving markets are to be found in particular in China but also in the Russian Federation, Brazil, Turkey, India or Indonesia.

For the future, global consumption of industrial round-wood model forecasts result a slight decrease, until 2030 by ca. 20 million m³. European consumption remains rather constant. Only Asia shows a remarkable growth path. Fuelwood consumption, though, is projected to rise significantly by about 500 million m³ until 2030. A rise happens in all regions. Consumption of semi-finished wood products is slightly increasing in Europe (wood-based panels and paper and paperboard outweigh sawn-wood). Again, only Asia shows a clear growth path, in particular for wood-based panels and paper and paperboard.

Also EFSOS II shows a (slight) increase in all material wood consumption. The significant positive overall trend in particular is owing to projected energetic wood consumption. EUwood forecasts a significant increase in consumption of all semi-finished wood products. In contrast to the models before, even sawn-wood continues its growth path here. These few partly differing findings point to the impact of the respective model assumptions.

On production side the share of planted forests is still low, but increasing, against the overall trend. The dimension of plantations equals planted semi-natural forests. Both primarily serve timber production. Planted forest’s area is projected to significantly continue growing, even in a pessimistic scenario. Each subdivision, coniferous and non-coniferous, holds about half of the area. Planted forests contribute to global timber production above average. Main purpose is material use. The strongest increase is expected to happen in Asia and South America. Additional timber production in the higher productivity scenario is substantial and in the same order of magnitude as forecasted consumption.

As a very condensed conclusion one can state that improving productivity matters and that volume is needed rather than specific dimensions and qualities. However, the kind of tree species may matter. Demand for wood is one cause for deforestation and forest degradation and hence planting forests might withdraw pressure from natural forests. Rising future demand requires additional or improved planted forests. Moreover green economy still is rather a political slogan than reality. Becoming reality it will impact demand, when and how much is not yet foreseen. Against this background IPC activities are highly valuable. They should take regionally different future demand in account.

Key words: Global, wood, production, consumption, regions, semi-finished, wood products.
IMPORTANCE OF THE PLANT MICROBIOME FOR GROWTH, HEALTH, AND STRESS TOLERANCE

Sharon L. Doty, Zareen Khan, Andrew W. Sher, Mahsa Khorasani, Andrea Firrincieli, Mitch Scott, Shyam Kandel, Pierre Joubert, Roger Bumgarner, Soo-Hyung Kim and Thomas H. DeLuca

Recent evidence points to symbiosis with internal microorganisms, termed endophytes, as a critical mechanism for non-nodulating plants to survive in nutrient-limited environments. Members of the Salicaceae family, including poplars (Populus sp.) and willows (Salix sp.), are early successional tree species able to colonize primary substrates of sand and cobble. The microbiota of these trees in their native habitats include strains able to fix dinitrogen gas, solubilize phosphate, and produce phytohormones, siderophores, and antifungal compounds. Addition of the microbial strains from wild poplar to cultivated hybrid poplar resulted in increased biomass, drought tolerance, and N-fixation. N-fixation within wild poplar was directly assessed using the $^{15}$N incorporation assay and indirectly using the acetylene reduction assay. Both methods indicated that N-fixation in poplar occurs in an unevenly distributed fashion. Nitrogenase gene sequencing and plate assays of culturable endophytes demonstrated wide variation in microbial density and composition. Plant physiological studies and genomic and microbial analyses indicated that the mechanisms for the endophyte-induced drought tolerance are also highly complex, involving reduced plant stress response and likely involving modulation of phytohormones by the endophytes.

The microbiota of poplar is important not only for general health and growth and stress tolerance but also for environmental applications such as phytoremediation. Addition of a TCE-degrading endophyte strain increased TCE metabolism not only in lab studies but also increased poplar growth and the accumulation of TCE metabolites in a field trial. Colonization of willow with a PAH-degrading endophyte from poplar resulted in reduced phytotoxic effects and increased PAH removal. A study in public perception of endophyte-assisted phytoremediation revealed overwhelming support and acceptance. The phytobiome therefore has profound implications for the environmental sustainability of plantations as well as for environmental applications of poplar and willow for increased growth, health, and effectiveness.

Key words: Biomass production, microbiome, sustainability, phytoremediation, drought tolerance, abiotic stress tolerance.

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PLANT REMODELLING IN TREES – BREEDING PERSPECTIVES IN POPLAR

Matthias Fladung

Under the scenario of a rapid ongoing climate change as well as a steadily growing world population, there are strong requirements for long-term conservation of healthy forests and to ensure availability of wood also in future. One possibility to meet these requirements is to improve trees with respect to growth and biomass production, abiotic and/or biotic tolerance/resistance, and quality parameters for use in both forests and tree plantations.

Biomass production can be increased by modification of tree architecture or by altering photosynthesis and photorespiration. Determinants of productivity are, among others, large leaves, sylleptic branching, narrow crown architecture, adopted activity of stomata, and a compact root system. Improved trees could show tolerances towards desiccation, anaerobic conditions and to high temperatures, and resistances to insect damage and diseases. To also ensure wood as a future resource of raw material for both material and energetic uses, wood quality as well wood composition could be changed with respect to the further use. For instance, for material uses structure of wood might be changed to increase wood density to make wood harder. On the other side, to use wood as raw material in green economies, trees could reveal changed lignin and cellulose composition.

Forest trees can be optimized genetically via classical breeding. However, even when some breeding progress has been made with poplar, willow, and pine species, forest tree “cultivars” can still be considered as nearly “wild plants” with little if any of the hallmarks of crop domestication. Breeding in trees is much more time consuming than in annual plants.

By applying bio- and gene technological methods or by novel molecular breeding methods, tree breeding can be accelerated significantly. For many tree species, e.g. poplars, spruces, pines and eucalyptus, tissue as well as gene technological methods have successfully been established. A range of targets are of interest for genetic engineering in trees, e.g. lignin and/or cellulose modification, pest resistance, and tolerance to abiotic stresses. Another application of gene technology to accelerate tree breeding is the use of early flowering genes. In poplar for instance, the non-reproductive phase, usually seven to ten years, could be shortened to six to ten months. Molecular breeding methods comprise approaches to correlate the phenotype with molecular markers for a marker assisted breeding (MAS) and to use the novel breeding technologies like cisgenesis, oligo-directed mutagenesis (ODM), and site-directed nucleases (SDN) (e.g. the CRISPR/Cas9 system).

Key words: Tree breeding, climate change, flowering-time gene, CRISPR/Cas, molecular marker, biomass, plantation.

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SRC AS FUEL HEDGE

Jan Grundmann

Energy Crops GmbH is a 100 % subsidiary of Vattenfall Europe Wärme AG, dealing with SRC in the northeast of Germany. The company was founded in 2010 to implement and operate SRC in order to secure a curtain portion of the biofuel demand for a new erected bio CHP with a thermal fuel capacity of approx. 30 MW. This bio CHP is the base load heat producer in a smaller district heat network, being located in the North of the City of Berlin.

The Energy Crops GmbH is by the time market leader in the German SRC business with 2.000 ha plantations under contract, of which about 400 ha are operated in western part of Poland, being located close to German border. About 90 to 95 % of the plantations are poplar plantations, planted with Max, Matrix and Hybrid 275.

Co-operation models with the big farms in eastern part of Germany, ways of planting and nursing the plantations, harvesting technologies and first experiences with the usage of poplar wood chips as a fuel are described.

Key words: Energy crops, biofuel, heat producer, Eastern Germany.

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POPLARS AND WILLOWS: A PHOTO LIBRARY

J.G. Isebrands¹ and J. Richardson²

The Salicaceae are an extremely diverse group of tree and shrub species, in terms of taxonomy, geographic range, form, ecological adaptation, uses, and even associated insects, diseases and environmental stressors. Drawing on the great number of images collected and contributed for the 2014 CABI/FAO publication ‘Poplars and Willows: Trees for Society and the Environment’, only a fraction of which could be included in the book, this presentation aims to illustrate in an informative and engaging way through the medium of photographs, the breadth and depth of what we know about, do with, and are concerned about poplars and willows.

The presentation will provide a sample from a project to create a photo library, an accessible repository which will supplement the earlier book.

Key words: Poplars, willows, photographs, compendium, taxonomy, ecology, pests, environment.

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THE REFORM OF THE INTERNATIONAL POPLAR COMMISSION (IPC) IN THE LIGHT OF MODERN FOREST POLICY REQUIREMENTS

Walter Kollert

In the aftermath of World War II poplar and willow cultivation was deemed a priority to help rebuild forestry economies in rural Europe. This brought about the creation of the International Poplar Commission (IPC) in 1947. After its placement as a Statutory Body within FAO, its membership grew steadily worldwide, particularly between the 1960s and the 1990s. Currently 37 countries from five continents are members of the IPC, of which more than half are developing economies (20 countries).

Since its foundation IPC aimed at promoting the cultivation, conservation and utilization of poplars and willows of the Salicaceae family. It carried out its mandate by supporting research and management activities through six international working parties and has had an important role in the development of the forest and timber sectors through the transfer of knowledge on poplar and willow cultivation and the exchange of technologies and breeding material.

Today, IPC is facing major institutional challenges. Membership has been stagnant since 2000; the IPC-Secretariat has suffered from a lack of resources; disconnect has emerged between the technical fields of the working parties and the nature of environmental and development issues facing member countries, and some National Poplar Commissions have become dormant. Because of the relatively narrow geographic and technical focus of the IPC, it has been difficult to attract donor and international programme interest as the links of poplar and willow cultivation with sustainable livelihoods and land-use are not always apparent, and the technical fields represented by the working parties need to be more integrated into multi-disciplinary and inter-sectoral environmental and development issues.

The paper will elaborate on how IPC, after more than 60 years since its creation, has reacted to this challenge by implementing a far-reaching institutional reform that will strengthen the IPC to better meet modern forest policy requirements and respond to topical themes of our time. This reform aims at increasing IPC’s relevance and effectiveness in serving member countries and facilitate better support to sustainable land-use and livelihoods, including food security and poverty alleviation.

Key words: Poplars, willows, IPC reform, FAO, forest policy.

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THE POPLAR IN THE URBAN ENVIRONMENT – EXPERIENCES WITH ITS USE AND USABILITY IN THE NETHERLANDS

Jitze Kopinga

The Netherlands is known as 'land of poplars'. In almost all regions the tree species is present in forests and row plantations along roads, rivers and canals, determining the coulisse-like scene of the landscape. Besides pedunculate oak and common ash it is the most commonly used tree species in the Dutch landscape. But also within the urban environment the poplar is frequently used; more specifically in town extension areas, in order to provide these with a 'green' appearance within a relatively short period of time. The most used poplar species in the urban environment are *Populus x canadensis*, *P. nigra* and *P. x canescens*. The latter especially in coastal areas because of its tolerance to sea wind. In the older parts of towns, more particular species and cultivars can still be seen, such as: *P. nigra* 'Italica', *P. simonii* 'Fastigiata' and (to a lesser extent) *P. berolinensis*. The appreciation of the poplar as urban tree mainly concerns its uncomplicated and rapid growth. However, as an adult tree its ecological value regarding flora and fauna (birds, bats, etc.), is also regarded as one of the 'strong' points.

However, the poplar also has some 'weaker' qualities that are restricting its general use. A general point is the production of seed fluff during the early growing season. Occasionally this is experienced as a public nuisance. The problem however can simply be met by planting only male cultivars. Also the formation of root suckers by some of the species is often considered as an inconvenience regarding the maintenance of lawns or ground covering plantings. This phenomenon can be partly traced back to the method of propagation by tree nurseries. More serious inconveniences concern traits such as rooting behaviour causing damage to pavements, as well as the high level of evaporation of some of the species with damage to roads and housings on shrinkable soils as a result. Occasionally also damage of roots to underground infrastructure (intrusion in sewer pipes, etc.) is mentioned, although this is also a general behaviour of many other tree species.

More recently additional considerations entered the scene. Most of these can be attributed to an increasing attention for public safety (also called tree safety). More than before the 'spontaneous' breaking of branches has been pointed out as an undesired quality. Just like the increasing rate of dead wood formation at older age of the tree (consequently trees had to be pruned for obvious reasons of public safety). However, it needs to be said that the intensity in which these qualities are experienced as a problem quite often, if not always, is related to the annual budget for tree maintenance in general.

Generally, pests and diseases are not insurmountable limiting factors for the use of poplars in the urban environment. Although attacks by wood boring insects such as *Cossus cossus* are sometimes mentioned as a problem on local scale, because of reasons of public safety. Nevertheless these attacks can usually be prevented by adequate green management.

In this presentation the backgrounds and mechanisms of a number of desired and less desired qualities and traits of poplars will be highlighted with emphasis to its use in the urban environment. This together with the (many) opportunities and sometimes limitations regarding an adequate choice of tree species and/or cultivars and proper planting and tree management, including technical solutions.

**Key words:** Urban environment, poplar weaknesses, qualities, pests and diseases.

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GLOBAL AND REGIONAL MARKET TRENDS FOR POPLAR PRODUCTS

Arvydas Lebedys¹

The presentation gives an overview of major trends in production, international trade and prices of products made from poplar wood such as logs, sawnwood and panels. The analysis is based on publicly available information documented in national production statistics and IPC country reports, and on data from national customs records that are published in the Global Trade Atlas by the Global Trade Information Services (GTIS, www.gtis.com) according to the product identification codes of the Harmonized Commodity Description and Coding System (in brief, the Harmonized System, or HS).

Key words: Poplars, forest products, statistics, international trade, trends.

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PHARMACEUTICALS AND PERSONAL CARE PRODUCTS: *POPULUS ALBA* PHENOTYPING AND UPTAKE

Erika Carla Pierattini¹, Alessandra Francini³, Andrea Raffaelli² and Luca Sebastiani¹

Pharmaceuticals and personal care products (PPCPs) are widespread compounds continuously released in the aquatic environment and their scarce removal by conventional wastewater treatment plants has been demonstrated. Phytoremediation is a promising technique for completing the removal of these substances from wastewater, both for its effectiveness and low-cost; it has been shown that plants have the capability to absorb, translocate, and metabolize organic xenobiotics such as PPCPs. Among PPCPs, the antibiotic erythromycin and the detergent sodium dodecyl sulfate (SDS) are two of the most detected compounds that cause serious environmental issues.

*Populus alba* Villafranca clone L., a model species for PPCPs was treated with realistic environmental concentrations of erythromycin (0, 0.01, 0.1 and 1 mg L⁻¹) and physiological response as well as antibiotic uptake were evaluated. Plants maintain healthy traits (growth parameters, photosystem II efficiency, photosynthetic pigment content) during the whole experimental period (28 days), despite the uptake of erythromycin, which was found mainly concentrated in roots.

Since SDS is a surfactant whose use for enhancing phytoremediation of heavy metals polluted soils has been described, it was tested on Villafranca clone together with a sub-toxic zinc concentration (1 mM Zn(NO₃)₂; 0.5 mM SDS; 1 mM Zn(NO₃)₂ + 0.5 mM SDS; and control). An acropetal progression of necrosis in leaves and subsequent leaves abscission was observed in plants treated with SDS and SDS+Zn, starting from 2 days of experiment, while control and Zn-treated plants maintain healthy traits for the whole experimental period (21 days). Sodium accumulation in SDS and SDS+Zn treated plants seems to have an important role in foliar damage.

**Key words:** Erythromycin, poplar, sodium dodecyl sulfate, zinc.

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ENGINEERED WOOD PRODUCTS BASED ON POPLAR/WILLOW WOOD

Joris Van Acker

This paper is related to the 2nd ‘Conference on Engineered Wood Products based on Poplar/Willow Wood’, taking place in León, Spain from 8 to 10 September 2016. This event is co-organised by Pro-Populus, created in 2008 as the European Poplar Association and the International Poplar Commission (IPC), more specifically through the Working Party on Harvesting and Utilization of Poplar and Willow Wood. The local industry partner is the company Garnica Plywood that also provided a visit in a plant in Valencia de Don Juan on 8 September.

The call for papers mainly aimed at receiving contributions on the following topics:

1. Technology of engineered wood products such as structural plywood, laminated veneer lumber (LVL), laminated strand lumber (LSL), cross laminated timber (CLT), glulam and OSB products.
2. Glue bonding and impact on product performance.
3. The use of coatings.
4. Suitability of wood preservation and wood quality improvements; e.g. wood modification (chemical and thermal).
5. Poplar/willow wood properties relevant for engineered wood products.
6. Integrated processing of non-structural products.
7. Food contact of poplar packaging.
8. Innovation in integrated utilization of poplar/willow wood for bioenergy.

The outcome of this conference allows to suggest that a wide range of important innovative products is feasible. Not only is poplar/willow wood based on a fast growing resource, it also allows to outcompete or at least be equivalent to wood products based on softwoods. Especially in view of a future where planted forests with similarity to growing agricultural crops will be part of the global wood production, this poplar/willow based engineered wood products will be a main part of the sustainable bio-based economy.

Key words: Conference, engineered wood products, utilisation.

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INCORPORATING SHRUB WILLOW INTO MULTIFUNCTIONAL SYSTEMS USING A LANDSCAPE DESIGN APPROACH

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There is potential to sustainably produce over one billion dry tonnes of biomass annually in the U.S. Short-rotation coppice (SRC) systems, such as shrub willow (\textit{Salix} spp.) and poplar (\textit{Populus} spp.), are projected to supply 20-25\% of this material. While some environmental and rural development benefits associated with SRC willow are documented, the economic value associated with them is often externalized, which creates a barrier to deployment of the crop. Incorporating willow into multifunctional systems using a landscape design approach is one way to capture additional value. Multifunctional systems are intentionally designed to integrate and balance the production of multiple products and environmental and/or social benefits through site selection, system design, and management practices. Recent discussions have focused on using a sustainable landscape design approach and engaging a wide array of stakeholders to effectively incorporate multifunctional systems into the existing landscape.

Several types of multifunctional willow systems have been deployed and studied in the U.S. including nutrient and riparian buffers, alternative vegetative covers, and living snow fences (LSF). Field trials and watershed modeling of willow buffers installed in a corn field reduced nitrogen pollution but were unlikely to generate positive economic returns for just the biomass produced. However, the cost of nitrogen removal using willow was between $1.8 - $37.0 kgN\textsuperscript{-1} yr\textsuperscript{-1}, lower than other practices such as cover crops ($55 kgN\textsuperscript{-1} yr\textsuperscript{-1}) or crop rotations ($43 kgN\textsuperscript{-1} yr\textsuperscript{-1}). About 40 ha willow evapotranspiration cover established on a former industrial site in central New York effectively reduced percolation and runoff from the site, achieving the primary goal of this project. The cost of a willow evapotranspiration cover is an order of magnitude lower in terms of costs, energy investments and greenhouse gas emissions compared to traditional clay or geomembrane alternatives. Although, biomass production is a secondary product from this system, initial harvests have begun and testing has shown there are no concerns with the composition or quality of the biomass from this site. Recent research has demonstrated that willow LSF are an effective way to reduce blowing snow on roads, which can save on road maintenance costs, improve road safety, and provide additional environmental and public benefits. Incorporating multifunctional willow systems into landscape designs is intended to provide both ecosystem services and a source of renewable biomass. The biomass or ecosystem services may not drive the deployment, but when benefits are combined there is potential to expand plantings across the landscape.

\textbf{Key words}: Multifunctional system, landscape design, shrub willow, ecosystem services.

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A combination of increased energy demand and political decisions, such as the COP21 climate agreement in Paris, has raised the ambitions of European policy-makers to increasingly redirect future energy supply from fossil to renewable energy sources. For example, by 2050, Sweden envisages achieving a sustainable and resource-efficient energy supply and no net emissions of greenhouse gases in the atmosphere; and the Swedish government has the ambition to make the vehicle fleet independent of fossil fuel by 2030. This means that raw material for the energy sector and the pulp and wood fiber industry is increasingly needed in Sweden and the Baltic region.

A promising way to meet the increasing demands is the establishment of fast-growing tree plantations at commercial scale. Poplars, aspens and willows have the potential to offer a flexible, sustainable source of biomass and material in Sweden. Nevertheless, existing plant material is often not well adapted to the local climate and photoperiod in many parts of Sweden and other regions with similar climate and photoperiod conditions. To overcome this hindrance, we need to identify the plant material characteristic(s) that best match the current and future climates in different parts of these regions, develop efficient plant breeding tools for the rapid production of climate-adapted plant material, and develop business plans for the case of better plant material in the future.

Major motivation for developing tree-based production systems for the provision of renewable biomass is based on environmental and ecological sustainability considerations, which however often are de-coupled from the trait-based crop improvement programmes. There is therefore a great need to investigate the links between the plant traits, which can effectively increase production, and important ecosystem functions, which determine how environmentally friendly a plantation of fast-growing trees is. An ongoing field trial (ECOLINK-Salix, www.slu.se/ecolink-salix) is presented in which the links between plant traits, genotype diversity and ecosystem processes important for ecological sustainability in willow (Salix) short-rotation plantations are explored.

In conclusion, this contribution will highlight some recent developments in poplar and willow research in the context of the quest for renewable resources especially under the Swedish conditions, and critically discusses the possibilities for poplar and willow plantations to significantly contribute to delivering renewable resources in a future bio-based economy in Sweden.

Key words: Biomass production, ecological sustainability, photoperiod, plant breeding, Populus, Salix. 

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The Poplar Technology Center (PTC), at the Universidad de Talca, Chile, has been dedicated to the genetic selection of new poplar varieties during the last 17 years. Its germplasm collection includes more than 2,500 hybrids, imported from the United States and Europe, which have been assessed in a network of clonal trials distributed in the center and south of Chile (34° - 39° south latitude). Selection objectives have been based mainly on mechanical and physical wood properties, and biomass production. Traditional genetic improvement of poplars can be enhanced by genomics-based breeding technologies.

In that context, and considering the development during the last years of high throughput technologies for sequencing and genotyping, a project is being carried out to support the genomic selection of genotypes suitable for bioenergy purposes. It is expected that poplars contribute as an alternative to the current sources of energy in Chile. Phenotypic information includes traits related to growth (diameter, total height, biomass, etc.) and wood properties (mechanical, physical, and chemical properties). Analyzed populations comprise genotypes representing the following crosses: *Populus trichocarpa* x *P. deltoides*, (*P. trichocarpa* x *P. deltoides*) x *P. deltoides*, (*P. trichocarpa* x *P. deltoides*) x (*P. trichocarpa* x *P. deltoides*), and *P. deltoides* x *P. nigra*. Genotypic data (SNP markers) will be generated by using a genotyping by sequencing approach, in collaboration with Fraunhofer Chile Research Foundation. Results dealing with the phenotypic and genotypic characterization will be presented and discussed during the meeting.

**Key words**: Biomass, genomic-selection, Chile.
MORPHOLOGICAL VARIABILITY OF HAIRY AND TYPICAL EUROPEAN BLACK POPLAR (*POPLUS NIGRA* L.)

Davorin Kajba¹, Dalibor Ballian², Marilena Idžojtić¹, Igor Poljak¹ and Ivan Andrić¹

The aim of investigation was to determine the morphological differences between the hairy type of European black poplar (*Populus nigra* subsp. *caudina*) and the typical type from the riparian forests populations as well as between the river systems. Hairy black poplar spreads in a mosaic pattern across the Submediterranean climatic type along the River Neretva and the typical European black poplar is growing on alluvial soils along large rivers in the territory of Croatia and Bosnia and Herzegovina. Samples for leaf morphometric analysis were collected in 17 natural populations of European black poplar along six rivers in Croatia and Bosnia and Herzegovina.

Discriminant analyses have determined that in the differentiation of population groups largely contribute some characters such as the distance between the leaf widest part and the leaf base (DBW) and the petiole length (PL). The differences between populations and analyzed groups, as well as the differences between populations belonging to a particular river system, were confirmed for all studied characteristics.

Significant differences have been determined between the typical and the hairy type of European black poplar in the studied morphological traits and these dissimilarities are in accordance with the climatic differences in respective habitats of continental riparian forests and the Submediterranean type of climate. Populations sampled in the lower course of the River Neretva, which correspond to the hairy type of the European black poplar, have smaller leaves and a greater angle between the first lower lateral vein and the midrib.

**Key words:** Leaf morphological traits, European black poplar, *Populus nigra* subsp. *Caudina*, genetic variability.

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REGISTRATION OF *POPULUS* AND *SALIX* CULTIVARS

Yulia A. Kuzovkina¹ and Lorenzo Vietto²

The exploration of poplar and willow germplasm has resulted in selection or breeding of many genotypes that could be successfully applied for various economic purposes. The extent and importance of modern *Salicaceae* culture for many countries is manifested by the fact that there are about 60 active poplar and willow breeding programmes worldwide. The ongoing programmes provide a continued and regular release of superior cultivars that meet new challenges. As selection and hybridization within *Populus* and *Salix* continue to expand and new cultivars are entering into commercial production, their clear and standardized records are important multi-national goals.

The International Poplar Commission (IPC) holds the International Cultivar Registration Authority (ICRA) for poplars and maintains the International Register of *Populus* Cultivars (IRPC). The first edition of IRPC was published in 1992 and included more than 300 cultivars. Some additional cultivars were included into a reissue of the Register in May 2000, and an updated comprehensive new edition of the Register is produced in 2016 for the 25th Session of the IPC in Berlin, Germany.

In 2013 the IPC was appointed as the ICRA for willows, and compilation of the *Salix* Cultivars Checklist, which included 700 cultivars, was completed in 2015. The new registration protocol for *Salix* cultivars will be established at the 25th Session of the IPC.

Effective outreach efforts to all involved in cultivar development are required to facilitate comprehensive compilation of international records. These important initiatives will contribute to the nomenclatural stability of cultivated poplars and willows. Therefore, the urgent goal is to raise awareness among breeders of the importance to establish the new poplar and willow cultivar epithets following the rules of the Cultivated Plant Code and of their registration through the ICRAs. While the ICRA system is international in its scope, its success depends upon the assistance of all those involved with the creation of new selections. An integrated approach to networking with breeders and outreach to all organizations involved in domestication programmes are fundamental for development of an international database and its effective adoption for domestication programmes and scientific research.

**Key words:** *Populus*, *Salix*, International Poplar Commission, International Cultivar Registration Authority, International Register of *Populus* Cultivars, *Salix* Cultivars Checklist.

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DEVELOPMENT AND REGISTRATION OF NEW LATVIAN *SALIX DASYCLADOS* AND *POPULUS x WOOSTI* CLONES FOR MULTIFUNCTIONAL USE

Dagnija Lazdina¹, Martins Zeps¹, Ilze Veinberga¹, Agnese Gailite¹ and Dainis Rungis¹

Salix species are fast-growing trees or shrubs which readily hybridise, and are easily vegetatively propagated via root cuttings because of the high auxin content in willow bark, making these species suitable for rapid breeding processes. Poplars, like willows, can also be efficiently vegetatively propagated and utilised in breeding programmes. Many clones have been selected in breeding programmes, but only some of them are actively used for biomass and timber production. Many of them are protected by plant variety rights, which increases their price and makes them less attractive to customers. Local germplasm is already adapted to the climatic and other growing conditions within a region or country, and therefore crosses between selected local and highly productive introduced clones could improve the productivity of local germplasm, while also retaining locally adapted traits. On the other hand, demand for raw material, harvesting and processing technologies is rapidly changing, and in recent years, the ecosystem services provided by tree plantations are increasingly valued, influencing the selection parameters used in breeding programmes.

Researchers at the Latvian State Forest Research Institute Silava have identified local willow germplasm for multifunctional utilization, which would be advantageous for commercialisation in the limited market in Latvia and the Baltic states. Two clones of *Salix burjatica* Nasarow – Visvaldis (male, registration no. 20133297) and Monika (female, registration no. 20130683) were selected from roadside ditches, pre-tested and registered in the Community Plant Variety Office (CPVO). Both clones have high rooting capacity, bright decorative shoots, very good regrowth after harvesting, their flowers are attractive to bees and other pollinators, and the twigs could be used for furniture making and other handicrafts. Both clones have medium yield and are suitable for mechanized harvesting with “Bioballer type” machines.

The hybrid poplar clone *Populus x woobstii* (R. I. Schröd. ex Regel) Dode (registration no. 20142267) was initially planted in Latvia at the end of the last century and had good growth results (4.2–9.8 t of dry matter per year in both forest and agricultural conditions), and was approved as forest reproductive material in Latvia and registered in the CPVO, and tested for homogeneity.

The willow and poplar clones have been genetically fingerprinted using simple sequence repeat (SSR) markers in the LSFRI Silava Genetic Resource Centre laboratory to enable rapid and unambiguous identification of these clones.

Research activities were supported by three European Rural Development Fund projects “Elaboration of models for establishment and management of multifunctional plantations of short-rotation energy crops and deciduous trees”, “Developing the methods of plantation cultivation of fast-growing forest crops and evaluating the suitability of their wood for pelletizing” and “Elaboration of technologies of fast-growing tree species vegetative propagated clones identification”.

**Key words:** Clone, breeder rights, Poplar, willow.

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Genetic engineering has been progressing at a steady pace for the past several decades in tree species. Initially, recombinant genes were recruited from bacteria, animals and plants for genetic transformation. Gene transfer was, and still is, mediated by Agrobacterium or by biolistic methods in plants. The first wave involved transfer of reporter genes for detecting their integration and expression in transgenic plants. The second wave of transgenic plants carried economically important genes coding for herbicide tolerance, pest resistance, stress and drought resistance, salt tolerance, freeze tolerance, and flowering control. Subsequently, a number of genetically-modified agricultural crops and tree species with several useful traits have undergone confined field trials, and some of them have been commercialized worldwide. Although relatively stable transgene expression has been reported in a number of plant species, including trees, there were also unintended unstable events in transgenic plants. This was very likely due to the fact that transgene integration achieved by the two traditional methods of gene transfer, involving Agrobacterium and biolistic approaches, in plants is random and one or multiple copies of the transgene may be integrated at one or several locations in the genome.

In order to overcome the problem of transgene integration randomness, site-specific transgene integration strategies involving genome editing have been experimentally tested in plants, including trees. These new gene editing techniques, involving zinc finger nucleases (ZFNs), transcription activator-like nucleases (TALENs), and, more recently, clustered regularly interspaced short palindromic repeats (CRISPR/Cas9) system, offer prospects for not only stable transgene integration and expression in the transgenic plants, but also their potential for activating/editing native genes for herbicide tolerance, pest resistance, increased yield and biomass, and other useful traits in plants/trees. Such innovations will pave the way for next generation biotech trees to be less regulated by federal oversight, as these novel genotypes will be, more or less, substantially equivalent to genetically-unmodified trees. In order to broaden the potentialities of transgenic plants, biotechnologists have explored other useful avenues for their utility in green economies. With finite reserves of fossil fuel reserves and climate change, and growing demand for fuels for energy, plastics, and pharmaceuticals, transgenic plants have been used as production platforms for these commodities. This paper is an overview of transgenic tree plantations undergoing confined field trials before their commercial deployment, and the next generation of biotech trees, particularly short-rotation trees, which can serve as bio-factories for bio-fuels, bio-plastics, and other useful bio-products to meet human demands in the future.

**Key words:** Tree biotechnology, genetic transformation, genome editing, transgene stability, genetically-modified trees, bio-fuels, bio-plastics.

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COMPARISON OF GROWTH BEHAVIOR OF *POPULUS CASPICA* AND THEIR PROGENIES IN NORTH OF IRAN

F. Asadi¹ and H. Mirzaie-Nodoushan²

Destruction of natural habitats and decrement of genetic diversity of *Populus caspica* caused a vast reduction of its regeneration and growth potential in north of Iran. Hence, first, seedling mass production of the species was performed. Then the seedlings were used to check the growing power in comparison with their parents. Ramets of three selected seedlings from 17 parent trees, along with ramets of their parent trees, 1020 ramets in total, were planted in a randomized complete block design with three replications. During growing season of 2013, height growths of the seedlings were measured for six time-periods.

Results showed significant differences in height growth between the time periods, progenies, parental trees, and their interactions. Seedlings of Mazandaran 5, Gilan 3 & 4 and Golestan 3, revealed the best results. In the other hand, Mazandaran 4, Golestan 5 & 6 revealed the lowest results. July and August showed highest height growth. During all of the time periods, progeny height growth was more than that of their parents, so that mean height growth of progenies and parents were 285.1 and 250.4 cm respectively. Also, mean diameter of progenies, 20.9 mm, was significantly more than that of their parents with a value of 18.2 mm. As the main result of this research high performance of seed-born seedlings of *P. caspica* progenies (due to superiority of sexual reproduced seedlings compared to asexual reproduced ones) can be used for reforestation in degraded forests in north part of Iran.

**Key words**: Sexual reproduction, *Populus caspica*, height growth.

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FLOWERING TIME GENES INFLUENCE BIOMASS PRODUCTION IN POPLARS

Tobias Brügmann¹ and Matthias Fladung¹

Flowering time genes are key regulators in plants for the induction of flowering. Since their discovery, pleiotropic functions were also found. With Arabidopsis mutants, it was shown by Melzer et al. (2008) that downregulation of the known flowering genes SOC1 and FUL induce perennial growth and consequently wood formation. Both genes act as transcription factors that induce the transition from vegetative to reproductive meristem identity. In transgenic approaches with two different poplar hybrid lines, corporate impact of SOC1 and FUL onto biomass formation was confirmed. The overexpression of the two Arabidopsis genes led to growth-restricted poplars which lost their intense growth. A simple RNAi knockdown of AtSOC1 and AtFUL in poplar did not lead to altered phenotypic parameters and biomass formation. Recently, a first evidence of early flowering was noticed in these RNAi lines. Due to ancient genome duplication in poplars, three or two paralogs of SOC1 and FUL, respectively, were found in poplars which could be able to absorb the knockdown. Thus, a new multiple target knockout approach concerning all paralogs via CRISPR/Cas9 will be realized.

According to Melzer et al. (2008), the double knockout of SOC1 and FUL should result in an increase of biomass. Trees with increased biomass are of high economic interest serving as feed material for the direct retrieval of energy or of biopolymers in the pulping industry, respectively. Adapted trees can be grown even on set-aside agricultural land what is usually nutrient-poor since trees show a high nutrient-efficiency and it is not necessary to fertilize trees in short rotation plantations.

Five other genes which are expressed in both developing xylem and catkins or developing xylem and roots were examined in both knockdown and overexpression approaches. Interestingly, several noticeable phenotypes with increased biomass formation could be identified. To date, these lines are under investigation to unravel the origin of the growth alterations.

Key words: Poplar, wood formation, biomass, biotechnology, knockdown, meristem identity, CRISPR/Cas.

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BREEDING OF MULTIPURPOSE WILLOWS ON THE BASIS OF SALIX DAPHNOIDES, S. PURPUREA AND S. PENTANDRA

Ben Bubner¹, Volker Schneck¹, Matthias Zander², Jan Gloger² and Christian Ulrichs²

Willows can be planted in an environmental context (e.g. protection of river embankments, early spring nutrient delivery for bees) and in an economic context. Commercial plantations use biomass willows in short rotation coppices (SRC) for fuel production (heating). The clones available for SRC plantations in Europe are based on Salix viminalis and related species. Other potential commercial uses of willows are the extraction of natural salicylic compounds as alternatives to chemically-synthesized acetyl salicylic acid (medical use) and the extraction of natural phenolic compounds from the cortex as alternative to mineral tanning agents (leather production).

In order to provide a wider genetic base, a collection of several hundred wild type genotypes of S. daphnoides, S. purpurea and S. pentandra was used for an extensive crossing and selection programme. Wild type clones and crossings have been selected for several parameters: drought stress resistance as tested in greenhouse experiments with controlled irrigation, salicylate content measured by HPLC, biomass production measured in field trials as shoot length and dry mass, and rust resistance measured by field screenings and in vitro tests. DNA analysis of the willow rusts in stock collections and field trials revealed that S. daphnoides is exclusively infected by specialized fungus Melampsora epitea-typica f. sp. daphnoides. The selection process yielded 48 genotypes that have been planted in three comprehensive field trials. They serve as basis for further investigation in biomass, salicylate and phenolics production.

Key words: Clones, crossings, biomass production, salicylate and phenolics production.

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INVESTIGATION ON GROWTH OF F1 HYBRID SALIX SEEDLINGS IN EXPERIMENTAL FIELD OF KARADJ, IRAN

Mohsen Calagari

Willow species is one of the main trees of valleys, plains and the river margin of the country. It is important for economic (wood production, fodder) and environment applications. The aim of the study was inter- and intra-specific crosses between three willow species and production of new hybrids as well as evaluation and comparison of growth of hybrids and parents. Inter- and intra-specific crosses were performed between crosses of *S. alba x S. alba*, *S. alba x S. excelsa* and *S. alba x S. fragilis*. Artificial pollination was performed on *S. alba* (female) branches isolated. Hybrid seeds were planted in pots containing sand and were kept in greenhouse and then transferred to the field in April 2012.

In the first stage, superior hybrids were selected based on growth characteristics. In the second stage, hybrid seedlings and parents were evaluated by planting cuttings (5 cuttings for each hybrid and parents) in the nursery. Growth traits such as survival percent, collar diameter, height, number branch and stem form measured in the end of growth season. The measurement growth characteristics of hybrids showed that 7 hybrids from *S. alba x S. alba*, 7 hybrids form *S. alba x S. excelsa* and 2 hybrids from *S. alba x S. fragilis* crosses was high diameter and height growth and straight stem form.

Analysis of variance showed there are significant differences (P≤0.01) among hybrid seedlings and parents for growth characteristics. The diameter growth mean of hybrid seedlings that were planted by cuttings showed *S. alba x S. alba* cross with 1.82 and 1.72 cm diameter and 2.08 and 2.04 m height had the highest growth respectively. The four hybrids of *S. alba x S. excelsa* cross with 2.14, 1.14, 2.06 and 2.22 m and one seedling from hybrid of *S. alba x S. fragilis* with 2.1 m had highest height growth compared to the parent. Stem form of superior hybrids was straight. Finally, the superior hybrid seedlings can be evaluated in the next phase of compatibility.

**Key words**: Growth traits, hybrid, seedling, willow.

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GROWTH CHARACTERISTICS OF *POPULUS EUPHRATICA* SEEDLINGS FROM SUPERIOR GENOTYPES IN RESEARCH STATION OF KARADJ

Mohsen Calagari¹, H. Mirzaie Nodoushan and F. Asadi

Because of adaptability to different ecological conditions, cross pollination and heterozygosity, *Populus euphratica* has high genetic diversity. It could have an important role in superior phenotypes selection, inter- and intra-specific hybridization processes. The aim of this study was to identify and select superior phenotypes of *P. euphratica* and seed propagation for new genotypes and also select elite genotypes by evaluation of growth rate and stem form traits.

A total of 29 superior trees from 13 natural stands were selected. Seedlings were produced by seed culture in greenhouse condition. Evaluation of seedlings was performed in a nursery of Karaj Research Station (RIFR) during 2011 to 2013. Quantitative and qualitative characteristics, including plant diameter at 20 cm above ground, height, survival percentage, number of branches, stem form and branch angle with main stem were recorded. Analysis of variance showed significant differences among the seedlings of superior phenotypes with different habitats for quantitative and qualitative characters. Also mean of diameter and height variables showed seedlings of the superior trees with Kerman and Khojir origins with 4.66, 4.51 cm diameter and 4.1, 4 m height had the most growth values respectively. Seedlings of the superior trees with Kerman, Zabol, Khojir and Golestan origins had better quality stem compared to other parent trees.

Overall, some of seedlings had a suitable qualitative and quantitative growth that can be used in next phase study.

**Key words**: Growth parameters, *Populus euphratica*, seedling, superior trees.

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BREEDING WILLOW CLONES FOR BASKET-MAKING IN ARGENTINA.
FIRST RESULTS

Teresa Cerrillo¹

Several species of shrubby willows (*Salix* spp) have been grown for centuries in different countries of the world and their branches have been used for basket-making. In Argentina, basket-willows are planted in the Paraná River Delta, a region with suitable soils and ideal climate conditions for growing willows. Today, these cultivations remain as a very important diversification activity for the smallholders of the region, and the need for new varieties is recognized as one of the main tools to improve the local production. Consequently, to produce a broader diversity of clones for basket-making, a breeding programme was initiated at EEA Paraná Delta-INTA in 2012.

The selection criteria are mainly aimed to produce genotypes with: high rooting percentage; fast growth; resistance/tolerance against pests and diseases; right form of the branches (and without secondary branches) and suitable characteristics for basket-making. Since 2012 the first phases of the programme have been carried out by controlled hybridization, using cultivars of the species *Salix viminalis*, *Salix fragilis* and *Salix caprea* as parental genotypes. Currently, the programme is at initial-consolidated stage with approximately 300 new genotypes in different selection phases. These are described, along with the practical crossing technique and selection procedures used in the breeding cycle.

After the first evaluations, in 2015, there are 20 genotypes in the most advanced phase, all those derived from *Salix viminalis*; seven of them are being pre-selected because of their outstanding preliminary performance. These pre-selected ‘potential clones’ will be tested in field trials in the next step, in order to evaluate the productivity.

**Key words:** Basket-willows, improvement, clones, smallholders, Paraná River Delta.

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FROM A CONE INTO THE PETRI DISH AND TO THE FIELD: ABOUT THE UNUSUAL TRIP OF AN IMMATURE SEED

María del Carmen Dacasa Rüdinger\textsuperscript{1}, Marianne Kadolsky\textsuperscript{1}, Wolfgang Hüller\textsuperscript{1}, Heino Wolf\textsuperscript{1}, Anna Kraft\textsuperscript{2} and Kurt Zoglauer\textsuperscript{2}

Vegetative propagation of plant material by means of somatic embryogenesis permits the establishment of clones for tree species where propagation via softwood or hardwood cuttings is impossible or inefficient. Forest breeding employs this technic to provide large amounts of high valued plant material derived from selected basic material to afforestation projects. A good example is the breeding work of the public enterprise Sachsenforst with hybrid Larch done in cooperation with the Humboldt University of Berlin in the joint research project ‘DendroMax’.

Seed of hybrid Larch is obtained from controlled crosses performed by Sachsenforst between selected family parents of European and Japanese Larch. The immature seed is provided to the Humboldt University of Berlin. Immature zygotic embryos are excised from the seeds and placed on Petri dishes with nutrient medium. After eight to ten weeks, embryogenic callus consisting of somatic embryos develops. A part of the embryogenic mass is cryopreserved for future use. The remaining mass is placed on specific media for its maturation and germination. Seedlings are then sent to Sachsenforst for their acclimatization in the greenhouse and further cultivation outdoor until they reach the targeted conditions for being planted in the field. Part of this plant material has been used for reforesting 1,2 ha in the forest district of Leipzig during spring 2015. A total of 69 hybrid Larch clones from six full sib families á 18 ramets has been planted at a spacing of 3 x 3 m. This stand shall serve later as a cover for beech. For this, rows of larch will be removed two to three decades after setting the stand and the beech seedlings will be planted between rows. The superior quality of the planted Larch should contribute to higher returns from the thinning as obtained with standard material.

The successful establishment of a Larch stand with clonal material derived from immature seeds via somatic embryogenesis shows the potential of this technic to support the breeding work with species that do not propagate well from cuttings and provide reforestation activities with plant material of high quality.

Key words: Hybrid Larch, somatic embryogenesis, reforestation.

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FAST-GROWING POPLARS IN THE NORTH OF EUROPEAN RUSSIA

Natalia Demidova

Poplar, as one of the most fast-growing species of the boreal and temperate climate zones, is widely used for plantation cultivation worldwide. Poplar and aspen timber is a valuable raw material for the pulp and paper industry, furniture and plywood production. Poplars are used for the restoration of degraded lands, forest landscapes, and climate change mitigation. Currently poplars become more in-demand for growing bioenergy plantations for biofuel production. The trembling poplar or aspen (Populus tremula L.) is the only poplar species growing naturally in the North of European Russia. But one of the major disadvantages of aspen is that, by the age of maturity, it is massively damaged by heart rot caused by false aspen polypore (Phellinus tremulae (Bond.) Bond. Et. Boriss.), which greatly reduces the wood quality. Growing of poplar plantations has not been studied in the North of European Russia, although it is of certain interest since the pulp and paper companies have already faced the problem of raw material supply. Any attempts to create poplar plantations in the conditions of the North of European Russia have not been undertaken yet.

Studies on the poplars introduction have been held in the Northern Research Institute of Forestry since 1969, and testing clonal progeny of the best species and hybrids since 1989. For this purpose, we have introduced 16 poplar taxa. Promising poplars taxa in terms of resistance, growth and productivity were selected; those can be successfully used for the cultivation on plantation. The Neva poplar (P. × newesis Bogd.) and the trichocarpa poplar (P. trichocarpa Torr.et Gray) are offered for this purpose according to our research.

The growth course study of the introduced poplars, determination of quantitative ripeness of timber and cutting age of poplar plantations in the conditions of the North of European Russia were carried out for the first time.

The analysis of tree growth of the P. × newesis model trees showed that the diameter of the intense growth starts at the age of 10. The intensive growth in height occurs between the ages of 10 to 20 years. The intensive growth in diameter and height of the P. trichocarpa occurs between the ages of 10 to 15 years. The maximum percentage of the diameter growth (of Pd, %), either the P. × newesis (28,9-33,75%), or the P. trichocarpa (32.9%) occurs in the age of 10 years. The greatest current increment in volume for the P. × newesis is marked at the age of 25 years, and for the P. trichocarpa at the age of 20 years.

The average height of the P. × newesis under the conditions of the North of European Russia at the age of 23 years is 19.1 m, the average diameter 19.4 cm, the average timber volume of this hybrid is 342.2 m³/ha. The P. trichocarpa is slightly inferior in growth: the average height (18.1 m), the average diameter (18.5 cm), the average volume is 230.4 m³/ha.

Key words: Poplar, plantations, North of European Russia.

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GENOME-WIDE ANALYSIS OF MICRO-RNA RESPONSES TO THE PHYTOHORMONE ABSCISIC ACID IN POPULUS EUPHRATICA

Hui Duan1, Xin Lu, Conglong Lian, Yi An, Weilun Yin and Xinli Xia

MicroRNA (miRNA) is a type of noncoding small RNA with a regulatory function at the post-transcriptional level in plant growth development and in response to abiotic stress. Previous studies have not reported on miRNAs responses to the phytohormone abscisic acid (ABA) at a genome-wide level in Populus euphratica, a model tree for studying abiotic stress responses in woody plants. Here we analyzed the miRNA response to ABA at a genome-wide level in P. euphratica utilizing high-throughput sequencing.

To systematically perform a genome-wide analysis of ABA-responsive miRNAs in P. euphratica, nine sRNA libraries derived from three groups (control, treated with ABA for 1 day and treated with ABA for 4 days) were constructed. Each group included three libraries from three individual plantlets as biological replicate. In total, 151 unique mature sequences belonging to 75 conserved miRNA families were identified, and 94 unique sequences were determined to be novel miRNAs, including 56 miRNAs with miRNA sequences. In all, 31 conserved miRNAs and 31 novel miRNAs response to ABA significantly differed among the groups. In addition, 4132 target genes were predicted for the conserved and novel miRNAs. Confirmed by real-time qPCR, expression changes of microRNAs are inversely correlated with the expression profiles of their putative targets. The Populus special or novel miRNA-target interactions were predicted might be involved in some biological process related stress tolerance. Our analysis provides a comprehensive view of how P. euphratica miRNA respond to ABA, and moreover, different temporal dynamics were observed in different ABA-treated libraries.

Keyword: Populus euphratica, ABA, microRNA, high-throughput sequencing, target.

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PROTOPLAST FUSION BASED ON BREEDING OF STERILE POLYPLOIDS IN VARIOUS POPLAR SPECIES

Nadia Efremova1, Peter Welters1 and Guido Jach1

Triploid (3n) poplar plants are known to produce long fibers and more biomass offering potential advantages for bioenergy production and/or the paper industry. In fact, many types of polyploids are sterile and some are showing faster growth. Within the community, current efforts to gain triploid poplars are focused on selecting rare natural triploids or generation of triploids via crosses between diploid (2n) and tetraploid (4n) clones, whereby tetraploids are usually induced using chemical mitotic inhibitors such as colchicine or dinitroanilines.

Phytowelt Green Technologies established protoplast electrofusion as an efficient alternative to the mitotic polyploidization in poplar. The electrofusion of protoplasts followed by regeneration of plants may prove to be a beneficial procedure, because formation of mixoploids (plants having cells with different numbers of chromosomes) is rare.

We developed appropriate protocols for electrofusion and regeneration of protoplasts in seven different poplar species (P. alba, P. tremula, P. tremula x tremuloides, P. x canescens, P. nigra, P. trichocarpa x deltoides and P. nigra x maximowicii). Using this approach, tetraploid and triploid fusion lines were obtained and characterized by flow cytometry analysis.

Phytowelt Green Technologies conducted three field trials of selected polyploids interplanted with diploid parental lines. The plants were propagated for the field trials from in vitro cultured shoots (in 2013 and 2014) and through wood cuttings (in 2016). Stability and reversions of polyploids to diploids were monitored by flow cytometry. Phenotypic analysis showed that some lines exhibited significantly stronger growth as compared to the parental clones. While tetraploids are potentially very promising material for breeding work, triploid lines could be directly used for biomass production.

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**Key words:** Poplar clones, polyploidy, tetraploid, triploid, protoplast electrofusion, breeding.
IMPROVEMENT OF THE INDUCIBLE ACTIVATION TAGGING Ac/Ds TRANSPOSON SYSTEM BY EMPLOYING THE POSITIVE SELECTION MARKER TMS2

Matthias Fladung¹

So far, only very few naturally available tree mutants are known, most of them are showing alterations in the tree habitus (e.g. dwarf, columnar, pendula mutants) and/or variations in leaf form/shape/color (e.g. lanceolate, brevifolia, and pale green leaf mutants). In preceding work, the fundamentals for transposon (Ac-Ds from maize)-based activation tagging in a tree species (Populus spec.) were developed. Proof-of-concept for using the two component systems ATDs to generate poplar mutants was provided by employing the phenotypic selectable marker gene rolC from Agrobacterium rhizogenes. Excision of the ATDs fragment was verified by large-scale PCR experiments, however, only a small percentage of the regenerated poplar plants revealed to be positively transposed.

To improve the in vitro selection system, we have tested the positive selectable marker gene tms2 from Agrobacterium tumefaciens. The idea behind is that non-ATDs transposed poplar cells (still expressing the tms2 gene) metabolize naphthalenacetamid (NAM) to active IAA leading to callus formation instead of plant regeneration. Thus, only ATDs positively transposed lines regenerate to plants.

We have produced 17 double transgenic lines harboring the ATDs-tms2 gene construct. Using these lines, we initiated three independent transposon tagging experiments to induce ATDs transposition. We treated 72,042 (heat-shock 1), 24,040 (heat-shock 2) and 1,344,782 (heat-shock 3) micro explants and obtained in total 538 putative new activation tagged variants for heat-shock 1 and 2. For heat-shock 3, 1,384 putative new activation tagged variants were obtained. A forth heat-shock experiment with the two lines N232-1 and N229-10 HS is in preparation.

All the putative variant lines will be analyzed molecularly mainly by PCR and phenotyped after transfer to greenhouse. To understand the molecular basis behind the mutation, the insertion locus of the AT-Ds element will be determined.

Key words: Gain of function, mutagenesis, transposition, jumping gene, functional genomics.

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Under the scenario of a rapid ongoing climate change as well as a steadily growing world population, there are strong requirements for long-term conservation of healthy forests and to ensure availability of wood also in future. One possibility to meet these requirements is to improve trees with respect to growth and biomass production, abiotic and/or biotic tolerance/resistance, and quality parameters for use in both forests and tree plantations.

Biomass production can be increased by modification of tree architecture or by altering photosynthesis and photorespiration. Determinants of productivity are, among others, large leaves, sylleptic branching, narrow crown architecture, adopted activity of stomata, and a compact root system. Improved trees could show tolerances towards desiccation, anaerobic conditions and to high temperatures, and resistances to insect damage and diseases. To also ensure wood as a future resource of raw material for both material and energetic uses, wood quality as well wood composition could be changed with respect to the further use. For instance, for material uses, the structure of wood might be changed to increase wood density to make wood harder. On the other side, to use wood as raw material in green economies, trees could reveal changed lignin and cellulose composition.

Forest trees can be optimized genetically via classical breeding. However, even when some breeding progress has been made with poplar, willow, and pine species, forest tree “cultivars” can still be considered as nearly “wild plants” with little if any of the hallmarks of crop domestication. Breeding in trees is much more time consuming than in annual plants.

By applying bio- and gene technological methods or by novel molecular breeding methods, tree breeding can be accelerated significantly. For many tree species, e.g. poplars, spruces, pines and eucalyptus, tissue as well as gene technological methods have successfully been established. A range of targets are of interest for genetic engineering in trees, e.g. lignin and/or cellulose modification, pest resistance, and tolerance to abiotic stresses. Another application of gene technology to accelerate tree breeding is the use of early flowering genes. In poplar for instance, the non-reproductive phase, usually seven to ten years, could be shortened to six to ten months. Molecular breeding methods comprise approaches to correlate the phenotype with molecular markers for a marker assisted breeding (MAS) and to use the novel breeding technologies like cisgenesis, oligo-directed mutagenesis (ODM), and site-directed nucleases (SDN) (e.g. the CRISPR/Cas9 system).

**Key words:** Tree breeding, climate change, flowering-time gene, CRISPR/Cas, molecular marker, biomass, plantation.

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PRODUCTION OF NEW CLONES OF ‘CRICKET BAT WILLOW’ (*SALIX ALBA*) FOR FAST GROWTH AND QUALITY TIMBER

S. A. Gangoo, P. A. Paray, T. H. Masoodi and P. A. Sofi

*Salix alba* is known world wide for the production of cricket bats. This species has been introduced in Kashmir valley from England by Sir Abey during 1920 for the production of fuel wood. Since quality timber fetches good prices, it began to be graded for production of blades for cricket bats, timber for fruit boxes and veneer for plywood. A cricket bat is a specialized piece of equipment used by a bats man in the sport of cricket to hit the ball typically consisting of cane handle attached to a flat-fronted willow wood blade. The length of the bat should be no more than 38 inches (965 mm) and the width no more than 4.25 inches (108 mm). Good quality ‘cricket bat’ timber is exclusively supplied by J. S. Wright and Sons in England. Kashmir cricket bats are considered inferior because of inferior quality of timber used. In this study, new clones have started to be produced for production of quality timber.

One hundred female candidate plus trees (CPTs) were selected throughout the valley. Both stem cuttings and seeds were collected from these CPTs and grown in nursery. Maturity indices of willow seed were studied. Obtaining clean seed from catkin and the associated floss was standardized. Progeny trial of ‘open pollinated families’ was laid. Seed germination was studied. Maximum height of plants obtained was 113.2 cm for CPT26 after one season growth. This CPT has maximum value for leaf characteristics, i.e. leaf length of 11.5 mm and leaf width of 1.89 mm. Mean seed weigh was determined as 86.1mg/100 seeds with maximum value of 18.5 mg/100 seeds. Seedlings obtained an average height of 23.7 cm in one growing season. Variance, coefficient of variation and genetic parameters viz. heritability, genetic advance and genetic gain has been calculated for all the traits. ‘Within family selection’ was practiced for selection of better seedlings. These seedlings were analysed for various genetic characters viz. height, collar diameter, leaf dimensions and branch angle.

These seedlings will be planted in the field and their growth will be studied with the objective of mass production of fast-growing ortets and quality timber for cricket bats.

**Key words:** Willow, *Salix alba*, cricket bat, progeny trial, maturity indices.

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REPRODUCTION OF POPULUS INTERSECTIONAL HYBRIDS BY MEANS OF OVULE MICROCULTURES

Abbas Ghamari Zare¹, Maeysam An Sari¹, Lila Mirjani¹, Narjes Vahidi², Mohsen Kalagari³, Rafatolla Ghasemi³ and Alireza Modirrahmati³

Iran is located in the central natural range of Populus euphratica Olivier, the most well-known and widely distributed of section Turanga Bunge in Eurasia and Africa. This species can tolerate hot and cold temperature, arid, saline conditions, water logging, sandstorms and high radiation. It found from sea level on river bank, on sand desert up to 2300 meter height on Alborz Mountains in Iran.

This species is a promising parent in hybridization programmes of which the objective is to create tolerance to high solar radiation, heat and soil salinity. But its trunk is not suitable for industry. One of the most distinctive poplars, P. alba from section Populus, is widely distributed over northern Africa, southern Europe and west and central Asia. It has very straight and cylindrical trunk and has long been considered a superior for timber in Iran, too. Colons of the latest species in comparison to P. euphratica do not tolerate water and soil salinity and alkalinity. The combination of complementary characters of both species in a single genotype could extend timberland into salinity and alkalinity environmental conditions. The hybridization is a barrier for this aim, because of its difficulties. The embryo rescue and ovule microcultures coped to hybrid seedling production of many crosses between four colons of P. alba from five provenances of P. euphratica, in Iran.

The initial results, also, indicated tolerance to water and soil salinity and alkalinity, heresies and maternal effects. The researchers are going to introduce a few high-yielding hybrid colons with tolerance to saline conditions.

Key words: Inter-specific hybridization, populus intersectional hybrid, embryo rescue and embryo culture.

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WOOD QUALITY ASSESSMENT OF CLONES OF *POPULUS DELTOIDES* DEVELOPED BY THE FOREST RESEARCH INSTITUTE, INDIA, THROUGH CLOSED AND OPEN POLLINATION

Sangeeta Gupta and Raman Nautiyal

*Populus deltoides* has firmly established itself as the most preferred plantation species, especially in the northern India. Lot of work is going on regarding tree improvement of this species. The Forest Research Institute (FRI), India, under its tree improvement programme, has carried out breeding programmes and has developed various clones of *Populus deltoides* through open and closed pollination.

The FRI Silviculture Division raised seedlings from the seeds of 19 open-pollinated and 24 control pollinated families. Best individuals of each family were cloned after one and a half year of age. The clones were repeatedly tested in nursery. The best 95 clones of open pollination and 74 clones of control pollination have been assembled in a germplasm bank at FRI campus for further multiplication and field evaluation. All these clones were studied for their wood quality with the objective of screening better clones. Specific gravity, fibre and vessel characteristics were evaluated.

Statistical analysis was carried out for establishing variation in between and within the families and in between clones of the open-pollinated and closed-pollinated families. Multivariate analysis showed that fibre length (FL), lumen diameter (LD), fibre wall thickness (WT) and vessel length (VL) were significantly different between the families but non significant differences were found within the family of one year ramets indicating heritability even at juvenile stage.

In closed pollinated families FL, LD, WT and VL varied significantly between the 24 families and between the clones, while within a family the variation was not significant. FD varied non-significantly in between and within the families. However, it significantly varied between the clones. Specific gravity ranged from 0.293 to 0.580. Post hoc tests revealed the cluster of families that differed significantly. Based on student Newman–Keuls test (as the number of observations differed in each of the clone) for 24 families, two clusters were identified. Post hoc tests were also performed to find out subsets of the clones that differed significantly. Based on student Newman–Keuls test for 74 clones, eight clusters were identified.

In open–pollinated families FL, FD, LD, WT and VL varied significantly in between the 19 families and between the clones. However, within a family the variation was both significant and non significant for different families. Specific gravity ranged from 0.335 to 0.485. Post hoc tests revealed five clusters of 19 families and 32 clusters of 95 clones that differed significantly.

**Key words**: Poplar, open pollinated, closed pollinated, FRI.

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FAST BREEDING OF POPLARS AND OTHER TREE SPECIES: FUTURE PROSPECTS AND BIOSAFETY CONCERNS

Hans Hoenicka

Global warming and the ongoing worldwide spread of plagues and diseases represent a threat for many tree species. The proliferation of international transportation is breaking down biogeographical boundaries. The effective collapse of world ecological barriers is a phenomenon, as far as we know, without precedent in the entire history of life.

The development of efficient breeding strategies is a straightforward way to counteract the increasing number of problems related to forest tree species. Recently, we developed an early flowering system, based on genetic transformation with the gene AtFT, which allows us crossings with six-month-old poplar plants. This system can be employed in breeding programmes as established for annual plants (high-speed breeding technology) as well as for research purposes (genomic and biosafety research).

However, there are still concerns towards transgenic plants in general. The Cartagena Protocol on Biosafety, based on the precautionary principle, has been ratified by many countries. This protocol aims at ensuring an adequate level of protection of native ecosystems through the safe transfer, handling and use of organisms resulting from modern biotechnology.

Until now, the broad use of genetic modified plants is limited to a relatively few number of countries due to biosafety concerns. Therefore, the widespread use of transgenic early flowering systems for tree breeding should ideally require the elimination of transgenes from plants before release. In accordance with Mendelian inheritance, we showed that transgene elimination can take place after crossings in 50% of the offspring. Fast breeding under controlled conditions (biosafety level 1) and the selection of transgene-free plants once the breeding process is concluded offer a very attractive alternative breeding strategy for trees even under very restrictive biosafety regulations.

Key words: Poplar breeding, early flowering, biosafety.

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AN EARLY FLOWERING SYSTEM ALLOWS RELIABLE INDUCTION OF FERTILE FLOWERS AND CROSSINGS IN JUVENILE POPLAR

Hans Hoenicka¹, Denise Lehnhardt¹, Valentina Briones¹,², Ove Nilsson³ and Matthias Fladung¹

Forest tree species reach reproductive maturity only after many years or even decades of juvenile growth. Early flowering clones have been obtained for only few forest tree species so far. Special treatments, based on plant hormones, growth inhibitors, the manipulation of growth environment or physical methods, have promoted flower development in juvenile plants from several forest tree species but not in poplar. Only genetic engineering with ‘flowering-relevant genes’ has allowed early flowering to be induced in juvenile poplar plants.

Until now, early flowering approaches led almost exclusively to the development of sterile flowers in poplar. In this study, several strategies aiming at inducting fertile flowers in pHSP::AtFT-transgenic poplar were tested, in particular the influence of temperature and photoperiod. Our results provide evidence that temperature, and not photoperiod, is the key factor required for development of fertile flowers in early flowering poplar. Fertile flowers were only obtained when a cold treatment phase of several weeks was applied after the heat treatment phase. Heat treatments induce AtFT gene activity through activation of the heat-shock promoter (pHSP). Photoperiod did not reveal a strong influence on flower fertility as pollen grains were obtained under both long- and short-day conditions. Fertility was confirmed in flowers of both male and female plants. For the first time, crosses were successfully performed with female transgenic early flowering poplar lines. All mature flowers obtained after eight weeks of inductive treatments were fertile. Gene expression studies also confirmed that low temperatures influence the expression of poplar genes homologous to “pollen development genes” from Arabidopsis thaliana. Homology and expression patterns suggested a role for PtTDF1, PtBAM1, PtSERK1/2, and PtMS1 on anther and pollen development in poplar flowers.

The approach developed in this study allows a fast and reliable induction of fertile male and female poplar flowers in a very short period of time. The non-reproductive phase, usually seven to ten years, can now be shortened to six to ten months, and fertile flowers can be obtained independently of the season.

Key words: Poplar breeding, early flowering, fertility.

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GENETIC IMPROVEMENT OF POPLAR AND PROSPECTS FOR POPLAR CULTIVATION IN GERMANY

Martin Hofmann¹ and Alwin Janßen²

Many poplar cultivars were tested in Germany since the early 1960s. Clone comparison tests during the early phase of development by observing them in nurseries were made as well as test plantations on different sites. The sections suitable for planting in Europe, i.e. Aigeiros, Leuce and Tacamahaca, are jointly compared and evaluated contrary.

Italian cultivars show the best growth among black poplars. Their cultivation can, however, be recommended in Germany only with reservations due to climatic conditions. In most cases they do not perform well in Short Rotation Coppice (SRC). The typical black poplar soils in riverine regions are high productive for cultivating cash crops and are not available for poplar plantations in a larger scale. In contrast to P. canadensis clones, the full advantage of Balsam poplar hybrids and Aspen seems to be on sites outside the riverine locations. Their adaptability to heavy, fine textured soils is proofed. This is a frequent experience with Balsam poplars and Aspen. Their superiority as compared with P. canadensis clones especially on such soils is most striking.

The joint research project FastWOOD focuses at breeding fast-growing tree species for the production of renewable resources in short rotation coppices. Selecting poplars and willows, and respectively breeding high-yielding varieties with high resistance to biotic and abiotic stress was done. The main results are presented. Yet the area of SRC poplar stagnates more or less since recent years. Perspectives for growing Balsam poplar hybrids and Aspen are seen on forest sites in mixture or to initiate reforestation after windthrow calamities, and several other forest purposes.

The presentation addresses following questions:

- Which cultivars may be recommended due to the site-suitability and may be planted successfully in view of the evaluation of their growth and their resistance?
- Which yield can be expected from poplar stands?
- Which kind of poplar culture is promising in the future?
- Can new breeds with outstanding height and diameter growth in SRC test plots perform in longer rotation periods as well?
- What are the consequences of the results obtained with respect to breeding of new poplar cultivars?

Key words: Poplar, breeding, yield, clones, short rotation coppice, silviculture.

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SSR BASED DNA FINGERPRINTING AND GENETIC DIVERSITY ANALYSIS OF 92 POPLAR CULTIVARS IN CHINA

Pei Sun, Huixia Jia and Jianjun Hu

There are more than 100 poplar clones, mostly from Populus nigra and P. deltoides, used in the poplar plantation and breeding programmes in China. Accurate identification and estimation of genetic diversity of these poplar cultivars are necessary not only for poplar commercial plantation but also for future breeding programmes. DNA markers are very useful to fingerprint and assess genetic diversity of poplar clones, which is important in poplar conservation and breeding programmes.

In this study, 18 pairs of Simple Sequence Repeat (SSR) primers that showed stable amplification and had multiple alleles were selected to construct the fingerprinting map and analyze the genetic diversity of 92 cultivars. A total of 128 alleles were obtained from 18 loci, with a mean of 12.4 per locus, indicating a high genetic diversity among the accessions. The polymorphic information content (PIC) and power of discrimination (PD) value ranged from 0.092 to 0.890 and 0.103 to 0.947, with averages of 0.702 and 0.812, respectively. DNA fingerprints of the 92 cultivars were obtained with these SSRs, and five SSR markers could efficiently distinguish these cultivars.

To characterize the genetic diversity among these 92 cultivars, phylogenetic analysis was performed based on the Jaccard’s similarities; 92 cultivars were divided into four groups that were in accordance with section classification of Populus, but three cultivars (P. simonii var. fastigiata, P. cathayana, P. simoni var ‘Huilin88’) from Tacamahaca and one (P. tremula) from Leuce were clustered within Aigeiros, and three Aigeiros cultivars (P. deltoides var. monilifera, P. nigra var italic, P. × deltoides cl. ‘San Martino’) were classified together within Tacamahaca. Furthermore, we found that seven cultivars gained three polymorphic loci patterns at several loci, implying these cultivars may be triploids. Flow cytometry detection of these seven cultivars further verified the occurrence of triploid.

Therefore, this study provides a valuable genetic information for the identification and the intellectual property rights protection of breeders for poplar cultivars. Meanwhile, the genetic relationships of these cultivars could be used in design of poplar breeding programme.

Key words: Populus, SSR, DNA fingerprinting, genetic diversity, flow cytometry.

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CULTIVATION OF FAST-GROWING HYBRID LARCH (LARIX x EUROLEPIS) DERIVED FROM SOMATIC EMBRYOGENESIS

Marianne Kadolsky¹ and Heino Wolf¹

In a joint research project, the public enterprise Sachsenforst and the Institute for Botany of the Humboldt University of Berlin are working on the propagation of hybrid larch by somatic embryogenesis for large-scale production. Hybrid larches have shown heterosis in growth, stem form and wood mechanical properties as compared to the parental plants. By using qualitatively high value plant material, new efficient and robust varieties could provide additional resources for wood production and bring higher earnings within relative short-rotation periods. But difficulties in traditional seed production due to the biology of the species Larix could make the use of biotechnological methods worthwhile. In Sachsenforst, we investigated the post vitro behaviour of hybrid larch derived from somatic embryogenesis.

Selected plus trees from the long-term breeding programme of Sachsenforst comprising 5 family parents were used for 20 controlled crossings. The immature seeds were supplied to Humboldt-University as starting material for somatic embryogenesis. The emblings were returned to Sachsenforst for acclimatisation and further cultivation. For acclimatisation in a greenhouse with computer-controlled atmosphere the emblings were sorted to quality and transplanted into Jiffy peat pellets. After acclimatisation, the young plants were potted into Quickpot plates of different sizes and transferred to the outdoor area. At the end of the vegetation period the plant height was measured. The following year in spring they were planted on several forest plots for demonstration purposes together with zygotic seedlings as control.

342 somatic embryo producing genotypes were established. More than 12.000 emblings were put into acclimatisation, resulting in 9.900 young plants. Depending on the quality stage the acclimatisation success was 98% and 69% respectively, with an average of 79%. The plant height at the end of the vegetation period varied between the clones and was positively influenced by the size of the Quickpot plates. 30 weeks after planting the over all average height was 35 cm. Phenotypic aberrations were nearly absent.

Somatic embryogenesis proved to be a suitable method for mass propagation of hybrid larch in a relatively short time. All steps of the basic process could be performed with good success: Controlled crossings, induction of somatic embryogenesis in a broad spectrum of genotypes, production of up to several hundred plants per genotype, acclimatisation and young plant culture. Automatizing the process or parts of the process seems possible and should enable production costs to be kept at a competitive level. So far the performance of the plants seems to be comparable with or superior to seedlings. If this continues, and this remains to be seen on the demonstration plots as well in coming parallel trials with seedlings, the long-term aim of producing new fast growing varieties can be achieved.

Key words: Larix x eurolepis, somatic embryogenesis, acclimatisation, post vitro growth.

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Indigenous Populus nigra clones and Populus x euramericana clone I-214 are the main clones grown in the Southeast Mediterranean and Southeast Anatolia regions which have temperate climate. To find a new hybrid clone suitable for the regions, a study has been carried out by the Poplar Research Institute. At the final stage of the project, seven clones, which were generated by artificial hybridization between Populus deltoides ve Populus nigra at Casale Monferrato Poplar Research Institute, Italy, in 1983-1984 and I-214 as control were compared.

Trails of this study were established at Adana-Ceyhan and Sanhurfa-Birecik Forest nurseries. The clones were compared according to their diameter, height, survival and volume production with hectare criterions. According to the results obtained at Adana-Ceyhan trial site, the volume of production of clones ranged from 195,5 m³/ha to 51,0 m³/ha after 13 years, and the clones 83011015 and 83011018 are the best performers for that site. At Sanhurfa-Birecik trial site, the volume of clone production ranged between 164,2 m³/ha and 45,9 m³/ha after ten year and clones 83011015 and 83011013 were the best performers.

According to the results hybrid poplar clone ‘83011015’ was recommended for plantation with control clone I-214 in the Southeast Mediterranean and Southeast Anatolia Regions.

**Key words:** Hybrid poplar, clone, Anatolia.
**SELECTION OF POPLAR CLONES FOR BIOMASS PRODUCTION**

Teoman Kahraman¹, Filiz Kahraman², Cihan Atmaca², Yusuf Tastan² and Burcu Uzan²

*Populus deltoides* and *Populus x euramericana* are the two poplar species existing in plantations in the Turkish temperate region. Poplar wood obtained from these plantations is mainly utilized as roundwood, but also for fiber and chip production. The demand related to the poplar wood sector in Turkey is changing accordingly. Consequently biomass production from poplar plantations will become another main production system for Turkey.

The objective of this paper is to evaluate different clones of *Populus deltoides* and *Populus x euramericana* for biomass in high density plantations in the Marmara Region of Turkey. A number of 50 clones was selected from the clone collections of the Poplar Research Institute, according to previous clonal selection research studies. Three experiment sites were established to reveal the performance of the clones after three years. Experimental designs were randomized in complete block with four replications and four cuttings used at 1.85m x 1.1m spacing for each row. Data were collected for each clone for the first year survival, diameter, height and selection of clones for next phase of study by volume index "VI = [(D/2)² x H x 3.1416] x N" (D: diameter, H: height, N : number of survival ). Analyses of variance were conducted on clone mean values and Duncan’s Multiple Range test was applied to rank clones.

Significant differences were found between trail sites and clones for all characters at 0,001 probability level for all characters. Clone by site interaction was significant 0,01 probability level at height and survival while 0,001 probability level for volume index and non-significant for diameter character. Rank orders of clones for volume index showed that clones were separated into 12 groups and first group consisted of 9 clones (6 *P.x euramericana* 3 clone *P. deltoides*). Best performer clones selected for the next phase of study which will established 3.0 x 2.2 meter spacing and will observe for five years.

**Key words:** *Populus x euramericana*, *Populus deltoides*, biomass, clone test.

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SELECTION OF WHITE WILLOW (*Salix alba* L.) AND CHINESE WILLOW (*Salix matsudana* Koidz.) FOR BIOMASS PRODUCTION

Davorin Kajba¹ and Ivan Andrić¹

Willows, compared with other species, are the most suitable for biomass production in short rotations because of their very strong growth during the first years. Nowadays, in Croatia, a large number of selected and registered willow clones are available. The main objective of the research should be to find genotypes which, with minimum nutrients, would produce the maximum quantity of biomass. In breeding the White Willow (*Salix alba* L.) and Chinese Willow (*Salix matsudana* Koidz.), methods of intraspecific and interspecific hybridization and back cross have been used and by cloning of plus variants from the hybrid families it was possible to make a selection of new genotypes that are suitable for biomass production. Clonal test of the arborescent willows include the autochthonous White Willow (*Salix alba*), interracial hybrids of the autochthonous White Willow and the English ‘cricket’ Willow (*S. alba* var. *calva*), interspecies hybrids (*S. matsudana* × *S. alba*), as well as multispecies hybrids of willows. The average production of dry biomass (DM ha⁻¹ a⁻¹) per hectare was estimated in regard to the clone, survival, spacing and the number of shoots per stump.

Clonal tests were established in two-year rotation and mean biomass production at the first two-year rotation period was 19.1 t DM ha⁻¹ a⁻¹. At the second and third rotation periods, the average production was 20.6 and 25.1 t DM ha⁻¹ a⁻¹ respectively. The highest average biomass production, as well as the best adaptedness and phenotypic stability on testing sites were shown by clones ('V 374', 'V 461', 'V 578' from 21.6 – 25.7 t DM ha⁻¹ a⁻¹) originated from backcross hybrid *S. matsudana* × (*S. matsudana* × *S. alba*) and by one *S. alba* clone ('V 95', 24.4 t DM ha⁻¹ a⁻¹). These clones are now registered and these results indicate significant potential of Chinese Willow for further breeding aimed at biomass production in short rotations. Clones showed that high biomass production on marginal sites and dry biomass could be considerably increased with the application of intensive silvicultural and agrotechnical measures. No nutrition or pest control measures were applied (a practice otherwise widely used in intensive cultivation system), while weed vegetation was regulated only at the earliest stage.

**Key words:** *Salix* clones, short rotation forestry, marginal lands, Croatia.

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COMPLETE GENOME SEQUENCES OF *POPULUS TREMULA* CHLOROPLAST AND MITOCHONDRION AS NEW RESOURCES FOR HOLISTIC POPLAR BREEDING

Birgit Kersten¹, Patricia Faivre Rampant², Malte Mader¹, Marie-Christine Le Paslier², Rémi Bounon², Aurélie Bérard², Cristina Vettori³, Hilke Schroeder¹, Jean-Charles Leplé⁴ and Matthias Fladung¹

Along with the completion of the *P. trichocarpa* reference genome sequence, the first of any tree species, and the further development of next and third generation sequencing platforms, genomics-based breeding has become a realistic tool in *Populus* breeding. For *Populus*, approaches like candidate gene and marker-assisted selection are feasible today as a large number of gene/marker-trait associations have been detected. However, these approaches are dominated by the use of nuclear genes in poplar breeding, and so far neglect the important function of genes located in the chloroplast and mitochondrion genomes. Mitochondria, e.g., are very important for plant breeders because they are involved in cytoplasmic male sterility (cms) and in redox processes that occur during defence responses.

To fill this gap, we generated the complete genome sequences of the organelles chloroplast and mitochondrion for two clones of the section *Populus*, *Populus tremula* W52 (KP861984, KT337313) and *P. tremula* x *P. alba* INRA 717-1B4 (KT780870, KT429213), based on next generation sequencing data using CLC Genomics Workbench. The chloroplast/mitochondrial genomes of both clones are very similar in size and structural organization. The *P. tremula* chloroplast genome sequence of about 156 kb is the eighth in the genus *Populus* and the large mitochondrial genome sequence of about 800 kb is even the first in the family of *Salicaceae*. The annotation of the *P. tremula* chloroplast genome provided 85 putative protein coding genes, 37 tRNA genes and 8 rRNA genes. In the mitochondrial genome, 55 putative protein-coding genes (22 of unknown function), 22 tRNA genes and 3 rRNA genes were predicted. All these genes may include potential targets for future breeding efforts. Beside genes, also intergenic regions in the organelle genomes are of interest for breeders because markers for species and origin identification have often been identified in these regions. In search for potential *P. tremula*-specific chloroplast markers, we compared the two *P. tremula* chloroplast genomes with all other available complete chloroplast DNA sequences of *Populus*. We identified 163 potential *P. tremula*-specific SNPs and 69 InDels. Selected SNPs located in the intergenic linker *trnH-psbA* were validated in an extended set of *Populus* individuals representing 13 different species. All validated SNPs were proven to be suitable as markers for the differentiation between *P. tremula* and the other species in the maternal line. The validation of selected large InDels in intergenic regions is under way.

With the availability of the genome information of the chloroplast and the mitochondrion together with nuclear genomic information (http://popgenie.org/) a holistic approach in *Populus* molecular breeding is envisaged.

**Key words:** Chloroplast genome, mitochondrial genome, molecular markers.

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ISAP (INTER-SINE AMPLIFIED POLYMORPHISM) – 
A RETROTRANSPON-_BASED MARKER SYSTEM FOR IDENTIFICATION OF VARIETIES, 
CLONES AND ACCESSI ONS OF POPLAR

Anja Kögler¹, Kristin Morgenstern², Thomas Schmidt¹, Doris Krabel² and 
Marie Brückner³

Fast-growing species of deciduous trees, for example poplars and willows, are particularly important for the production of the renewable raw wood material. Poplar accessions vary extremely in growth rate and it is important to select high-yielding genotypes. Molecular markers which are based on the genome sequence are excellent tools to differentiate species, accessions and clones. So far, only molecular marker techniques of limited use are available for a comprehensive differentiation of poplar genotypes.

We established ISAP markers which are rapid, robust and cost-efficient for poplar providing genotype-specific fingerprints of high resolution. ISAP (Inter-SINE Amplified Polymorphism) markers are based on Short Interspersed Nuclear Elements (SINEs), a repetitive DNA sequence class belonging to mobile DNA sequences (retrotransposons), which are present in high copy number and widely dispersed in plant genomes.

Our aim is to characterize and differentiate poplar varieties, clones, and accessions using ISAP marker profiles in order to establish a comprehensive fingerprint database. This database will be used for the determination of genetic variation, marker-assisted selection for breeding, and quality control.

Key words: ISAP marker, Short Interspersed Nuclear Elements, poplar

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WIDENING OF GENETIC BASE OF *POPULUS DELTOIDES* IN INDIA THROUGH HYBRID CLONE DEVELOPMENT

Ashwani Kumar

*Populus deltoides* (commonly referred to as poplar) is widely planted in agroforestry plantations in the plains of North-West India comprising Western Uttar Pradesh, Punjab and Haryana, and to some extent in the outer plains/valleys of Uttarakhand and Himachal Pradesh. It is planted as block plantation as well as boundary plantation with agricultural crops at a rotation of six to eight years. The productivity of poplar plantations is 20 to 25 cubic metres per ha. The tree is much valued for wood which is used in plywood, paper and match industry. The Indian Council of Forestry Research, Dehradun has introduced the species in Vaishali district in Bihar State; the success of this initiative has led to its spread in other districts in northern Bihar.

The genetic base of poplar in India is very narrow and is prone to disease and insect outbreaks. In order to widen the genetic base of poplar plantations and enhance productivity, new hybrid clones have been produced in India. The Forest Research Institute, Dehradun, Uttarakhand Forest Department, Haldwani, Uttar Pradesh Forest Department, Bareilly and Wimco Seedlings Ltd., Rudrapur have carried out breedings among the best clones of earlier introductions. This paper gives an account of the poplar breeding work carried out by the author while at research wing of the Uttar Pradesh Forest Department.

Controlled pollination was carried out using ten female clones (82-29-2, 430-4, 11-3, 82-33-3, 82-40-2, G48, S7C7, D121, 3324 and S7C8) and four male clones (G3, S7C4, 73-53-7 and S7C1) for producing hybrid population during 2001. The progeny consisting of 579 individuals was tested in the nursery. Out of them, the best 152 individuals were cloned as POP-2401-BLY to POP-2452-BLY. Clonal testing in the nursery led to gradual refining of the selection to 100, 69, 36 and 16 clones in the years 2004, 2006, 2007 and 2008 respectively. The best 16 selected clones were planted in field trials at two sites in 2011. Control crosses S7C8 x G3, G48 x G3, D121 x G3, D121 x S7C1, D121 x S7C4, G48 x S7C4 and S7C8 x S7C4 have proved as the most successful families so far. Incidence of any significant disease or insect attack has not been noticed in the new clones. The best 16 clones have been supplied to the Forest Research Institute, Dehradun for registration with the National Poplar Commission of India.

**Key words:** Poplar breeding, clones, controlled pollination.

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POPLAR GENETIC TRANSFORMATION FOR SUSTAINABLE GROWTH IN SHORT-ROTATION PLANTATIONS

N. Kutsokon, V. Rudas, M. Shinkaruk, O. Lakhneko, B. Morgun and N. Rashydov

Sustainable production of the fast-growing poplar trees is necessary for an efficient and greener resource, and for a competitive economy protecting the environment, reducing emissions and preventing biodiversity loss. Therefore poplar plantations are important for such countries, as Ukraine, which depend on energy supplied by foreign countries.

The aim of our research is to receive transgenic poplars from local hybrid Populus nigra x P. deltoides cv. Gradizka, which is a higher productive clone for planting in short-rotation cycles. To conduct poplar genetic transformation, a model gene construct carrying selective genes of kanamycin resistance and marker GUS-gene was used.

The genetic transformation was performed using leaf, stem and petiol poplar explants. To identify the transformants, selection on medium with kanamycin, PCR and histochemical analysis was applied.

Successful transformants selected on kanamycin media were confirmed by the presence of PCR-product with the length 700 bp for the gene nptII, and GUS expression was also observed.

The method of genetic transformation established for P. nigra x P. deltoides cv. Gradiska will be used for further genetic modification of poplars to create clones that are profitable for short-rotation planting in Ukraine.

**Key words:** Populus, genetic transformation, short rotation plantations.
NATURAL REGENERATION OF BLACK, HYBRID AND BALSAM POPLARS IN THE LANDSCAPE

Heike Liesebach¹, Kristin Morgenstern², Doris Krabel³ and Matthias Meyer⁴

In the past, many non-native hybrid and balsam poplar clones were planted widely in Europe, including in Germany. Potentially, they can reproduce vegetatively, but they are also able to contribute to sexual reproduction. Poplars from assumed natural regeneration were collected at predominantly dry sites in Germany. After cultivation, they were genotyped by 18 nuclear microsatellite markers to analyse their taxonomic status. Among them are native European black poplars (Populus nigra), but also some introgression of hybrid black poplars (P. × canadensis) into European black poplar was detected. In addition, traces of a hybridisation event between a balsam poplar and the European black poplar were found in the collected samples. Natural regeneration was also produced by planted 'Fritz Pauley' (P. trichocarpa), 'Androscoggin' and 'Hybride 275' (P. maximowiczii × P. trichocarpa). Generative offspring developing on dry sites will be included into breeding processes.

Key words: Populus spp. L., hybridisation, introgression, selection on dry sites.

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TRIPLOID POPLARS AS A POTENTIAL FOR BREEDING FAST-GROWING TREES

Heike Liesebach¹, Kristina Ulrich² and Dietrich Ewald³

Sexual polyploidisation is one of the appropriate approaches in poplar breeding. Controlled pollinations were carried out with spontaneously formed, as well as induced, $2n$ gametes. In addition, several other triploid clones are present in our breeding stock. Altogether, 59 triploid clones were characterised by flow cytometry and genotyped by 18 nuclear microsatellite markers. The allelic configurations, especially tri-allelic patterns, and dosage effects were used to recognise diploid contributions of the male or female gamete. Three out of 18 markers localised near the centromeres of linkage groups I, X and XV. They are assumed to be unaffected by crossing over events and, therefore, able to ascertain the mechanism of first division restitution (FDR) or second division restitution (SDR) to generate diploid gametes.

Altogether, 22 diploid pollen (10 FDR and 12 SDR) and 19 diploid ovules (1 FDR and 12 SDR) as well as 6 cases of postmeiotic reconstitution were determined with no inconsistency for the three markers. A female hybrid aspen clone ($\textit{Populus tremula} \times \textit{Populus tremuloides}$) was assured to be able to frequently spontaneously form diploid ovules by the SDR mechanism. The transferred average heterozygosity in FDR gametes was assessed to be remarkably higher than that in SDR gametes. However, a selective inducement to favour FDR gametes seems not to be feasible with the current thermotreatment techniques. Selected, fast-growing clones were propagated by cuttings or by tissue culture methods to include them into field trials.

**Key words:** \textit{Populus} spec. L., breeding, triploid, SSR markers, unreduced gametes, FDR, SDR.

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Improvement on Poplars of the Section *Populus* in Germany

Mirko Liesebach1 and Volker Schneck2

Aspen (*Populus tremula*, *P. tremuloides*), like silver poplar (*P. alba*) and other Asian and North American species, belong to the section *Populus* (white and trembling poplars). The growth pattern of poplars in this section diverges from black poplar and balsam poplar in that the growth parameters culminate somewhat later. Thus they cope better with stress events and are less susceptible to disease. Furthermore they tolerate a broader site spectrum; i.e. they can also grow on sandy nutrient-poor soils in the sub-continental climatic regions in Germany.

The first genetic improvement studies began in the 1930s after the discovery of triploid aspen. Aspen breeding trials were based on the selection of plus trees, the controlled crossbreeding of those trees and finally progeny trials. So far systematic provenance trials have not been established. Since the 1980s, tests of aspen as a potential short rotation coppice species have been conducted. Whereas, earlier genetic improvement trials focused on improvement of vigour, stem form and resistance to stem diseases, now the goals are directed more towards production potential as short rotation coppice, resistance to leaf diseases, good regeneration capacity as well as high biomass productivity.

In corresponding trials aspen produces about 10 t ha-1 year-1 of aboveground dry biomass in a 10-year rotation period. In these trials, hybrid aspen from European and American aspen were more productive than progenies of pure European aspen. Of the pure European aspen progenies, the growth of those with mother trees from Saxony is comparable to the inter-species hybrids. By rotation periods on agricultural land between 10 and 20 years, the wood biomass yield can be increased.

In Germany there are clones, clone mixtures and parent trees from the section *Populus* whose reproductive material has been approved under the Forest Reproductive Material Act. So far, however, only limited reproductive material has been available commercially because either the parent trees do not flower or limited demand has curbed clone reproduction activity. Therefore, the crossbreeding programme was resumed, and new crossbreeding combinations were carried out with the still remaining parent trees. Data of existing field tests were evaluated and already new well growing progenies were approved under the Forest Reproductive Material Act. Furthermore, research is going on in implementation of new breeding methods, and improvement of production methods.

Key words: Tree breeding, hybridization, *Populus*, hybrid aspen, yield, reproductive material.

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As novel identified sugar transporters in plants, the SWEETs (Sugars Will Eventually be Exported Transporters) play essential roles in many physiological processes. To date, the roles of this family in woody plant poplars characterized with a different sugar allocation property have not been systematically investigated.

In this study, a total of 27 SWEET genes were identified in *Populus trichocarpa* genome. The phylogenetic relationship, gene structure, conserved motifs, and chromosomal location of these SWEET genes showed that they fell into four clades, with exon/intron organization and motif composition relatively conserved in each clade. The chromosomal duplication and tandem duplication events contributed to the expansion of the PtSWEET gene family. Representative SWEET members from each clade were selected for further functionally characterization. These PtSWEETs were localized to the plasma membrane, vacuolar, endoplasmic reticulum (ER), or Golgi. Four members could transport glucose, mannose, galactose or sucrose in yeast cells. Real-time quantitative PCR analysis showed PtSWEETs have distinct expression patterns in various tissues, and *PtSWEET5, 7, 10b, 10c, 15b, 17a, and 17c* exhibited high expression in stem. Histochemical GUS assays further confirmed *SWEET7* and *SWEET17a* are highly expressed in the phloem and the latter also in xylem and ray cells. The transgenic poplars with overexpression of *PtSWEET7* and *PtSWEET17a* exhibited increased stem growth and enhanced xylem development, suggesting their roles in the sugar allocation to the wood tissues.

Collectively, these results provide valuable information for the elucidation of their biochemical functions in woody plants.

**Key words:** Evolution, gene expression, *Populus*, sugar transporters, SWEETs, xylem development.
The first cultures with hybrid poplars were established in Romania since 1915. Throughout the period 1962-1985, the culture of hybrid poplars had the greatest development. Annually between 3,000 ha to 4,000 ha of poplar clones were planted and the total cultivated area was approximately 66,000 ha at the end of this period. At present, in Romania, poplars are cultivated on approximately 35,000 ha (NFI 2012) and 11 clones are certified as basic material to produce forest reproductive material (44 ha qualified sources).

In 2014, within the Project EW13/14: Testing of poplar clones from EU member states for the use in short-rotation coppice, coordinated by ASP Teisendorf, two trials with 21 new clones of poplars were established. The research institutes, the owners of the deliverable clones, are from the following countries: Belgium, Italy, Germany, Czech Republic and Hungary. One experiment was conducted in the Danube delta (Nufaru) and another in steppe site conditions (Baragan).

The results after the second growing season highlighted a high variability among tested clones for growth traits, bud flushing and survival in both experimental trials. In each experiment clones showed exceptional growth performances exceeding the control clone (I214) with values between 18% to 33% at Baragan, and 19% to 58 % at Nufaru.

Although the soil and climate factors from tested sites are very different, some clones revealed a high phenotypic plasticity, obtaining superior growth performances and high percentages of survival in both experiments.

The results recommend the use of clones in other site conditions than those known so far for the poplar culture in Romania. Also, the most valuable clones could be designated as tested sources and ex situ conserved as mother plants cultures, of course with the owners agreement.

**Key words**: Poplars, growth traits, bud flushing, survival, genetic resources.

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Demand for renewable carbon to produce energy, fuels, and materials is increasing. Biomass is the only renewable source of carbon, and identifying crops that can thrive on idle or retired agricultural land is necessary to avoid competition with already strained food and fiber production. Crops that can be managed successfully with minimal inputs (e.g. water, chemicals, and energy) will be the most desirable. In many parts of the world, poplar hybrids promise to be that crop. Performance of sixteen poplar varieties was examined for seven years at six sites throughout Michigan, USA in a large-plot, well replicated yield trial. Sites were established over a three-year period to accommodate limitations of labor and planting stock availability and were allowed to develop without irrigation or fertilization. The most recent set of measurements allowed for comparison of fifth-year growth across the entire test.

Performance of the best variety at each site varied widely; from an unacceptable low of 8.5 dry Mg·ha\textsuperscript{-1} to an impressive high of 40.0 Mg·ha\textsuperscript{-1}. An analysis of variance in fifth-year biomass growth in the network was performed to understand this variability. The majority (52\%) of the variability was due to site effects. This reinforces the need to test varieties at many locations in order to accurately predict yields. Variety differences accounted for 9\% of the variation but 12\% of the variation was due to genotype by environment interactions. This means that varietal choice is very important but that relative varietal performance will change dramatically among sites. Even though all the trees in this trial were clonally propagated, 27\% of the total variation was due to tree-to-tree differences within the sample plots. This variation creates challenges when managing and harvesting these crops, and can reduce feedstock quality. An analysis of variance in seventh-year biomass accumulation in the oldest sites in the trial produced similar results. Poplar hybrids have the potential to be productive biomass crops in Michigan but will require extensive, variety-specific, localized testing to establish reliable variety recommendations and yield estimates. One of the biggest issues to be addressed in the future will be to understand and then to control within-variety growth variability.

**Key words:** Biomass, hybrid poplar, yield, genotype by environment interaction.

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Hybrid poplars are prime fiber and biomass producing crops around the world. Growth varies widely in response to climate, edaphic factors, varietal genetics, cultural practices, pest pressures, and the interactions among all these things. Testing is expensive and so is often done over short time intervals, at single sites, using a limited number of varieties, and done only once, which means that conclusions must be qualified with many caveats. Because of poplar’s tremendous variability and the practical limitations that constrain research, reported responses from individual poplar trials are often not precisely repeatable in large, widespread commercial operations.

Michigan State University began a series of hybrid poplar trials in 1998. These included herbicide trials, fertilizer trials, variety trials, yield trials, and spacing trials. Some trials were conducted at the Forest Biomass Innovation Center in Escanaba, Michigan, USA but others were replicated throughout the state. Here we attempt to distill the observations made in these individual trials over the last 18 years into a cohesive summary of biomass yield projections, growth patterns and rotation length projections, and varietal responses to stress and cultural treatments. We also suggest what research remains to be done to improve the chances of commercial deployment of the production system being developed here.

Key words: Biomass, hybrid poplar, yield, growth curves, rotation age, pathogens, stresses, variety.

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POPLAR BREEDING PROGRAMME IN ARGENTINA: 2013 COMPARATIVE CLONAL TRIAL
NETWORK STATUS

María Silvana Monteverde¹, Silvia Cortizo² and Nora Abbiati³

Since 1961, the National Agricultural Technology Institute (INTA) conducts a *Populus* breeding programme in order to select superior genotypes based on the concept of overall quality of the tree. As Argentina does not have any native poplar population, seeds belonging to *P. deltoides* plus trees selected in natural populations and clones of *P. deltoides* and *P. x canadensis* resulting from breeding programmes in Italy, France, USA and Australia were introduced so as to form the programme base population and select clones adapted to the region. Clonal selection was made using the independent culling level method through the successive programme stages and using the criteria: growth, stem form, tolerance to pests, adaptability and wood quality, in accordance with the common practices of the region. In 1987 a programme of intra- and interspecific hybridizations was implemented in order to broaden the genetic base of the breeding population and thus ensure the continuity of the programme and the capability to face the new challenges posed by pests, the industry, the market and global climate change.

Out of 3,460 genotypes obtained from 8 different crossings in 2006 and 2008, and installed in progeny banks in the Paraná Delta Experimental Station, 164 individuals were selected and agamically multiplied and evaluated in clonal banks. 34 of them exceeded the thresholds considered in our programme for the following criteria: rooting ability, *Melampsora medusae* (rust) and *Septoria musiva* (canker) tolerance, growth rate and stem form; and they were incorporated into a network of comparative clonal trials in 2013, consisting of 4 independent units in single-tree plot with at least five repetitions per site. The number of clones in the established testing network is within the recommended limit to reduce the risk of failure due to atypical environmental conditions and the evolution of virulence in pathogens of most clonal programmes.

This paper presents the results of qualitative and quantitative assessments made in the third year of planting. The qualitative variables were taken together with leader forest growers and forestry companies. Quantitative variables were analyzed using mixed models with the SAS statistical package version 9.4.

Although results are preliminary, 7 of these clones showed a promising experimental behavior and were installed in a regional comparative trial using a greater number of plants per plot.

**Key words**: Poplar breeding, *P. deltoides*, hybridization, clonal selection, clonal trials.

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TRANSPIRATION AND WATER RELATIONS OF FOUR POPLAR GENOTYPES UNDER SRC

A. Navarro¹, M. Balzarolo¹, S. Vanbeveren¹ and R. Ceulemans¹

In Europe short-rotation coppice (SRC) plantations are particularly developed in the Northwest of Europe. Poplar (Populus spp.) is one of the most commonly cultivated species in experimental trials and in commercial plantations. The genus receives particular attention as an SRC crop as it is among the fastest growing tree genera in temperate latitudes, characterized by the easy generation of new hybrids, the effective regeneration from woody cuttings and the high productivity in early growth stages. These characteristics enable highly productive SRC plantations depending on soil water availability.

As poplar is sensitive to water shortage, the future development of its cultivation strongly depends on water availability, also in NW Europe. Projections of climate change predict an increase of the intensity and the frequency of extreme events as well as warmer winters and drier summers in Central and Western Europe. Therefore, selection criteria for commercial SRC poplar genotypes need to take not only biomass yield or calorific value into account, but also water consumption and water loss by transpiration. Furthermore the physiological adaptations developed to mitigate climatic change effects, e.g. increased temperature, should also be considered. To identify the water limitations of SRC poplar cultivation and to classify genotypes according to their physiological traits and water consumption, this contribution examines the transpirational water loss at the leaf and the individual tree levels of different poplar genotypes under an SRC regime, together with their different physiological responses.

The experimental site is a commercial scale multi-genotype SRC plantation, established in Lochristi, East-Flanders province (Belgium). Unrooted cuttings of 12 selected and commercially available poplar (Populus spp.) genotypes belonging to different species and interspecific hybrids were planted in April 2010 over a total area of 14.5 ha at a density of 8,000 plants ha⁻¹. In this work four of the 12 genotypes (three individual trees per genotype) were specifically chosen to cover a wide genetic background.

To achieve the proposed objective, this contribution reports results of the transpiration and the physiological responses at the leaf level by means of leaf transpiration, stomatal conductance and photosynthesis measurements, and at the tree level through sap flow and daily stem diameter variation measurements. Measurements at the leaf level are performed on specific days of the growing season (from May to September) with a different evaporative demand, temperature, incoming radiation and soil water status, while the parameters at the tree level are continuously registered during the entire growing season. In combination with instantaneous measurements of gas exchange parameters, stem water potential and leaf relative water content are also determined, providing better insights in the water relations and the physiological traits of the different poplar genotypes.

**Key words:** SRC poplar, transpirational water loss, gas exchange, growing season.

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STUDY OF TRANSPORTERS OF HMA AND NRAMP FAMILY IN WILD TYPE AND TRANSGENIC LINE (35S::aqua1) OF POPULUS ALBA STRESSED WITH CADMIUM

Andrea Neri¹, Alessandra Francini¹, Andrea Andreucci² and Luca Sebastiani¹

The homeostasis of essential heavy metal ions in plants involves transport proteins belonging to various families, including the ATPase and NRAMP transporters. Many of these can also transport non-essential heavy metals like cadmium (Cd) that does not have any biological function in plants. Moreover, Cd accumulation is also related to plants transpiration stream.

A better understanding of metal uptake mechanisms will facilitate the successful design of remedial systems, as well as the genetic modification of poplar species to increase their phytoextraction ability.

In this study, the roles of HMA and NRAMP transporters in root-to-shoot Cd translocation and tolerance, was assessed in Populus alba Villafranca clone L. wild type and aquaporin (aqua1, GenBank: GQ918138) overexpressing line GM16 that have higher water use efficiency compared to wild type. Plants were treated with realistic environmental concentrations of cadmium nitrate (10 μM) in an hydroponic system for 1, 7 and 60 days and Cd concentration and gene expression (HMA and NRAMP gene family) were measured at each sampling time.

Despite the uptake of Cd, which was found mainly concentrated in roots, plants maintained healthy traits (growth parameters, photosystem II efficiency) during the whole experimental period (60 days). The gene expression of PtNRAMP 3.1, PtNRAMP 3.2, PtNRAMP 1.3, PtMRP 9.1, PtHMA 3-like and, PtHMA4 was strongly influenced by the Cd following a time course dynamic that was different in each organ and line studied.

These results could be useful to address genetic modification aimed to modify Cd accumulation and translocation in poplar.

Key words: Poplar, cadmium, transgenic, aqua1, hydroponic, gene expression.

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Black poplar (*Populus nigra* L.) clones obtained from intraspecific and interspecific crosses were tested at Filyos Forestry Nursery in Turkey. Growth traits and various morphological characteristics were assessed after two growing seasons. Significant clonal differences were observed regarding height, diameter, volume index and survival rate. Ten intraspecific crosses had significantly better growth performances than control clones “I-214” based on volume index values, but most of the clones showed poor survival rates comparing to control clones.

High heritability values were found for the clone means of tree dimensions and survival rate, ranging from 0.32 to 0.57. Factor analysis was applied for 18 components and 83.75% of total variance was explained by the first five components. Volume index was determined as the most important variable in component 1. Groups of the clones were separated by discriminant functions and five highest groups were indicated with the most effective variable volume index.

**Key words:** Black poplar, genetic variation, growth trait, morphological characteristic, heritability, tree dimensions.
INTRA-SPECIFIC VARIATION IN POPLAR DROUGHT RESPONSES

Andrea Polle¹, Shanty Paul¹ and Henning Wildhagen¹

The demand for sustainable production of renewable resources is increasing because of a growing world population and of dwindling reserves of fossil fuels. Woody biomass can substitute many oil-based products because of its multiple usages, e.g. as a construction material, as a raw material for added-value wood products, as a feedstock for the chemical industry and as a resource for energy generation. Sustainable wood production requires insights into the molecular mechanisms of wood formation and its structural, anatomical adaptation to environmental variations such as seasonality, climate change, water limitation and other stress factors. The main goal of our studies is to improve drought performance of fast-growing tree species on marginal soils.

We subjected different poplar genotypes to drought and investigated transcriptomes by RNAseq, wood by microscopic analysis, hormones by GS-MS, and biomass. We constructed transcriptional networks, and merged them with data on anatomical changes and hormonal regulation. Hormones were studied by reporter gene approaches. Thereby we identified core sets of genes underlying biomass production and wood formation in different poplar genotypes.

Strategies how molecular and physiological approaches can be applied to uncover marker genes for biomass production will be discussed.

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Key words: Fast-growing tree species, growth, transcriptome.

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TOWARDS A HIGH AND SUSTAINABLE BIOMASS PRODUCTION: THE SALIX MOLECULAR BREEDING ACTIVITIES PROGRAMME (SAMBA)

Ann Christin Rönnberg-Wästljung¹, Berit Samils², Nils-Erik Nordh³, Jan Stenlid² and Martin Weih³

Greenhouse gas emissions need to be reduced globally to fulfil the climatic goals. A change from using fossil energy systems to more sustainable and environmental friendly energy systems is thus required. Short-rotation coppice of Salix is one option that can play an important role to meet the increased demand of biomass during this change. New plant materials characterised by high biomass production, adapted to diverse environments and with high resistance towards pathogens and pests are desired.

The SAMBA programme has combined expertise from different research fields as genetics, genomics, ecophysiology and plant pathology with the goal to develop molecular markers that could be used as selection tools in plant breeding of Salix. We have with different genetically characterized plant populations and experiments in field, greenhouse and lab made studies of the genetic background of biomass traits, phenology, drought tolerance and resistance. We have identified genes and genetic variation within these genes that is connected to the corresponding trait variation. Genetic markers reflecting this variation will be tested further for use in breeding.

We have planted a bi-parental offspring population in contrasting environments (Sweden – Italy) where the Italian experiment also contained two experimental treatments (irrigated and non-irrigated), to study the genetic background of growth traits as well as the plasticity of traits across environments and treatments. We have identified “hot spot” regions where many of the quantitative trait loci (QTLs) co-localize, e.g. for phenology and growth traits and QTLs for plasticity were in many cases co-located with the trait QTL.

We are now focusing on an association mapping population with 320 unrelated S. viminalis individuals collected in different parts of Europe. The population is planted in replicated field experiments at two locations in Sweden and has a high genetic diversity; we have identified four different subpopulations corresponding to individuals from Western Russia, Western Europe, Eastern Europe and Sweden. We will perform association mapping with SNP markers from a genotyping by sequencing effort of all individuals in the population together with growth and resistance data for the population.

Key words: Salix, plant breeding, molecular markers, rust resistance, biomass, drought tolerance.

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TRANSCRIPTOME ANALYSIS OF POPLAR CLONES TO UNDERSTAND DIFFERENCES IN THEIR GENETIC PERFORMANCE IN MONO AND MIXED STAND WITH BLACK LOCUST

Johanna Ingeborg Ropertz and Reiner Finkeldey

The need for biomass production leads to an intensification of land use systems and lower diversity. *Poplar* hybrids are widely used for bioenergy in monoculture systems due to their rapid high-biomass production. *Robinia pseudoacacia* L. is a lesser known species for energy production, but is known to have the ability to fix nitrogen. The hypothesis of the project IMPAC states that mixing high biomass production, an economic important tree species with a nitrogen fixing tree species may improve ecological functions and enhance crop systems stability.

In 2006 the genome of *Populus trichocarpa*, was fully sequenced by the Joint Genome Institute, United States Department of Energy, USA. This genome assembly can be used as a reference genome sequence for further genetic analysis of Poplar species with ecological and economical importance. Transcriptome analysis allows a detailed look into gene expression of tree species at different developmental stages for a better understanding of gene functions. To identify differences in gene expression levels in leaves, gene expressions in different growing and site conditions will be analyzed by RNA Seq. Simultaneously, phenological traits like plant height (m), stem diameter (mm), Bud set, number of Leaves on (main) stem, leaf area index, carbon/ nitrogen content and photosynthetic pathway for further association studies will be examined. The association studies may show a relation between gene expression levels at different developmental stages, different site and growing conditions. Further objectives are to discover genetic markers which are responsible for growth performance, resistance against diseases and insects and tolerances to abiotic stress conditions. Initial studies were conducted by genotyping Black Locust provenances and Poplar clones.

Quantitative gene expression analysis will be conducted by using RNA sequencing with new generation sequencing technology to verify candidate genes which are differentially expressed in different poplar clones using real time quantitative PCR (RT-qPCR). RNA extraction and RNA amplification of plant material are in progress to characterize plant material and to detect differentially expressed genes. Gene expression levels will be analyzed by Illumina Sequencing and using RT-qPCR.

**Key words:** Poplar clones, Black locust, transcriptome analysis.
CHLOROPLAST AND MITOCHONDRIAL SNP-MARKERS SUPPORT HOLISTIC POPLAR BREEDING

Hilke Schroeder¹ and Matthias Fladung

Molecular marker systems offer an appropriate tool for identification and taxonomic classification of organisms. Especially for a genus like Populus with several species being cross-compatible between sections, methods for clear identification of species are urgently needed. During the last 100 years, several interspecies-hybrids have artificially been produced in huge breeding programmes all over the world to combine the most advantageous characters of the different species in respect to wood application, for pulp and paper characteristics or energy production.

To determine all the species used within these interspecies hybrids by morphological criteria is often very difficult. But registration of new high performing clones necessitates unambiguous species knowledge. Thanks to the ‘barcode of life’ initiative (http://www.ibol.org/, http://www.barcodeoflife.org/), several chloroplast (cp) primers are available that already have been used for differentiation of a broad range of plant species. Earlier, we already published a couple of species-specific cp SNP-markers for differentiation of 14 most common cultivated poplar species. But more species are used in breeding programmes and we permanently add further species and validate the species-specificity of the established markers using as many individuals as possible. At the moment, we are able to differentiate 17 poplar species using not only cp markers but also mitochondrial (mt) markers. Though, both marker types are maternally inherited in angiosperms, mt markers often function as adaptive markers.

For the development of cp and mt markers, we tested 40 and 17, respectively primer combinations for the successful amplification in PCR experiments. The number of total SNPs (single nucleotide polymorphism) or InDels (Insertion/Deletion) per species differed dramatically (from 1 to 63) as well as the number of species-specific SNPs or InDels. For an easy-to-use application, we combined three chloroplast regions containing different InDels that allow us the identification of 17 poplar species with only three PCR reactions and one multiplexed run on a sequencer.

Thus, the overall aim of the study presented here is to provide fast and easy to use methods for species identification as well as a greater couple of markers including adaptive ones to support poplar breeding programmes.

Key words: Chloroplast markers, mitochondrial markers, SNPs, InDels.

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GEO-CLIMATIC GRADIENT SHAPES FUNCTIONAL TRAIT VARIATIONS IN SALIX ERIOCEPHALA

Raju Soolanayakanahally

Intraspecific variations in seasonal phenology and growth physiology reflect adaptation to local climate. North-temperate and boreal tree species occupying larger geographic areas use day length and temperature cues to time their phenology. To explore the patterns of local adaptation along latitudinal and longitudinal clines, an extensive collection was used of the AgCanSalix (Agriculture Canada Salix) comprising >500 distinct genotypes planted into a common garden at Indian Head (50.33°N, 103.39°W) Saskatchewan, Canada. In this study, latitude is a proxy for day length, frost free days, precipitation and temperature that co-vary in a linear fashion.

Thirty-four populations (N = 338) of Salix eriocephala Michx. sourced from its natural ranges across Canada were examined for 6 phenology and 19 ecophysiology traits over two growing seasons. Photosynthetic assimilation rate (A) increased with increase in latitude when measured during free growth. In spite, the negative correlation between stomatal density and stomatal conductance ($g_s$), higher A is facilitated via larger pore length among genotypes from short growing seasons. It was also observed a strong positive correlation between $A$, leaf N and leaf mass per unit area (LMA) implying that low latitude genotypes invest more nitrogen towards foliar structures to withstand biotic and abiotic stressors, while fast-growing high latitude genotypes allocates more nitrogen to photosynthetic apparatus. In addition, the observed latitudinal clines in nitrogen isotope discrimination ($\delta^{15}$N) imply that high latitude genotypes possess higher capacity to assimilate inorganic nitrogen in roots and/or leaves compared to low latitude genotypes. Growing season phenological traits considered in this study accounted high heritability ($H^2 = 0.65-0.94$). Greater susceptibility to Melampsora rust is largely explained by evolution of plant defenses which also display latitudinal clines.

Overall, the results support the hypothesis that functional trait variations are largely explained by climate of origin and facilitate selection of parents with superior adaptive traits in the Canadian willow improvement programme for bioenergy and environmental applications.

**Key words:** Willows, latitude, phenology, photosynthesis, nitrogen isotope composition, LMA.

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EVALUATION OF IMPROVED WILLOWS IN NORTH PATAGONIA, ARGENTINA

Esteban Thomas\textsuperscript{1} and Teresa Cerrillo\textsuperscript{2}

In the North Patagonian region, in the South of Argentina, there is an irrigated valley area of about 140,000 ha, with little precipitations (rainfall in these regions averages between 240 and 300 millimeters per year) and alluvial soils with high productive potential. In these lands, Salicaceae plantations, mainly of poplars, are used to protect vegetable and fruit cultivations. However, willows show very good prospects for sustainable development in the region, including the production of industrial wood and firewood.

Considering the significant potential of willows, new improved genotypes obtained by the Breeding Willow Program of INTA are being tested in a broad trial series in different regions of the country, aiming at developing productive clones with adaptation according to the characteristics of each location. The selection criteria of the Program include: adaptability, disease resistance, fast growth, stem form, and wood quality. Specifically in the North Patagonian region, a first screening trial was established in August 2010 in EEA Alto Valle, Río Negro, with the aim to compare \textit{in situ} the growth of the 16 new genotypes obtained by the Breeding Willow Program of INTA, from controlled crossings \textit{S. matsudana} x \textit{S. alba}, \textit{S. babylonica} x \textit{S. alba}, and from open pollination of \textit{S. alba} and \textit{S. amygdaloides}. A randomized block design was applied, with single plots and sixteen replications.

At the fifth year of the trial, total height (Ht) and diameter at breast height (DBH) of all trees were measured. Analyses of variance (ANOVA) showed significant differences among clones (p<0.001) for Ht, DBH and volume. The genotypes that have reached the highest Ht were: experimental clones \textit{S. matsudana} x \textit{S. alba} ‘96.01.12’ (6.93m ± 1.20), ‘94.08.43’ (6.89m ±1.04) and ‘94.08.74’ (6.85m ±1.10), and the new selected clones \textit{S. matsudana} x \textit{S. alba} ‘Los Arroyos INTA-CIEF’ (6.79m ±1.28) and ‘Agronales INTA-CIEF’ (6.76m ± 1.00). Considering the variable volume as a trend at this early age of the trial, nine new clones showed a volume higher than the commercial clone \textit{S. babylonica} x \textit{S. alba} ‘Ragonese 131-27 INTA’; in the top three clones the volume was 85% (‘94.13.06’), 62% (‘98.07.71’) and 45% (‘Los Arroyos INTA-CIEF’) better than the ‘Ragonese 131-27 INTA’. In the last year, yield trials are being established with these better new clones in order to know the productivity.

Key words: Willows, clones, selection, Patagonia Argentina.

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CONSERVATION OF ECONOMICALLY VALUABLE UNDER-UTILIZED WILD MANGO - *SPONDIAS PINNATA*

Anita Tomar

*Spondias pinnata* (L. f.) Kurz (*S. mangifera* Willd.), belongs to Anacardiaceae family, and is a small or medium sized, fast-growing deciduous tree commonly known in India as wild mango. Its fruits are fleshy drupes with woody endocarp surrounded by fibers. Unripe fruits are light green colored, changing into yellow when ripen. The fresh fruit can be transformed into jellies, sauces, pickles or preserves. It is a good source of minerals and vitamin C. The timber is used for making interior furniture. Its wood is employed for packing cases, tea chests and match splints. Wood is utilized in temporary construction, core stock of plywood and pulp. Because of its lightness and softness, the wood is more suitable in the manufacture of matchsticks, matchboxes, boxes and crates. Despite of being a valuable plant, *S. pinnata* is not cultivated on a large scale in its native habitat. Therefore an attempt was made to grow the cultivation of *S. pinnata*.

Fruits of *S. pinnata* were collected from sites situated between latitude 25°07’ to 25°10’N and longitude 81°54’ to 81°58’E and at 98 m elevation. For the present study, fruit morphological parameters and seed germination tests were conducted. Seeds were cleaned and after 12 to 24 hours of soaking, treated with mercuric chloride (HgCl₂) solution. Germination test involved 4 replications of randomly selected 25 seeds each from the working sample. Results were expressed as germination percentage, which was the percentage of live seeds having germinated at the end of the test. The highest coefficient of variation (CV) of 30.32 % was encountered in a number of fruits per kilogram. This is due to the fact that the actual values varied from a minimum of 40 to a maximum of 72 fruits per kg. The mean value was 54.0 fruits per kg. The fruit length varied from 3.7 to 4.9 cm, fruit thickness from 27.43 to 34.94 mm and 100 fruits weight 2.19 to 2.53 kg. However, the fruit length and width had a variation of 6.52 and 7.79 respectively. Germination result reveals that germination started the tenth day onwards after sowing and continued up to 20 days. The seed germination varied significantly (ANOVA; F-value = 5.46 and p = 0.02) during the study period. Total germination recorded was 96%, - the maximum germination (64.0%) was observed in the second week of sowing, while 32.0% germination was recorded in the third week. The germinants were transferred to poly bags in the nursery.

An attempt was made to grow seeds of *S. pinnata* so that quality seed may be assured for its conservation as well as cultivation. Research on this under-utilized but fast-growing species is intended to promote the preservation of the species presently under threat. This tree can be grown in 'human altered environment' outside the 'natural ecosystem' and harvested according to its respective rotation period. The efforts in promoting fast-growing, commercially viable trees like *S. pinnata* is aimed at ensuring that it becomes optimal for renewable resources.

**Key words:** Deciduous tree, timber, germination test, human altered environment, natural ecosystem, conservation.

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SURVIVAL AND GROWTH ANALYSIS OF ASPEN HYBRID FAMILIES IN THE CENTRAL CHERNOZEM AREA OF RUSSIA

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Research results were obtained in aspen hybrid collection established in 1982 by Victor P. Petrukhnov at Semiluky (Voronezh region) experimental site in Central Chernozem area of Russia. The plantation comprised a total of 1,093 root cuttings of hybrids and half sibs from 9 hybrid families. On the occasion of the 2010 plantation inventory, the overall survival of planted aspen trees at the age of 29 years was 53.8%. The hybrid families: P. tremula ‘Obojan’ × P. tremula (local), P. tremula ‘X₂’ × P. tremula (local) and P. ‘Yablokowii’ × P. tremula (local) were the best in productivity. Their mean stem volume at the age of 29 years was 0.42–0.60 m³.

The cause for a sharp falling survival rate (up to 34.8% on average) was the strong drought during 2010. The hybrid family P. davidiana’ × P. alba var. bolleana had the least drought-resistance. Its survival in the autumn of 2013 had decreased by more than 50%. On the contrary, the hybrid families: P. tremula ‘X₂’ × P. tremula (local), P. canescens × P. tremula (local) and P. ‘Yablokowii’ × P. canescens were more drought-resistant. Their natural mortality in the three years following the 2010 drought varied from 20% to 35%. The half sibs of local P. tremula were most drought-resistant. Their natural mortality was only 18.9%. The 2010 drought influenced hybrid families’ survival in the following years. The 2015 plantation inventory showed a reduction in overall survival of 26.4%. Such drought resistance was also observed among individual hybrid families: in the hybrid family P. davidiana’ × P. alba var. bolleana 75% of trees died, and in the family P. tremula ‘X₂’ × P. tremula (local) – 35%. The half sibs of local P. tremula were the best drought-resistant, as before. Their mortality reached 33.8% at the age of 34 years (66.2% survival).

The 2015 growth and productivity analysis of aspen hybrids showed that mean height of individual hybrid families varied from 17.2 to 22.3 m, mean diameter from 20.2 to 29.1 cm, and mean stem volume at the age of 34 from 0.28 to 0.68 m³. The highest growth indices stood out in the hybrid family P. tremula ‘X₂’ × P. tremula (local), and the least ones in half sibs of P. davidiana. Sufficiently good growth and productivity results at the age of 34 years among the next hybrid families: P. tremula ‘Obojan’ × P. canescens and P. ‘Yablokowii’ × P. tremula (local) (20.2–22.3 m height; 27.0–29.1 cm diameter; 0.48–0.68 m³ stem volume). The control (local P. tremula) growth indices at the same age are considerably smaller than above: 18.4 m; 22.3 cm; 0.30 m³ respectively. The smallest growth indices were found in three families with a P. davidiana mother tree (17.2–18.2 m; 20.2–23.6 cm; 0.28–0.34 m³).

The best drought resistant and fast-growing genotypes may be used for science and practical needs to establish productive and resistant aspen plantations.

Key words: Aspen, poplar, hybridization, survival, growth, productivity.

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METABOLOMIC RESPONSES OF DOWN-REGULATED P-COUMAROYL QUINATE/SHIKIMATE 3’-HYDROLASE (C3’H) AND CINNAMATE 4-HYDROLASE (C4H) GENES IN THE LIGNIN BIOSYNTHETIC PATHWAY OF EUCALYPTUS UROPHYLLA x E. GRANDIS WITH REDUCED RECALCITRANCE

Timothy Tschaplinski¹, Madhavi Martin², Sara Ellen Johnston³, Will Rottmann⁴ and Maud Hinchee⁵

The generation of transgenic plants and the identification of natural variants with reduced lignin production and/or altered lignin composition have been a major focus of research that attempts to reduce the recalcitrance of cell walls of biomass crops to deconstruction for sugar release for conversion to biofuels.

We have conducted a number of studies that have targeted gene knockdowns at different steps within the lignin biosynthetic pathway and the knockdown of genes remote to the lignin pathway, but regulating flux to the pathway. In this study, we targeted the knockdown of p-coumaroyl quinate/shikimate 3’-hydrolyase (C3’H) and cinnamate 4-hydrolyase (C4H) genes in the lignin biosynthetic pathway of Eucalyptus urophylla x E. grandis, which resulted in the reduced recalcitrance of cell walls of stemwood. Broad spectrum gas chromatography-mass spectrometry-based metabolomics was conducted on aqueous ethanolic extracts of fast-frozen stem biomass that was subsequently lyophilized and milled. Metabolomic analyses yielded both expected and unexpected outcomes. Metabolites immediately upstream of the metabolic perturbation, as well as their conjugates, accumulated as expected, but accumulations remote to the lignin pathway, including certain terpenoid-based betulinic sterols but declines in others, are evidence of diverted carbon flux to alternative secondary pathways. Although lignin content and syringyl/guaiacyl ratios declined in transgenics, as expected, monolignol glycosides surprisingly accumulated, which suggests concomitant down-regulation of genes later in lignin biosynthetic pathway and/or the possible functioning of alternative routes for the synthesis of monolignols.

The results of these analyses will be presented, as well as implications for the use of specific transgenics as improved biomass feedstock crops with reduced biomass recalcitrance.

Key words: Metabolomics, mass spectrometry, lignin, Eucalyptus.
PRODUCTION OF DIPLOID POLLEN IN POPULUS BY HEAT-INDUCED
DEPOLYMERIZATION OF MEIOTIC MICROTUBULE CYTOSKELETONS

Wang Jun¹, Li Daili¹ and Kang Xiang-yang¹

Unilateral sexual polyploidization using 2n gametes is an important approach for triploid production in plants. Change of temperature is fundamental to trigger the formation of 2n gametes. High temperature has been successfully applied to induce 2n gametes of Populus, and plenty of triploids were harvested by sexual polyploidization. However, it was little known that the change of gamete development responded to high temperature. In this investigation, the 2n pollen of Populus pseudo-simonii Kitag., an indigenous Populus species of China, was induced by high temperature and heat-induced pollen variation, meiotic abnormalities and depolymerization and restoration of microtubular cytoskeletons were analysed to reveal the cytological mechanisms of heat-induced 2n pollen formation.

Compared with the control, heat treatments lead to an increased frequency of aborted pollen grains. The diameter of heat-induced pollen grains with 38°C for 2 hours at the diakinesis-metaphase stage I showed a bimodal distribution with a wider range from 11.7 μm to 60.6 μm and a larger mean at 37.64 ± 0.27 μm, compared to an approximate Gaussian distribution of the control pollen with an average of 27.33 ± 0.10 μm. There was a significantly difference in pollen diameter between control and heat-induced samples (Wilcoxon rank test, P <0.001), showing that the heat treatment was able to increase the size of pollen grains.

Cytological observation showed that heat treatments increased the frequencies of parallel, fused and tripolar spindles in the second meiotic division. The heat treatment induced depolymerization of the meiotic microtubular cytoskeletons. The depolymerized microtubules became fragments and even disappeared in cytoplasm, which generated a stained background. The microtubular cytoskeletons were able to recover in some heat-treated cells after transfer to normal conditions. We found that the microtubules were likely to launch a re-polymerization schedule close to the region of cytoplasmic membrane, where it exhibited a high intensity of microtubular fluorescence.

Key words: 2n/large pollen, high temperature, meiotic abnormality, microtubular cytoskeleton, Populus.

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TESTING OF NATIVE WILLOWS FOR SHORT-ROTATION COPPICE ON AGRICULTURAL LAND

Jan Weger¹, Jaroslav Bubeník¹, Dušan Reininger² and Přemysl Fiala²

The long-term task of our work is to evaluate possibility of utilisation of willow and poplar species which could be grown as perennial crop in short-rotation coppice (SRC) plantations on agricultural soil for multiple purposes including biomass production, site recultivation, agroforestry systems etc. We have focused on native species of willows and their natural hybrids, because growing of not-native species, including their hybrids, has been limited or forbidden in landscape by national legislation in the Czech Republic. Native species (geographically autochthonous) can be used with much less limitations. They can be now used also in the Ecologically Focused Areas which should cover 5-7% of arable land of farms which want to be eligible for full Basic Payment Scheme of EU agricultural subsidy.

Our experimental plantations (yield tests) were established on two different stand conditions locations: Michovka in Průhonice by Prague (300 m; øt=8,5°C, ΣP=550 mm) and Stachy (800 m; øt=6,4°C, ΣP=742 mm) in Šumava Mts in South Bohemia. Planted areas were 38 × 18 m in Michovka and 90 × 77 m in Stachy, respectively. Both experiments were planted manually in April 2010 in single-row planting scheme 0.5 × 2.1 resp. 0.4 × 2.5 m (density 9524 resp. 10000 pc./ha) with four repetitions and schematic block design. Two most promising clones were planted of native willows resp. their natural hybrids ([Salix ×smithiana](https://en.wikipedia.org/wiki/Salix_smithiana) Wildl respectively [Salix ×fragilis](https://en.wikipedia.org/wiki/Salix_fragilis) L syn. S. × [rubens](https://en.wikipedia.org/wiki/Salix_rubens) Schrank ) in both sites. Poplar clone Max–4 ([Populus nigra](https://en.wikipedia.org/wiki/Populus_nigra) L. × [P. maximowiczii](https://en.wikipedia.org/wiki/Populus_maximowiczii) Henry) was planted as a standard, which is now the most popular clone/variety in Czech SRCs (3000 ha in 2015). Willow clones were originally selected from natural populations or occurrences in the Czech Republic and Slovakia.

Plantations were weeded in the first year of growth and also in the second year in Stachy. All clones have created a dense tree canopy in 2nd or 3rd year which suppressed growth of grass layer (weeds). The plantation has not been watered nor fertilized since its establishment. Such “low-input” agronomy is widely used in most of the commercial SRC plantations with poplar ‘Max-4’ on suitable sites in the Czech Republic. The evaluated area of plantations in the experiment consists of equal blocks in 4 repetitions for each clone on each locality. All blocks were harvested for the first time after 5 years of growth in January 2015. We measured height of trees, stem diameter in 1 meter height, weight of trees, number of stems, survival rate for each individual and content of water per clone in harvested biomass samples.

The survival rate in all blocks/clones was quite good after 5 years: between 97% and 100% at Michovka and 79% and 98% at Stachy. The average calculated yield of all clones was much higher at Michovka (49,1 o.d.t. ha⁻¹) than at Stachy (16,6 o.d.t. ha⁻¹y⁻¹). The highest yielding clone was Max-4 in both sites (54,7 and 18,6 o.d.t. ha⁻¹) followed by willows S-195 (49,7 resp. 12,8 o.d.t. ha⁻¹) and S-218 (42,9 and 18,5 o.d.t. ha⁻¹). Willows had mean number of stems per tree 1,5-2 times lower in Stachy than in Michovka. Preliminary results after first harvest show that selected clones of autochthonous willows can reach similar biomass yields (1-9% lower) than popular polar clone Max-4 while this difference seems to be lower in less favourable conditions of Stachy. Both willows are now in variety testing and should be available for growers soon (2016-2017).

**Key words:** Willow, poplar, native species, yields, short-rotation coppice (SRC).

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INTEGRATED SNP CORRELATION, CO-EXPRESSION AND GENOME-WIDE ASSOCIATION NETWORKS FOR *POPULUS TRICHOCARPA*. PLEIOTROPIC AND EPISTATIC NETWORK-BASED DISCOVERY

Deborah Weighill$^{1,2}$, Carissa Bleker$^{1,2}$, Gerald Tuskan$^1$, Wellington Muchero$^1$, Tim Tschaplinski$^1$ and Daniel Jacobson$^{1,2}$

Biological organisms are complex systems that are composed of pleiotropic functional networks of interacting molecules and macro-molecules. Complex phenotypes are the result of orchestrated, hierarchal, heterogeneous collections of expressed genomic variants. However, the effects of these variants are the result of historic selective pressure and current environmental and epigenetic signals, and, as such, their co-occurrence can be seen as genome-wide correlations in a number of different manners. Biomass recalcitrance (i.e., the resistance of plants to degradation or deconstruction, which ultimately enables access to a plant’s sugars) is a complex polygenic phenotype of high importance to DOE’s biofuels programmes.

We are using data derived from the resequenced genomes from over 1000 alternate *Populus trichocarpa* genotypes in combination with transcriptomics, metabolomics and phenomics data across this population in order to better understand the molecular interactions involved in recalcitrance. The resulting Genome Wide Association Study networks, integrated with SNP correlation and co-expression networks, are proving to be a powerful approach to determine the pleiotropic and epistatic relationships underlying cellular functions and, as such, the molecular basis for complex phenotypes, such as recalcitrance.

**Key words:** Genomic, biomass recalcitrance, biofuels.

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For about 70 years, the Department of Forest Genetics and Tree Breeding in Pirna-Graupa, Saxony, Germany, has been responsible for tree breeding activities with fast-growing tree species, i.e. Aspen, hybrid larch and Douglas fir among others. During this period, breeding had to face the challenges of afforestation of clear cut areas after the 2nd World War, of large scale air pollution damages until the mid of the 1990s as well as of increasing impacts of climate change in the northern parts of Saxony since the beginning of the 21st century. Each generation of forest tree breeders had to cope with the influences of changing environments by adjusting the breeding programmes in a proper way. Beside the information on breeding of fast-growing tree species, this presentation will also introduce the post-session field trip to Saxony.

The tree species Aspen, Norway spruce, Scots pine, Birch, Larch and Douglas fir have been dealt with most intensively. To improve the forest reproductive material, a broad spectrum of breeding tools have been applied like selection of plus trees and stands, crossbreeding and establishment of seed orchards as well as provenance research and progeny tests. The selected material was and is phenotypically and genotypically characterised using morphological, phenological and physiological traits as well as genetic markers. Field trials have been combined with testing under controlled conditions in the greenhouse. Breeding work and measures of conservation of genetic resources have always been running together.

Resulting from breeding activities over seven decades, Sachsenforst established an extensive net of experimental trial plots as well as a system of approved seed stands and approved seed orchards distributed all over Saxony for most conifer and several broad leaved species. Improved forest reproductive material can be produced from approved basic material such as family parents of Aspen, Douglas fir and hybrid larch. The most important conservation objects (stands and single trees) of about 30 tree species have been identified, described and used as base for in situ conservation activities. Additionally, numerous conservation stands, seed orchards and clone collections have been established ex situ. In particular cases, this led to the development of species protection programmes, e.g. for Silver fir or Black poplar.

The conservation and the sustainable use of forest genetic resources go hand in hand. The conservation of the genetic potential is the base for its actual and future use. Knowledge on the characteristics and the adaptability of forest genetic resources under the present site conditions will assist the objective of the breeding work to maintain or improve the possibilities of production and use of timber under future conditions regarding stability, quality and productivity.

**Key words**: Fast-growing tree species, breeding, changing environments.

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THE ANALYSIS OF GENE EXPRESSION PROFILE IN SALIX UNDER SALT STRESS

Jie Zhou1, Jiwei Zheng, Baosong Wang and Xudong He

Soil salinization is a great ecological problem which impacts local economic and social development. The genus Salix comprises more than 500 species including trees, shrubs and creeping worldwide and has great genetic advantages such as modest genome size, fast-growing and easy vegetative propagation. However, there is no available information of genomic background for salt tolerance mechanism.

Here, to obtain a comprehensive transcription in Salix and an overview of its gene expression profiles under salt stresses, six transcripts from leaves of S. suchowensis treated with NaCl for 0h, 2h, 6h, 12h, 24h and 48h were built by using RNA-seq technology. In total, 287 933 894 clean reads were obtained, and 249 257 246 reads were mapped (86.57%). With the “Trinity” de novo assembler, a total of 127 397 isogenes were obtained with an average length of 1008bp and a N50 length of 1343bp. There were 808, 514, 318, 2091, 1560, 532 genes significantly differentially expressed after stress for 0h, 2h, 6h, 12h, 24h and 48h, respectively. DEGs were annotated and assigned with gene ontology categories and Kyoto Encyclopedia of Genes and Genomes databases in the five sets (0 vs. 2h, 0 vs. 6h, 0 vs. 12h, 0 vs. 24h and 0 vs. 48h). Biological process was the most abundant in the three sets (0 vs. 2h, 0 vs. 6h, 0 vs. 48h) and molecular function was the most abundant in the other two sets (0 vs. 12h, 0 vs. 24h). Meanwhile 22, 18, 15, 11, 17 pathways were highly enriched in the five sets. Dynamic changes of DEGs classified the highly expressed genes into 10 clusters. The real time PCR (qRT-PCR) was conducted to validate the validity of sequencing and the results were highly in agreement with the DGE results. Our study may provide an in-depth view of stress tolerance mechanisms in Salix.

Key words: Transcription, Salix, RNA-Seq, DEG, salt stress.
AN HISTOLOGICAL AND BIOCHEMICAL COMPARISON OF RESISTANT AND SUSCEPTIBLE

POPULUS GENOTYPES INOCULATED WITH SPHAERULINA MUSIVA

Nivi Abraham¹, Periasamy Chitrampalam, Pawel Borowicz, and Jared LeBoldus

_Sphaerulina musiva_, the causal agent of leaf spot and stem canker, is responsible for critical yield loss in _Populus_ spp. However, the mode of leaf infection and the defense response of _Populus_ spp. is still unclear.

To understand the host-pathogen interaction, histological comparisons were performed between resistant and susceptible genotypes of hybrid poplar inoculated with conidia of _S. musiva_. Leaf infection was examined at 48h, 96h, 1wk, 2wk, and 3wk post-inoculation (wpi) using scanning electron microscopy (SEM), fluorescent and confocal microscopy. Observations made with SEM and laser scanning confocal microscopy indicated no major differences in pathogen growth and penetration of leaves between resistant and susceptible genotypes. Infection hyphae from germinated conidia entered stomata and penetrated the cuticle directly. Growth of germ tubes from conidia appeared to be random over the host surface and not directed toward stomata or a specific surface feature. Germ tubes often branched and multiple infections originating from a single germ tube were observed. Attachment of the hyphae to the leaf surface was revealed by the appearance of fibrillary extracellular matrices. Swelling of conidia at the tip and middle were occasionally observed. Germ tubes typically originated from these swellings.

The host response will be studied by examining the accumulation of hydrogen peroxide (H₂O₂) using fluorescent microscopy after DAB staining. To better visualize the infection process _in planta_, _Agrobacterium tumefaciens_ mediated transformation of _S. musiva_ red fluorescent protein is currently being conducted.

**Key words:** _Populus, Sphaerulina musiva_, host-pathogen interaction, RFP transformants, SEM, confocal microscope, fluorescence microscope.

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GROWTH, PHOTOSYNTHETIC PIGMENTS AND NUTRIENT STATUS OF ECTOMYCORRHIZAL NON-TRANSGENIC AND TRANSGENIC

**POPULUS ALBA x P. GLANDULOSA**

N.S. Aggangan¹², S.H. Han³, YI Choi² and E.W. Noh²

Two concurrent experiments were conducted to determine the effect of inoculation with ectomycorrhizal (ECM) fungi on growth, photosynthetic pigments and nutrient status of non-transgenic (NT) and transgenic heavy metals (Zn, Cd and Pb) tolerant *Populus alba x glandulosa*. The transgenic clones were developed and produced at the Biotechnology Center, Korea Forest Research Institute, Suwon primarily for rehabilitation of mine tailings. In the first experiment, the transgenic clones were NYCf7 and PABC2 5 which were inoculated with ECM fungi *Pisolithus tinctorius*, *Paxillus involutus* or *Amanita pantherina*. In the second experiment, PCP301CGoR4 and Cd26c2 were inoculated with *P. tinctorius* or *A. pantherina*. Tissue cultured clones were inoculated with mycelia of ECM fungi during transplanting into plastic pots filled with autoclaved peat perlite vermiculite medium. The experiments were conducted following a Randomized Complete Block Design with 10 replicates.

Four months growth in a glasshouse revealed that ECM inoculation differed among clones and there was a significant interaction between clones and ECM. In the first experiment, *Pisolithus* was the best among the three ECM fungi tested followed by *Paxillus* while *Amanita* was the least effective. NYCf 7 and PABC2 5 grew better than the NT poplar. NT plants did not respond to ECM inoculation in the first experiment. However, in the second experiment, *Amanita* promoted the highest height, stem diameter and total biomass. In the second experiment, PCP301CGoR4 grew better than the NT poplar. *Pisolithus* and *Amanita* were equally effective in promoting the growth of PCP301CGoR4 and Cd2bc2. NT plants had the lowest height, diameter and dry matter yield except that these plants had the longest (*p<0.01*) root while PCP301CGoR4 grew better and had higher dry matter yield than Cd26c2. The Cd26c2 plants gave the highest chlorophylls a, b and a+b while the lowest were observed in PCP301CGoR4. *Amanita* and *Pisolithus* increased total plant biomass of NT and PCP301CGoR4 plants by 2.2 fold and 5.7 fold, respectively. *Pisolithus* and *Amanita* gave similar root colonization levels in each clone.

Irrespective of ECM treatment, PCP301CGoR4 had higher nutrient uptake than in Cd26c2 plants while NT had the lowest. *Amanita* promoted the highest growth, dry weight and nutrient uptake of NT, *Amanita* and *Pisolithus* promoted similar nutrient uptake of PCP301CGoR4 and Cd26c2. This study provided strong evidence that the mycorrhizal fungi *Amanita pantherina* and *Pisolithus tinctorius* can promote growth of non-transgenic and transgenic clones of *P. alba x glandulosa* thus, can be used in phytoremediation.

**Key words:** Amanita, ectomycorrhizal fungi, phytoremediation, Pisolithus.

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Acacia mangium Willd. is one of the favoured fast-growing legume reforestation species due to its high quality for wood for furniture making and can survive to stressed environmental conditions such as those in mine tailings. Survival in the latter is due to the tri-partite (nitrogen fixing bacteria-ecto and arbuscular mycorrhizal fungi) symbionts. This study was conducted to determine the efficacy of mycorrhizal inoculants with brand name MYKORICH® and MYKOCAP® in promoting growth of Acacia mangium under nursery and field conditions with applied increasing level of slow release (Osmocote, 14-14-14 NPK) fertilizer. MYKORICH® and MYKOCAP® are biofertilizers developed in the Philippines.

Aseptically germinated A. mangium were uninoculated or inoculated with MYKORICH® or MYKOCAP® coded as Myk or SC, respectively, during pricking. Mycorrhizal inoculants consist of eight mixed species under the genera: Glomus, Gigaspora, Scutellospora, Acaulospora and Entrophosphora. Mycorrhizal spore counts in Myk#00, Myk#1 and Myk#4 were 85, 38 and 25, respectively, while that in SC#00, SC#1 and SC#4 were 230, 74 and 24, respectively. Seedlings were grown in polybags filled with oven sterilized 1:1 garden soil and sand. Two weeks after pricking, five rates (0, 0.25, 0.5, 1.0 and 2.0 g/plant) of NPK fertilizer (as Osmocote, 14-14-14) coded as P0, P1, P2, P3, and P4, respectively) were applied to two inches below the soil surface.

Three months after transplanting, the control (no mycorrhizal and fertilizer) plants has the lowest height (19.1 cm) and stem diameter (0.44 cm) while mycorrhizal counterpart were 25-58% and 13–32% higher height and stem diameter, respectively, relative to the control. SC#00 gave the tallest height and stem diameter. Myk#00 and SC#00 promoted the highest shoot biomass at P1 whereas the control plants had the highest shoot biomass at P2. Youngest fully expanded leaf (YFEL) N concentration was increased from 15% to 31% and YFEL P from 20 to 26% relative to the control (1.149% N and 0.134% P), irrespective of P level. Nodules were observed only in seedlings with no applied fertilizer and those fertilized with 0.25g/plant (P1). P1 and P2 treatments generally, gave the optimum growth of A. mangium in the nursery.

SC#00 inoculated plants with no NPK fertilizer gave the highest height increment six months after field planting in marginal grassland which significant as compared with those inoculated with Myk#1, Myk#4 and control. Addition of 20g/plant (P3) on SC#00 inoculated plants gave the biggest stem diameter after one year in the field. At two years, height ranged from 3-5m and stem diameter from 10-13cm with no significant differences. The above results indicate that Mykorich SC#00 or Mykocap Myk#00 in combination with 0.25 to 0.5g NPK /plant can be effective in producing healthy A. mangium in the nursery that can be used for rehabilitation and reforestation programmes.

Key words: Acaulospora, Entrophosphora, Gigaspora, Glomus, osmocote.
PLANT DECLINE ETIOLOGY IN POPLAR SHORT-ROTATION COPPICES

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The fight against Global Changes requires the development of renewable energy sources alternative to fossil fuels. For this purpose, a very important role is represented by biomass from short-rotation coppice (SRC) plantations of various forest plants, especially poplars (\textit{Populus} spp.). With frequent coppicing cycles (every 3-5 years), one of the most serious problems of SRC is represented by stump mortality, usually attributed to physiological factors. In recent years, in some areas of central Italy, the stump mortality was particularly worrying, usually preceded by a more or less rapid shoots decline that seemed to be attributable to parasitic attacks. Investigations have therefore been conducted in order to determine the etiology of these phenomena, as well as to define the symptoms, the predisposing factors and the eventual clonal differences.

The observations were conducted in poplar SRC plantations located in Viterbo-Italy (dry Mediterranean climate), established with three clones and a planting density of 6060 plants/ha. Plantations are managed with a 3 year-coppicing cycle, and observations were carried out on stumps on the first, second, and third year after coppicing. The various symptoms of the phenomenon over time and the degree of shoot decline were evaluated according to a suitable rating scale. We carried out \textit{in vitro} isolation from altered tissues of diseased plants and pathogens identification were conducted through molecular analysis.

The external symptoms began with the yellowing and sometimes necrosis of the leaves, microfilia, reduced shoots growth, followed by withering, usually maintaining attached the dead leaves to the shoot. The phenomenon culminated with the death of the stump. Throughout stump sectioning, we detected browning of internal tissues of roots and shoots base, gradually more and more deepening into the organs. In severe cases, we observed wood decay in central part of the stump, more or less deepening into the root system. The observed symptoms were almost zero on stumps one year after coppicing, very modest in the second year after coppicing, and increased a lot in the third year.

In the light of laboratory analysis, it would appear that the phenomenon is due to a complex etiology disease, predisposed and triggered by various factors, leading some endophytic fungi to take pathogenic character, culminating with typical wood decay attacks. Among the already identified fungi, we isolated the genus \textit{Acremonium} and some colonies of the order \textit{Hypocreales}, and, among wood decay agents, the genus \textit{Pholiota} and \textit{Collibia}. Of the latter, we have also induced basidiocarps on toppled stumps stored in a controlled environment.

According to our observations, it would seem that the studied die-off is similar to a complex disease, that seemed to be predisposed by loose soils, triggered by prolonged drought, and finally the die-off is manifested by attacks of various weakness pathogens. Although the phenomenon appears to be mainly concentrated on the central and southern Mediterranean areas of Italy, it is likely that with the Climate Change it can also extend to northern areas. The choice of soil with good water retention, the use of tolerant clones to water stress, the reduction of the coppicing frequency and, where possible, supplemental irrigation could represent appropriate measures to prevent or mitigate the phenomenon.

\textbf{Key words:} Stump mortality, wood decay, etiology disease, climate change.

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LEAF BIOASSAY AGAINST CURVULARIA SP. TOxin FOR THE RESISTANCE SCREENING OF POPULUS DELTOIDES GERmplASM

Archana Bagwari¹, Y.P. Singh¹, J. Kumar² and R.C. Dhiman³

Poplar, an environment friendly plant species, is an alternative source of raw material for pulp production due to its wood quality and potential fast growth. In India, poplar is grown under forestry and agroforestry programmes as clonal plantations. Poplar clones, being raised as monocultures, are thus prone to a large number of pathogens and disease outbreaks. Scores of foliage diseases were recorded in poplar nurseries. During field surveys between 2008-12, Curvularia leaf spot was observed on several commercial clones of P. deltoides (G-48, Udaí, WSL-22 & WSL-39), underlying their wide presence. Such pathogens, in future, may cause large scale damage to the tree crop leading to substantial economic losses to the growers. The negative effects of pathogens on poplar growth have inspired breeders to make disease resistance as the major selection criterion in poplar tree improvement for last 50 years.

Various cultural and chemical control strategies have been suggested for most of the major poplar pathogens. If available, the use of resistant clones is the best long-term management practice. Toxins are compounds that are produced by the pathogens and cause part or all of the symptoms of a disease. So, leaf bioassay was performed for screening resistance of poplar genotypes against Curvularia sp. toxin(s). This method was employed to screen commercial clones of poplar (G-48, Udaí, WSL-22, WSL-39 etc.) by using 15 isolates of Curvularia sp. Experiments were designed to work out the concentration (20, 40, 60, 80 and 100% of toxin) and volume (30, 40, 50, 60 and 70 µl of toxin) of the toxin, position (lower, middle and upper) and condition (un-pricked and pricked) of the leaf. Observations on time of initiation and extent of symptoms were recorded after 24 and 48 hrs of toxin inoculation. The disease area was estimated by using Biovis software. Shoot juvenile experiment was also performed for screening.

Initially, only one isolate of Curvularia sp. (no. C-39) was used for the standardisation of the experiment. Based on time of initiation and extent of necrosis, 100% toxin concentration and 70 µL of toxin volume were selected for testing. Three isolates (no. C-5, C-29 & C-35) exhibited necrotic area on un-pricked leaf of all four P. deltoides clones tested showing their universal virulence. Un-pricked leaf showed delayed symptoms appearance as compared to pricked one hinting at existence of structural and/or biochemical defence in all the clones tested. In case of pricked leaf, upper leaf had earliest symptoms appearance. Barring WSL-22 (middle leaf), upper leaf showed more necrotic area in rest of the three clones tested. Isolate no. C-5 exhibited maximum necrotic area in all four clones tested making it potential choice for the screening. Clone G-48 took minimum and WSL-39 maximum time in symptom development when their shoot juveniles were tested against the toxin of isolate no. C-5 and C-35 of Curvularia sp. Both the methods were found quick and effective for screening and selection of promising germplasm against the leaf spot pathogen.

Key words: Agroforestry, clone, disease, germplasm.

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EVALUATION OF SOME GROWTH AND FUNCTIONAL RESPONSES OF SALIX CLONES IN RESPONSE TO FLOODING

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The Delta del Paraná area (Argentina) is constituted by a mosaic of wetlands in which willow and poplar crop forests have a relevant productive role and flooding is the dominant natural disturbance. Tolerance to flooding events is a key attribute for willow clones to maintain growth and productivity. We examined some growth and functional responses of two willow clones, subjected to different flooding regimes simulating waterlogging conditions during early establishment. In a manipulative experiment, stem cuttings of Salix matsudana x Salix alba ‘Barrett 13-44 INTA’ and Salix matsudana x Salix nigra ‘Lezama INTA-CIEF’, a recently registrated clone, were subjected from December to mid-February to three flooding regimes: control: without flooding (C), transient flooding (T) and permanent flooding (P).

At the end of the experiment, ‘Barrett 13-44 INTA’, in contrast to ‘Lezama INTA-CIEF’, showed a strong decrease in stem height and in the total aerial biomass at both levels of flooding treatments (T and P). ‘Lezama INTA-CIEF’, achieved similar average values for both variables among flooding treatments showing evidence of better tolerance to flooding stress conditions. The biomass of underground roots was higher for clone ‘Lezama INTA-CIEF’, irrespective of the flooding regime and, on average, decreased from C to T flooding treatment. The biomass of aerial adventitious roots was on average higher for the clone ‘Lezama INTA-CIEF’ than for ‘Barrett 13-44 INTA’, regardless of flooding regime. For ‘Barrett 13-44 INTA’ stomatal conductance strongly decreased in T and P flooding treatments compared to the control (C), whereas ‘Lezama INTA CIEF’ maintained similar levels of stomatal conductance among flooding treatments. On average plant water potential was lower for ‘Lezama INTA-CIEF’, irrespective of flooding conditions. The number and length of aerial adventitious roots (growing in the air-water interface) were higher for clone ‘Lezama INTA-CIEF’ than for ‘Barrett 13-44 INTA’, mostly when growing under permanent flooding conditions. Microscopic studies of aerial adventitious root tissue of “Lezama INTA-CIEF” from P flooding treatment, showed the presence of chloroplasts. These preliminary results indicated that the new clone ‘Lezama INTA-CIEF’ shows good tolerance to flooding based on some growth, morphological and functional behavior.

Key words: Salix, clones, flooding tolerance, growth, functional responses.

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METHODS FOR DIAGNOSIS OF ASPEN SUSTAINABILITY

Oxana Chernyshenko¹, Denis Rumyantsev¹ and Elena Sarapkina¹

Despite the long study of the mechanisms of aspen resistance, the causes of stable and unstable stands in nature remain unclear. Traditional research methods, e.g., analysis of polymorphism of aspen populations according to phenetic traits, have not revealed a satisfactory relationship between phenotypic characteristics and economically significant properties of plants. Selection methods of aspen (Populus tremula) undertaken in the USSR to date have shown some good results at present. First of all, it refers to the study of natural clonal diversity, selection, testing, and identification of valuable clones. The hybridization of clones and species of aspen can provide no less valuable results than a selection of genetic aspen forms in natural tree stands. Thus, the famous national forest geneticists analyzed the test results of different hybrid aspen offspring and impressive results were achieved.

High radial growth as a factor of resistance to stem rot caused by Phellinus tremulae can be achieved by artificial stimulation in the aspen stands. Stand management by regular thinning contributes to aspen stands stability by reducing stem rot. Further stimulation of radial growth can be achieved by different methods, and one of the most widely known is application of fertilizers. Other methods include the formation of agronomic schemes of tending, which change the microclimate of areas favorable for tree growth. Dendroclimatic diagnosis can be a first step for developing this kind of technological schemes of tending. One of the factors of disease control is a high rate of radial growth of the trunk, which allows to overgrow the wounds of dead branches quickly to prevent the possibility of penetration of Phellinus spores. In this regard, a study of the environmental factors limiting radial growth of aspen in natural and artificial stands is the focus of studying the resistance of aspen forests against rot.

Using dendrochronological information, the aim of our study is to identify aspen individuals that are resistant to rot and drought considering changes in meteorological parameters. For this, permanent and temporary plots were established in urban forests of Moscow, in the Central and Mordovian forest reserves, Valentinovka forest nursery. The results of the study revealed aspen trees with potentially enhanced genetic resistance to drought. According to the results of the calculations, true and stable correlations were established between the fluctuations of radial growth and variations of meteorological parameters. Moreover, factors were determined, affecting dramatically adversely the growth and condition of trees. Analyzing the research data, it should be noted, that many attempts to improve aspen forests productivity in Russia sustainably over the years of studies have not produced significant results in practice. No phenotypic forms of aspen resistant to rot were revealed on the economically significant level. At the same time, natural clones and artificially produced hybrids are already known, and we have reasonable hope of getting offspring resistant to rot.

On the other hand, it is necessary to carry out detailed research of the factors determining the diameter growth rate of aspen trees in forest stands, being in a critical age for the infection with Phellinus. This can be achieved using methods of dendrochronological analysis.

Key words: Aspen, Populus tremula, Phellinus tremulae, dendrochronology.

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BIOMASS AND CARBON STOCK IN PLANTATIONS: MANIPULATION THROUGH GENOTYPE AND SPACING

P.A. Clara Manasa¹, Ramakrishna Hegde¹, Abhiyu Singh² and B.K.M. Amanulla²

_Eucalyptus urophylla_ ST. Blake is one of the fast-growing tree species introduced to India as pulp wood species. Different clones of _E. urophylla_ have been identified for field planting. Attempts were made to identify most suitable clone for the region and standardize the spacing on yield.

The present paper deals with the findings on biomass and carbon stock of different clones of _E. urophylla_ under tropical humid conditions of South India. Further spacing trial was established to assess the effect of different spacing regime on the growth, biomass and carbon stock of clone EUB 31. After six years of planting, biomass and carbon stock in both the trials were evaluated. A significant influence of genetic stock and spacing on the carbon stock in the trees was evident in the study. Estimated carbon stock from different clonal plantations varied from 118.59 tonnes ha⁻¹ to 182.53 tonnes ha⁻¹ with a mean annual carbon sequestration of 19.75 tonnes ha⁻¹ yr⁻¹ to 30.42 tonnes ha⁻¹ yr⁻¹. The highest carbon was sequestered by E34 clone. Carbon stock for different spacing was ranging from 42.1 tonnes ha⁻¹ to 56.2 tonnes ha⁻¹. Among the different spacing regimes, spacing 2.00 m × 3.00 m was found to have higher carbon stock and mean annual carbon sequestration compared other spacing regimes. The carbon sequestered annually had a significant difference among the spacing regimes with values ranging from 7.02 tonnes ha⁻¹ yr⁻¹ (2.75 m × 3.00 m) to 9.37 (2.00 m × 3.00 m) tonnes ha⁻¹ yr⁻¹. Thus, carbon sequestration potential in trees can be manifested through selection of genetic stock and spacing.

**Key words:** _Eucalyptus urophylla_, clones, spacing, biomass, carbon stock, mean annual carbon sequestration.

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DROUGHT TOLERANCE VARIATION OF HYBRID LARCH IN GREENHOUSE EXPERIMENTS

María del Carmen Dacasa Rüdinger

Hybrid larch resulting from crosses between European and Japanese larch (Larix decidua x Larix kaempferi) has been shown to display heterosis for several commercial traits like growth and stem form and to thrive well on a broader range of ecological conditions than its parents. This makes hybrid larch especially interesting for its use in reforestation programmes within the frame of short-rotation management systems. However, a large variation exists among hybrid families regarding the extent of the heterosis effect. This fact has to be considered in breeding programmes in order to maximize the genetic gain for the desired traits. The department of forest genetics and tree breeding of the public enterprise Sachsenforst has been working on larch improvement for about 70 years. In view of the predicted rise of temperatures in Saxony, the current larch breeding programme aims at generating hybrid progenies that combine a superior performance of growth, stem straightness and branching quality with a higher resilience against drought stress.

The drought stress tolerance of five hybrid larch varieties has been assessed in a greenhouse experiment. All varieties correspond to the category “tested” as defined by the Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material. To prove the potential hybrid superiority, seedlings of the parental species of the hybrids, European and Japanese larch, were included in the experiment as a reference. A total of 50 one-year old seedlings per variety and parental line were used in the experiment and divided into two groups. One served as a control group and was regularly watered until the end of the experiment after nine weeks while the other group was left without watering during the whole period. In addition, the stress tolerance of 21 hybrid larch clones derived from somatic embryogenesis was determined using ten ramets per clone divided in a control and a treatment group. The clones represented five full sib families, two of them categorized as “tested” varieties. The level of drought stress resistance was determined based on a combined evaluation of the results obtained from three different assessments: the visual determination of plant vitality evolution, the calculation of height growth during the experiment and the measurement of chlorophyll fluorescence on a subsample of seedlings at different time points during the experiment using a portable chlorophyll fluorometer (Heinz Walz GmbH).

A large variation among and within progenies was observed in the reaction of seedlings to the drought stress treatment. One of the studied varieties did not show heterosis. By now, three hybrid larch varieties seem to be consistently more tolerant against drought stress than European and Japanese larch. This result has to be confirmed by field experiments. The clonal experiment confirmed the large variation among individuals, even when these belong to the same family. These important differences in the response of hybrid larch progenies and clones to drought stress emphasize the potential of phenotyping not only at family level but also at the individual one for detecting superior genotypes.

Key words: Hybrid larch, heterosis, drought stress tolerance.

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HEAT INJURY TO FRESHLY PLANTED POPLAR SEEDLINGS IN NURSERIES

Ramesh Chand Dhiman and J. N. Gandhi

Poplar (Populus deltoides) saplings are grown from stem cuttings which are planted during winters when it is under dormancy. Recently, Wimco Seedlings started its nursery production by first growing seedlings in containers (root trainers) from mini cuttings and then their planting in open nursery beds during post-spring season till onset of summer rains. It has been repeatedly observed that containerized seedlings planted late during the months of May and June get repeated drying after some time of planting when temperature rises very high to around 45°C. The classical pattern of heat injury forms a ring of 2-4 cm of dead tissues around the stem near the ground surface and the seedlings above this portion get dried. A close observation of such seedlings led to an inference that the dry and hot conditions during the months of May and June warm up the soil and/or water used for irrigation which remains stagnated in nursery beds/furrows for some time. The portion of seedlings below ground level remains alive, active and invariably produces coppice shoots from stem below damage or root suckers.

Twenty-five centimeters tall seedlings of clone Wimco 110 grown in containers were planted in two separate experiments viz. in 1500 cc capacity earthen pots and in the middle of furrows in open nursery beds. The freshly planted seedlings in May 2015 were irrigated for seven consecutive days with 400 ml and 3000 ml of 45°C, 60°C and 75°C temperature and normal water/seedling in pots and beds respectively. Observations recorded after 15 days of irrigation had significant effect on total number of old leaves, number of fresh leaves and mortality of seedlings. Maximum height of 31.7 cm was recorded in seedlings irrigated with normal water which was gradually reduced to 28.7 cm, 28.3 cm and 27.0 cm in 45°C, 60°C and 75°C hot water irrigated seedlings in nursery bed experiment. Similarly, the number of old leaves and of fresh leaves was maximum i.e., 14.3 and 2.3 respectively in seedlings with normal irrigation water. These values were as low as 1.0 and 0.01 in 75°C in seedlings irrigated with hot water. Maximum mortality (100%) was recorded in seedlings which were irrigated with 75°C hot water and this value was significantly higher when compared with those seedlings having normal irrigation water and those with 45°C hot water. Classical ring formation of dead tissues was recorded only in case of seedlings irrigated with 60°C and 75°C hot water. In pot experiment, too, the trend was similar to nursery experiment for all the studied parameters those also include ring formation of dead tissues and significantly higher mortality of seedlings irrigated with 60°C and 70°C hot water.

Key words: Heat injury, poplar seedlings, irrigation, temperature.

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TOLERANCE CHARACTERISTICS OF NEW TOP PERFORMING BLACK AND BALSAM POPLARS AGAINST MELAMPSORA LARICI-POPULINA TESTED IN SHORT-ROTATION COPPICES

Christina Fey-Wagner¹ and Alwin Janßen¹

The numerous advantages of the cultivation of fast-growing trees such as poplars and willows in short-rotation coppices (SRC) to produce biomass for energetic and material use is meanwhile widely accepted. So the importance of SRC with these species has been increased in Germany during the last few years. However, the reproductive material that is currently available on the market is based on a very limited number of suitable clones with a narrow genetic base. Due to the genetic susceptibility to disease and insufficient adaptability of the clones currently used on SRC, plant pathogens, mainly the leaf rust Melampsora larici-populina, evolved to an important risk factor for the operational safety of SRC.

So the focus of the joint research project “Breeding of fast-growing tree species for the production of renewable resources in short-rotation coppices” (FastWOOD) is breeding, genetic characterisation and evaluation of new black and balsam poplar as well as willow clones. The short rotation suitability of new varieties is controlled and evaluated not only on high yield but also by a continuous characterization of their tolerance characteristics under a broad range of rust infection and climate conditions as well as site properties on test trials distributed throughout Germany.

The tolerance behaviour of all selected high-yielding clones against the poplar leaf rust Melampsora larici-populina was frequently evaluated. Additionally the diversity of occurred pathotypes of the plant pathogen on selected poplar clones was analysed. First results from the test series show that newly bred varieties could double the yield of recently used clones. The results of the yield potential were combined with the evaluated tolerance characteristics of clonal rust infestation intensity. An overview of the development of leaf rust infections and pathotype occurrence during two mini-rotation periods related with the results of biomass yields at six black- and balsam poplar-plots established in the joint research project FastWOOD will be given.

Key words: Poplar, breeding, SRC, Melampsora larici-populina, leaf rust.

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IMPORTANCE AND MANAGEMENT OF THE RED POPLAR LEAF BEETLE (*CHRYSOMELA POPULI* L.) IN SHORT-ROTATION COPPICES (SRC): AN OVERVIEW

Richard Georgi¹ and Michael Müller¹

The cultivation of fast-growing tree species on agricultural land for the production of woody biomass is one key pillar for a sustainable supply of bioenergy in Germany. Owing to the use of a low number of clone varieties, the so called short-rotation coppice (SRC) plantations are highly susceptible to biotic risk factors. Therefore, damage caused by insect pests is of major importance in the management of SRC.

In a study carried out in 2013, the influence of the great red poplar leaf beetle (*Chrysomela populi* L.) on plant growth was determined by measuring the weekly increment of plants damaged by the feeding of beetles and larvae (n=120) in comparison to plants protected by insecticides (n=120). Additionally, all feeding development stages of *C. populi* were counted weekly. By using a linear mixed-effect model, a significant influence of the insect feeding on the weekly plant growth was confirmed, even though no second generation of *C. populi* developed this year due to the heavy predation of *Parasyrphus nigritarsis* larvae on egg clusters of the leaf beetle in spring. At the end of the growing season, all shoots were harvested and measured. The plant biomass in treated plots was 15% higher than in untreated plots (7.1 to 6.0 odt/ha).

An overview of integrated pest management strategies to minimize the impact of *C. populi* is given with an emphasis on biological control methods. Interestingly, natural enemies were found on all development stages of the leaf beetle, in spite of the defensive secretion of larvae and pupae. The predatory larvae of the hoverfly *Parasyrphus nigirtarsis* [Zett.,1834] and the parasitoid wasp *Schizonotus sieboldi* (Ratzeburg) rank among the most important antagonists. A laboratory experiment demonstrated that the presence of food sources, such as pollen and nectar, can prolong the longevity of female *S. sieboldi* individuals from 1 ± 1 day without food to 60 ± 9 days with nectar, which was found to be the best source of food.

Accordingly, further studies will focus on conservation of biological control measures aiming to keep the population of *C. populi* below the economic injury level in a biological manner.

**Key words:** Pest insect, economic injury level, integrated pest management, biological control.

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MIXED STRATEGIES FOR WILLOW DEFENSE - RESISTANCE AND TOLERANCE TO HERBIVORY UNDER VARYING NUTRIENT REGIMES

Carolyn Glynn¹, Daniel A. Herms², Olof Widenfalk³, Riitta Julkunen Tiitto⁴ and Ann Christin Rönnberg-Wästljung⁵

Combinations of plant traits (phytochemical production, regrowth capacity, resource allocation to below ground storage and regrowth biomass) are those that allow plants to express their resistance to and tolerance of herbivory. Genetic as well as environmental components of these coping strategies were investigated in Salix viminalis (high in tannins) and S. dasyclados (rich in phenolic glycosides) and six of their F2 hybrids. We subjected plants to three soil nutrient treatments and simulated winter browsing. After the second growing season we quantified the effects of willow genotype, soil fertility and browsing treatment on resource allocation to below and above ground biomass, photosynthesis and production of phenolic compounds. As a measure of plant resistance to insect herbivores, we assessed damage after natural colonization of the potato leafhopper (Empoasca fabae) and conducted laboratory bioassays on white marked tussock moth larvae (Orgyia leucostigma).

We found that phenolic levels decreased with increased soil fertility and that there was higher compensatory regrowth in all clones at lower soil nutrient levels. We found no evidence of a tradeoff between tolerance (biomass recovery after herbivory) and defense as measured by condensed tannins, flavonoids, chlorogenic acids or by total phenolics. There was a significant genotypic variation in the levels of these phenolics. Tolerance did not vary between genotypes despite large genotypic variation in accumulated plant biomass in all fertility treatments. Plants in low nutrient treatments compensated more of the loss due to browsing than did high nutrient plants. Leafhopper damage varied among willow genotypes but was not related to levels of secondary metabolites. White-marked tussock moth larvae bioassays revealed that willow genotype, fertility and browsing treatments all affected larval development. Our results show that factors such as plant genotype, soil fertility and herbivore damage strongly affect the defense interactions between willows and their herbivores.

Key words: Compensatory growth, insect resistance, genotypic variation, phenolic, browsing.

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GROWTH AND PHYSIOLOGY OF *SALIX* CLONES IN RESPONSE TO DROUGHT AND REWATERING

A.B. Guarnaschelli¹, P. Pizzorno¹, J.P. Esposito¹, A.M. Garau¹ and S. C. Cortizo²,³

Water is one of the most important resources for the growth of willow crops. Nowadays climate change is altering the water availability, and crops are subjected to frequent alternate drought and high water supply periods. The high productivity of hybrid *Salix* cultivated in Argentina could be compromised by droughts, but the severity could vary according to the time of the year when the water restriction occurs. In addition, the responses to drought and recovery could be different among genotypes. The understanding of how plants respond to such environmental variability and how they recover are key issues for crops productivity.

The purpose of this study was to assess willow clones performance, which were exposed during their first growing period to two cycles of differential irrigation. Stem cuttings of *Salix matsudana* x *Salix alba* ‘Barrett 13-44 INTA’ and *Salix matsudana* x *Salix nigra* ‘Lezama INTA CIEF’, clones of economic importance in the Paraná River Delta (Argentina), were exposed from the last days of November to mid-February to two water regimes: well watered (W) and water stressed (S). After that, plants of each treatment were divided in two groups and irrigated differently until the end of April, which resulted in four water regimes (WW, WS, SW, SS). Several physiological and morphological attributes were evaluated and their phenotypic plasticity indexes were calculated. Plants exhibited physiological and structural adjustments in response to the decrease in water availability. Leaf abscission and a decrease in stomatal conductance occurred in S plants. At the end of the first cycle, water restriction reduced plant growth in both clones. During the second cycle, drought conditions reduced tissue water potential, stomatal conductance and leaf area of WS and SS plants. By contrast, plants that were rewatered (SW), showed a rapid increase in tissue water content, higher rates of stomatal conductance, and produced new leaves. Although SW plants resumed growth, they did not reach values of WS plants. The effects of water stress reducing growth were more severe when drought occurred during the springtime. At the end of the second cycle, water stressed plants (WS and SS) had lower values of specific hydraulic conductivity ($K_s$) than well irrigated plants (WW and SW); and Barrett had higher values of $K_s$ than Lezama. Both clones were able to cope with drought conditions and had the capacity to recover after rewatering. Clone Barrett showed higher plasticity and was more productive than Lezama irrespective of the water regime.

These results are discussed considering the importance of plant phenotypic plasticity in the present scenario of environmental variability.

**Key words:** *Salix*, clones, water stress, recovery, growth, phenotypic plasticity.

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Unlike animals that can avoid injury by moving, plants utilize special defense systems against environmental stresses. In response to mechanical damage, herbivore attack and pathogen infection, plants can release a range of volatile organic compounds (VOC). Such VOC can serve as an odor of defense by directly repelling the herbivores or attracting predatory or parasitoid arthropods. Likewise, some odors might act as interplant signals that are perceived by neighbouring plants to adjust their defensive phenotype according to the present risk of attack. Some of these odors are constituent VOC, while others are released only after specific damage.

Our experiments, including herbivore damage to different poplar species, demonstrated by measurements with a gas-chromatograph/mass-spectrometry set up that the components of the odor bouquet released at different times upon herbivore damage change significantly in their intensity and by species revealing different defense strategies in these poplar species. Greenhouse and field trials, including choice tests, feeding assays, and field collection of insects, confirmed differentiated effects on herbivores and antagonistic insects hinting at non-linear hybridization effects regarding the composition of herbivore induced volatiles and resulting defense strategies.

**Key words:** Volatile organic compounds, poplar species, defense strategy.
RESULTS OF ANNUAL AND BIANNUAL WILLOW CLONES SHOOT SURVIVAL AND BROWSING INTENSITY IN WEST AND EAST REGIONS OF LATVIA

Dagnija Lazdina¹, Ieva Bebre¹, Kristaps Makovskis¹, Toms Sarkanābols², Irena Pučka³, Julija Konstantinaviciene⁴ and Pieter D. Kofman⁴

The willow family includes a lot of fast-growing high yield species, hybrids and clones of tree species, which are used as commercial willow short-rotation coppices (SRC). The most productive and resistant combinations of species and clones are selected for commercial uses. Before the introduction of new clones on the large scale, preliminary tests and establishment of small-scale pilot plantations are a good solution for simple determination of current clone suitability for local conditions. Simple tests of willow clone plantation of old (Olof, Sven, Torhild, Lisa, Stina, Tora, Klara, Inger, Tordis, Linnea) and new commercial clones (Estelle, Wilhelm, Birgit, Erik, Ester, Winter, Emma, Bella) and some willow material from Northwest German Forest Research Institute (“NW-FVA”), Hann. Muenden, experimental fields (9 clones of S. alba, 5 clones of S. viminalis, 2 clones of S. alba, S. alba x S. vittellina, S. malisii (x alopecuroides), S. x aquatica, S. x dasyclados, S. x helix), local species (S. viminalis, S. burjatica, S. purpurea) were planted in May 2013 in two sites on cropland (low management activity) in the western part of Latvia (56.700971, 21.717760) and in a forest tree nursery (high management activity) in the eastern part (56.681427, 25.963326). After the first and second year the resistance to winter frost of clones on both sites was evaluated, and the number of browsed twigs was counted as well.

Results show high frost resistance in commercial clones of EWB company Winter and Emma, Salixenergie company clones Inger and Lisa, the most frost resistant material from Germany were S. viminalis “Zieverich” in the western part of Latvia and S. malisii (x alopecuroides) “Malisii” in the eastern part of Latvia, and all of the local planting material. In general the least sensitive to winter frost were Winter, Emma, S. alba “Weide Godesberg” “Eckartsau”, S. viminalis “Zieverich” and Estelle.

The highest amount of browsed twig was observed in the rows where clones S. viminalis “Zieverich”, “Karmen”, Torhild and Wilhelm were planted in the eastern part of Latvia, but S. x rubens “Heilsbronn”, S. x dasyclados “Vaake”, Emma, S. x helix “Ulbrichweide” and S. alba “Rockanje” were attractive to deers in the western part of Latvia.

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Key words: Clone, willow, frost, resistance, browsing.
OLFACTORY NAVIGATION OF SAWFLIES (NEMATUS SPEC.) AS A DEVICE FOR HAZARD ANALYSIS OF DIFFERENT POPLAR VARIETIES IN SHORT-ROTATION COPPICE

Karoline Manthe¹ and Dirk Landgraf

The cultivation of fast-growing tree species on agricultural land in form of Short-Rotation Coppice (SRC) offers increasing potential for sustainable energy provision. However, the large-scale cultivation of monoculture is a major risk with respect to abiotic and biotic damaging factors, besides poplar leaf beetle (e.g. Chrysomela populi) that headed frequently in recent years to mass occurrence of sawflies, which caused large area outages in poplar plantation. Currently the regulation of mass outbreaks of sawfly (Nematus spec.) on plant protection products is restricted by special permission. The development of plant-based substances for repelling Nematus spec. seems therefore as increasingly relevant in future.

The navigation of sawflies by olfactory sensory perception has already been observed over the infestation of special poplar varieties, therefore a research project targeted extraction of specific ingredients to be examined by poplar leaves. Based on these background a newly, plant-based repellent method is being developed, that can be used in consideration of ecological, economic as well as legal conditions.

These plant-based substances are determined both by age and variety based on analysis by GC-MS. After successful determination of the volatile organic compounds of different poplar varieties, specific ingredients prove reactive with respect to the orientation behaviour of the sawfly in laboratory tests. It could be confirmed by investigations on GC-MS and behaviour tests, that poplar varieties from different sections emitting different scent pattern, with different attractiveness for adult sawflies. Nematus papillosus for example strongly preferred the poplar variety Max (Populus nigra x P. maximowiczii) in comparison to the poplar variety Jacometti (Populus x euramericana).

Key words: Sawfly, volatile organic compound, poplar, short-rotation coppice.

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COULD PATHOGENICITY BE USED AS A DETERMINING FACTOR TO STUDY ISOLATE VARIATION?

K. Naharia¹, S. Barthwal¹, U.S. Singh² and Y.P. Singh³

*Populus deltoides* is the most important part of the Indian agroforestry system. It is also used for large spectrum of products. Fungal pathogens invariably cause damage to poplar in nurseries and plantations. One of them, *Bipolaris* sp. was first reported on certain cultivars of *P. deltoides* from India in 1992. Pathogenecity is an important criterion which was designed to establish a causative relationship between a pathogen and disease. The Koch’s postulates of 11 isolates of *Bipolaris* spp. (B1, B6, B12, B15, B17, B19, B20, B86, B87, B88 and B89 from different genotypes) were proved using five commercial clones (4-month-old stem cuttings) G-3, G-48, Udaï, WSI-22 and WSL-39 of *P. deltoides*. Cuttings of different clones were transferred in poly-bags (1kg capacity) and four replications for each treatment were maintained. Spore suspensions of isolates (6 x 10³/ml) were prepared in sterilized, distilled water. The check plants were sprayed with sterilized distilled water only. The plants were kept in a moist chamber (temperature 35° to 38°C and relative humidity >90%). Treated plants were observed periodically for appearance of symptoms. Fungus was re-isolated from the diseases plants and was compared with the original culture of the pathogen for confirmation.

Drooping of young, terminal leaves of seedlings was the first symptom and there were differences in the time of appearance of drooping. Eight isolates (no. B6, B12, B17, B19, B86, B87 and B89) showed drooping from the 6th day after inoculation (dai) and in 3 isolates (no. B1, B15 and B20) on the 8th dai. On mature leaves, pink spots appeared starting from the 13th dai in isolate no. B6, B13, B15, B17, B20 and B89, 15th dai in isolate no. B12 and B15 and 19th dai in isolate no. B19, B86, B87 and B88. The pink spots started enlarging and coalescing in all isolates starting from 23rd to 30th dai. The merging of spots started from 23rd dai in isolate no. B12, 24th dai in isolate no. B1 and B15, 26th dai in isolate no. B1, B6, B19 and B20, 28th dai in isolate no. B86, B87 and B88 and 30th dai in isolate no. B89. In two isolates, no. B87 and B88, halloing was also observed on the 28th dai. Finally, the leaves started falling from the 28th dai in isolate no. B17 and B19, 30th dai in isolate no. B1, B6, B12, B15, B20 and B87 and 36th dai in isolate no. B89. Therefore, differences were observed in respect of time of initiation and types of symptoms. Out of 11 isolates of *Bipolaris* sp. isolate no. B-17 showed all the symptoms in minimum number of days while isolate no. B-89 took comparatively more time.

**Key words:** *Populus deltoides*, *Bipolaris* sp., Koch’s Postulates.

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SEASONAL ALTERATION OF PEROXIDASE IN BRANCH AND LEAVES OF 
EUCALYPTUS VIMINALIS

Pejman Parhizkar¹, Soudabe Korori², Farhang Moraghebi³ and Azadeh Yaghubian⁴

Eucalyptus viminalis is a fast–growing and ever-green tree. Deciduous and ever-green plants 
encounter internal changes as a consequence of seasons. Enzyme activities vary with changes of 
temperature, drought and salinity. Plants adapt to environmental changes with alteration of enzyme 
activities.

In this study, the peroxidase activity was measured in leaves and shoots of Eucalyptus viminalis 
during one year. Peroxidase activity was measured by spectrophotometer (530 nm) using the Worthington 
method. Data were analyzed to determine statistical relationship in peroxidase activity of individual trees 
and seasonal changes of enzyme activity by SPSS software.

Results showed that peroxidase activity was different in individual trees. The difference of 
peroxidase activity in different individual trees was low in April, July and January but was higher in 
September and November. The peroxidase activity decreased in all individual trees from April to July. 
Peroxidase activity of leaves was higher than those of branches in all of studied months. There was negative 
correlation between some months of peroxidase activity (α<0.05). There was not any correlation between 
leaves and branches peroxidase activity. Individuals were classified into three categories according their 
peroxidase activities using the JMP software (centroid method).

Key words: Enzyme, Eucalyptus viminalis, peroxidase, seasonal alternation, spectrophotometer.
ASEXUAL REPRODUCTION OF \textit{POPULUS CASPICA} BORN. STIMULAT OF CUTTINGS IN NORTHERN IRAN

Pejman Parhizkar$^1$, Farhad Asadi$^2$, Mostafa Khoshnevis$^3$ and Beitollah Amanzadeh$^4$

\textit{Populus caspica} Bornm. is a native species of northern Iran. Natural regeneration of this species has serious problems in the Caspian region of Iran.

In this research, hormones and different diameters of cutting treatments were used on \textit{P. caspica}'s saplings and then evaluated. Annual cuttings of 18 to 20 centimeters in three diameter classes (5, 10, 15 millimeters) were used. Also Indole Butyric Acid (IBA) Hormone has been prepared in 5 volumes (Control, 1250, 2500, 5000 and 7500 ppm). An examination was carried out as randomized completely block designs in Shalman station, Guilan, north of Iran.

Results showed that 10 millimeter cutting is the best character for asexual reproduction of \textit{P. caspica}. Using 2500 ppm IBA volume is appropriate only for 5 diameter cuttings but other sizes of cuttings or hormone volumes are not appropriate. If there are not enough numbers of cuttings with fine diameter, we can use instead IBA in the first year with recommended concentration (loss time for) producing one year seedlings for cutting production.

\textbf{Key words:} Asexual reproduction, cutting, Guilan Indole Butyric Acid (IBA), \textit{Populus caspica}.
TESTING PATHOGENICITY OF SCLEROTIUM ROLFSII CAUSING LEAF SPOT OF POPLAR

Suman Rawat¹, Santan Barthwal², R.C. Dhiman³ and Y.P. Singh¹

Populus species have become one of the most economically important groups of forest trees because of their fast growth rates, profuse vegetative propagation, adaptability to a variety of ecological sites and numerous uses. Poplar suffers from a number of diseases as they are being raised as single clone monocultures and are, thus, prone to disease outbreaks. In agro-forestry, the situation may further aggravates, where pathogens often diverse their activity from the common host range and cause extensive damage to either the inter-crop species. Sclerotium rolfsii is a soil borne plant pathogen of worldwide importance with a very extensive host range having more than 500 plant species, including agriculture, horticulture and forestry. In 2010-11, Sclerotium leaf spot was widely prevalent on many commercial clones of Populus deltoides (G-48, WSL-22, WSL-39, W-108 and W-110) in the nurseries of Uttarakhand state (located at latitude: 29° 30' N and longitude: 79° 28' E). The results of detection, identification and differentiation of microbial plant pathogens by various methods are expected to be validated by pathogenicity test.

Four-month-old cuttings of five clones (G-48, WSL-22, WSL-39, W-108 and W-110) were used to prove Koch's postulates of S. rolfsii by two methods (spray and soil inoculation). In spray method, the leaves of an individual plant were inoculated with hyphal bits and finely ground sclerotia suspended in 10 ml of sterilized, distilled water. In soil inoculation method, sterilised soil was mixed with sclerotia cultured on Potato Dextrose Broth for one month (@ 1 sclerotia/g of soil). The infested soil was, then, filled in polybags of 500g capacity. In spray method, symptoms were produced from the 3rd day of inoculation that were similar to observed in field. The pathogenic fungus was isolated from the infected plant and compared with the original fungus. There was no difference. On the other hand, no symptom was developed in soil inoculation method.

Key words: Agroforestry, clone, disease, Koch’s postulates.

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RESPONSES TO DIFFERENT LEVELS OF FLOODING IN WILLOWS (Salix spp)

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and Virginia Lúquez¹

In the next decades, there will be an increased demand of biomass for energy from willows (Salix spp). To meet these demands, plantations need to be established in marginal areas not used in agriculture, like flood-prone lowland areas. Climate change will increase the frequency of extreme rain events, causing flash flooding episodes, so it is important to breed willow clones that can survive these conditions. For willows plantations, the establishment phase is a crucial point, when the vulnerability to stresses is higher because the cuttings are still developing a root system. A flooding episode during this early period can have a negative effect upon plants.

In this work, we analyzed the responses of eight willows genotypes to flooding. Among these genotypes were individuals of Salix alba (3 clones), S. matsudana (2 clones), S. amygdaloides (1 clone) and two clones originated from open pollination of a S. matsudana x S. nigra mother. Most clones were used as parents in breeding programmes developed by INTA; in consequence it is important to know their response to flooding. The treatments were: Control (watered normally); partial flooding (submerged in water 10 cm above soil surface); deep flooding (submerged in water 45 cm above soil surface). The cuttings were planted in pots outdoors and the treatments started when the plants where 2 months old, lasting for 3 weeks. The variables measured were: height, diameter, number of leaves, leaf nitrogen content, stomatal conductance, and total biomass and its partition between different plant organs.

The deep flooding treatment caused a higher growth reduction than partial flooding in most clones, either measured as height, diameter or total biomass. Both flooding treatments reduced significantly the root-to-shoot ratio compared to control plants. The partial flooding treatment caused a decrease in foliar nitrogen content compared to control plants, while the deep flooding treatment increased the leaf nitrogen content. After 3 weeks of flooding, once the water drained, the plants that underwent deep flooding treatment increased their stomatal conductance compared to the control and partial flooding treatment.

The treatments changed plant and leaf traits in different ways according to the deep of the floodwater. These changes, especially in root-to-shoot ratio and leaf nitrogen content, could have lasting effects on photosynthesis and growth recovery in the post-flooding period. Clones which maintain higher root biomass and nitrogen leaf content probably will have a faster recovery once the flooding has passed.

Key words: Salix spp., flooding, nitrogen, growth.

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We present the preliminary results of a trial assessing the anthelmintic activity of eight *Salix* spp clones against *Haemonchus contortus* eggs and L3 infective larvae using the *in vitro* egg hatch assay (EHA) and larval migration inhibition assay (LMIA). *Haemonchus contortus* is the most significant nematode in small ruminants due to its adverse effects on production.

The extracts studied, grown in the “Delta del Paraná Experimental Station of the National Agricultural Technology Institute (INTA)” in Buenos Aires province of Argentina, were obtained from *S. viminalis, S. humboldtiana, S. matsudana x S. nigra ‘Lezama INTA-CIEF’, S. matsudana x S. alba ‘Agronales INTA-CIEF’, S. matsudana x S. alba ‘Los Arroyos INTA-CIEF’, S. matsudana x S. alba ‘Géminis INTA-CIEF’, S. alba x ? ‘Yaguareté INTA-CIEF’ and S.nigra x ? ‘Ibicuy INTA-CIEF’ leaves. The trial included samples taken in autumn and winter 2015. Both EHA and LMIA showed a clear dose-dependent response. The highest inhibition percentages (20%) occurred in those wells where eggs and larvae were exposed to the highest extract concentrations. The percentage decreased gradually with lower concentrations, reaching a minimal level in the last well.

These results show that the techniques employed were appropriate and reliable for a primary screening of substances with nematicidal activity. The trial helped characterize four clones according to their ovicidal and larvicidal effect: ‘Agronales INTA-CIEF’, ‘Los Arroyos INTA-CIEF’, ‘Yaguareté INTA-CIEF’ and ‘Ibicuy INTA-CIEF’. These clones will be further studied from leaves collected in spring and summer 2015. Once the studies are concluded, *in vivo* trials will be carried out in order to assess the possibility for including such clones in livestock feed or in antiparasitic formulations.

**Key words:** *Salix* spp; anthelmintic, *Haemonchus contortus*, Delta del Paraná.

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Forest tree breeding can contribute an increasing carbon sequestration of forest due to the improvement of tree growth and biomass production. Tree breeding has a long tradition in Germany but the breeding activities were reduced during the last few decades. However, in the last few years a growing interest in forest tree breeding can be observed. This development is driven through the increasing demand for wood, wooden products and bioenergy (fuel wood) for the substitution of fossil raw materials and energy sources.

The potential of tree breeding is shown on two examples with hybrid larch (*Larix decidua × L. kaempferi*) and hybrid aspen (*Populus tremula × P. tremuloides*). Results are presented for a large programme for breeding of hybrid larch with 141 hybrid progenies and 10 progeny tests. Many hybrid families outperformed the progenies of stands of pure European larch which were used as a control in volume growth significantly. Also for aspen hybrids between European and American aspen grew much better then progenies of the pure species. Some hybrid families outperformed the control seed-lot in biomass dry weight by three to four times.

**Key words:** Tree breeding, hybridization, *Larix, Populus*, hybrid larch, hybrid aspen, growth, biomass.
POPLAR CLONES DIFFER IN THEIR RESISTANCE AGAINST INSECTS FEEDING

Hilke Schroeder¹ and Matthias Fladung

The main aim of the breeding project FastWOOD is the investigation of different poplar species and clones for biomass production and their use in short-rotation coppices (SRCs). In general, SRCs are composed of only a low number of clones leading to an overall decrease of genetic variations with the result of an unsettled relation between the trees and associated insects. When such plant cultures are infested by herbivores, the damage is often much higher than in a natural forest. Planting of special clone mixtures and use of generatively produced reproductive material can increase the genetic and therefore the ecological diversity of poplars in SRCs. Combined with clones having higher resistance against insects can further reduce the risk of damages. The here presented part of the FastWOOD project deals with the resistance of different poplar clones against herbivorous insects.

For this purpose, 20 poplar clones belonging to five different sections standing on seven different study sites planted in 2010 or 2011 in five federal states in Germany have been assessed for presence of insects and foliage damage once a year from 2012 to 2015. Overall, the amount of foliage damage, and the number of insects have been low in all four years of investigation. Nevertheless, differences in foliage loss as well as in quality and quantity of insects between the poplar clones were found. The most often observed insect was the poplar leaf beetle *Chrysomela populi*. Furthermore, besides some Lepidoptera larvae, weevils of the genus *Bytiscus* and leaf beetles of the genus *Phratora* have been found. Altogether, there seems to be a preference of special insects for individual poplar clones.

To illustrate the different resistances of the poplar clones, a “resistance-ranking” were generated using the combined data for foliage damage and insect presence, where long established clones occupy the first five places followed by a newly bred one.

**Key words**: Poplar clones, resistance, insects feeding.

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Poplar is widespread and is a high economic agroforestry species in India. It constitutes an excellent raw material for paper, pulp, plywood and plyboard industries, 70% of the wood grown being used in plywood and plyboard manufacturing. It is the main source of economy of rural livelihood for farmers. Poplar is highly prone to insect attacks - approximately 108 insect species are causing damage. Out of these, Poplar defoliator *Clostera cupreata* (Lepidoptera: Notontidae) is one of the most damaging pest of poplar, which defoliates poplar plantations and often appears in outbreaks even causing death of trees. Repeated defoliation causes loss of MAI and CAI which adversely affects growth increment and quality of the timber.

In India, poplar defoliator is being controlled by unlimited use of insecticides leading to several health and environmental hazards. Moreover, insecticides used are not target specific, broad spectrum and develop resistance to insects. With a greater awareness of hazards associated with the use of insecticides, there has been an urgent need to explore suitable alternative for pest control. Screening of plant extracts is one of the approaches for control of insect pests. Little information is available on the control measures on poplar defoliator by using plant extracts. Therefore, the present study was undertaken to observe the effectiveness of *Calotropis procera* (family: Asclepiadaceae) leaves against *C. cupreata*.

The 3rd instar larvae of *C. cupreata* were collected from the field, reared in glass chimney and wooden cages in the laboratory for stock culture. *C. procera* leaf extractives were prepared with different solvents of elutropic series. The larvae of *C. cupreata* were exposed to a wide range of concentrations (0.0625 to 2.00%) and a control. After repeated experiments, an herbal *Bio-Pesticide* was developed. Almost, 70% of larval mortality was observed under laboratory as well as in outdoor cages. *Bio-Pesticide* is safe and economic alternatives to the synthetic insecticides and it will improve farmer’s livelihood through increased productivity of poplar.

**Key words:** Poplar, *Calotropis procera*, *Clostera cupreata*, *Bio-Pesticide*.
POPLAR CLONES IN LATVIA: JUVENILE GROWTH AND FALL FROST DAMAGES

Silva Šēnhofa1, D. Lazdiņa1, M. Zeps1, K. Makovskis1, I. Bebre1 and Ā. Jansons1

The majority of short-rotation plantations in the Baltic States, as well as in several other countries in the Northern Europe, has been established using hybrid aspen (Populus tremula × P. tremuloides). However, interest to use poplars has recently increased in this region due to lower establishment costs of the plantations. Information of poplar growth in Latvia is limited—few stands are left after the former introduction in 1960s (origin unknown); yet, no breeding has been carried out. During the last decade, several commercial poplar clones from other European countries have been introduced, but the northward transfer might be related to adaption problems. Therefore, the aim of the study was to assess the productivity and fall frost damages of the poplar clones from the former and recent introduction.

The juvenile growth and fall frost damages of poplar clones were studied in two sites. In the central part of Latvia (56°39´N, 25°7´E) height of 23 five-year-old poplar clones was measured and fresh above-ground biomass in the leafless stage was calculated; and in the eastern part of Latvia (56°41´N, 25°58´E) the fall frost damage of 19 one-year-old and 2-year-old poplar clones were assessed. The frost damage was assessed visually after the frost-event in the beginning of October 2015: the bud set was used to determine the phenological stage (active or dormant) and both leaf and stem damage was evaluated in the five grade scale. The relation between tree height and frost damage was assessed at the clone level for 16 clones which were common for both sites.

The significant (all $P < 0.001$) differences of the phenological stage, leaf and stem frost damage, as well as height and biomass were found between clones. In total, 65.4% of trees were in the active phenological stage. The dormant stage of all trees within the clone was found for three clones, among which two are progenies (cuttings) of the mature trees from the former introduction. Six clones had trees in both phenological stages but 10 clones had all trees still growing. Among the actively growing trees, 81% had damaged leaves and 12% had damaged stem. The height of clones varied notably—from 273.3 ± 60.2 to 711.0 ± 32.0 cm. The recently introduced clones were superior in height and biomass production. These clones significantly ($P < 0.001$) exceeded the formerly introduced clones by 28 and 62% for height and biomass, respectively. The three highest clones were also the most productive. The height of the three clones was 649.0 ± 21.5 cm, and the biomass was from 33.7 ± 4.2 to 55.0 ± 6.4 t fresh ha$^{-1}$; and they exceeded the other clones by 34 and 65% for height and biomass, respectively. More productive clones showed significant trend ($P < 0.049$) of more stem damage. In contrast, no significant ($P > 0.05$) relation was found between the frost damage of leaves and both tree height and stem biomass. The results suggest that, at the particular age, fast-growing and frost-tolerant clones could be selected.

**Key words:** Height growth, height increment, biomass, frost tolerance.

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TESTING OF FUNGICIDAL EFFICACY AGAINST ALTERNARIA LEAF SPOT OF POPLAR

Kartik Uniya1, R.U. Khan2, R.C. Dhiman3 and Y.P. Singh1

Poplar is one of the domesticated forest trees in India and has better synergy with agriculture system than forestry operations. Poplar wood offers an excellent raw material for more than three dozen goods, including firewood, paper pulp, panel products, match splints, artificial limbs, etc. Poplars are propagated vegetatively through cuttings in order to maintain their genetic purity. *Populus deltoides* has shown great promise in the north-western part of India. Often, single clones of poplars have been propagated extensively.

Presently, around 25 clones are commercially grown in the country. Ninety per cent of the total planted poplars comprise clones G-48, WSL-22, WSL-39, Udai, WSL-32, Wimco81 and S7C15 in the states of Punjab, Haryana, Uttarakhand and Uttar Pradesh. The use of a single genotype (clone) over a large area entails an enormous risk. Monocultures are widely believed to attract diseases and insects. High incidence of Alternaria leaf spot was noticed on different commercial clones of *P. deltoides* (G-48, Udai, WSL-22 and WSL-39) during surveys in poplar nurseries (2009-11).

The most common method of managing plant diseases is to use fungicides. *In vitro* efficacy of two fungicides, namely, propiconazole (systemic) and chlorothalonil (non-systemic) was tested against *Alternaria alternata* isolates, using poisoned food technique. It was observed that propiconazole was more effective in suppressing the growth of the fungus than chlorothalonil as 100% inhibition were achieved for all the isolates at 40ppm. Growth suppression of five isolates, no. A13, A32, A51, A64 and A65, was 100% from 20ppm onwards. On the other hand, 100% inhibition of growth were achieved for only four isolates, no. A15, A24, A41 and A47, at highest concentration of 400ppm of chlorothalonil.

The present investigation indicated that propiconazole proved to be effective even at very low concentration of 0.004% against *A. alternata* under *in vitro* conditions. Thus, it can be further tested in field condition for management of the leaf spot disease.

**Key words**: Disease, inhibition, monocultures, propiconazole.

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RAPD ANALYSIS OF *ALTERNARIA ALTERNATA* ISOLATED FROM *POPULUS DELTOIDES*

Kartik Uniyal, R.U. Khan, R.C. Dhiman and Y.P. Singh

Incidence of Alternaria leaf spot was predominant in the poplar nurseries of Uttarakhand, Uttar Pradesh and Haryana states of India surveyed during 2009-2012. In all nurseries, 72 isolates of *A. alternata* were collected from four major commercial clones of *P. deltoides*, viz., G-48 (27 isolates), WSL-22 (20 isolates), WSL-39 (18 isolates) and Udai (7 isolates). To ascertain their genetic diversity, seven RAPD primers of Operon series (OPA-16, OPC-08, OPN-11, OPP-16, OPP-19, OPX-12 and OPX-14) producing high polymorphism were selected. Total genomic DNA from the fungal isolates was extracted by using TES lysis buffer, quantified using spectrophotometer at 260nm. Further, the DNA was amplified using the RAPD primers which showed clear and reproducible banding patterns. The amplification was done in BIOER Gene Pro thermo-cycler at: 94°C for 10 min, the remaining steps in the programme were repeated for 40 times (cycles) and consisted of 94°C for 1 min, 37°C for 1 min, 72°C for 1 min and final extension at 72°C for 8min. The PCR products were separated using 1.5% agarose gel at 80V for 120min. in electrophoresis system. Gel was stained with ethidium bromide and photographed under UVP (Gel Doc-It 310 imaging system P/N 97-0266-02). Each amplification product was considered a DNA marker and was scored across all samples. Presence and absence of each band was coded as 1 and 0, respectively. The primers generated 858 amplified bands which ranged from 100 to 3,000bp. The total number of polymorphic bands was 110. Hundred percent polymorphism was noticed for all the primers used. The values for polymorphic information content (PIC) and resolving power were highest for primer OPX-14 (0.37 and 7.7, respectively). It can be recommended for future work on this pathogenic species. The scores were used to create a data matrix to analyze genetic relationship using the NTSYS-pc programme version 2.1 (Exeter Software, New York, USA).

A dendrogram was constructed based on Jaccard’s similarity coefficient using the marker data for each fungal isolates with Unweighted Pair- Group Method with Arithmetic Average (UPGMA) cluster analysis to group the isolates based on their overall similarities. Each RAPD pattern was compared with the other patterns and distance matrix was calculated. Cluster analysis using UPGMA dendrogram revealed genetic relatedness up to 62 per cent. The maximum similarity was noticed between isolate no. A11 and A9 (0.62). It is an indication of high variation amongst the isolates of *A. alternata*. The information could be used for further studies aiming at management of leaf spot disease.

**Key words:** Molecular, poplar, pathogen, polymorphism.

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**PDEPF1 REGULATES WATER USE EFFICIENCY AND DROUGHT TOLERANCE BY MODULATING STOMATAL DENSITY IN POPLAR**

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Water deficiency is a critical environmental condition that is seriously reducing global plant production. Improved water use efficiency (WUE) and drought tolerance are effective strategies to address this problem.

In this study, *PdEPF1*, a member of the *EPIDERMAL PATTERNING FACTOR (EPF)* family, was isolated from the fast-growing poplar clone NE-19 (*Populus nigra × (Populus deltoides × Populus nigra]*)]. Significantly higher *PdEPF1* levels were detected after induction by dehydration and abscisic acid. To explore the biological functions of *PdEPF1*, transgenic triploid white poplars (*Populus tomentosa* ‘YiXianCiZhu B385’) overexpressing *PdEPF1* were constructed. *PdEPF1* overexpression resulted in increased water deficit tolerance and greater WUE. We confirmed that the transgenic lines with greater instantaneous WUE had approximately 30% lower transpiration but equivalent CO₂ assimilation. Lower transpiration was associated with a 28% reduction in abaxial stomatal density. *PdEPF1* overexpression not only strongly enhanced WUE, but also greatly improved drought tolerance, as measured by the leaf relative water content and water potential, under limited water conditions. In addition, the growth of these ox*PdEPF1* plants was less adversely affected by reduced water availability than plants with a higher stomatal density, indicating that plants with a low stomatal density may be well-suited to growth in water-scarce environments. Taken together, our data suggest that *PdEPF1* improves WUE and confers drought tolerance in poplar; thus, it could be used to breed drought-tolerant plants with increased production under conditions of water deficiency.

**Key words:** Poplar, drought tolerance, *PdEPF1*, WUE, stomatal density, growth rate.
RELATIONS BETWEEN INSECT RESISTANCE AND TREE AGE OF TRANSGENIC TRIPLOID POPULUS TOMENTOSA PLANTS

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The resistance stability during tree development of transgenic insect-resistant trees and the effects of the natural environment remain unclear.

This study aims at investigating different transgenic lines and how their insect resistance changes with the increase of tree age. Nineteen transgenic Populus tomentosa lines expressing a Cry1Ac gene were selected as plant material. The presence and expression of the transgene were verified using polymerase chain reaction and enzyme-linked immunosorbent assay analyses. The toxicity of the trees to Clostera anachoreta and Lymantria dispar were evaluated after the trees were planted in the field for the first two years and the sixth year. Fresh, detached leaves were fed to the first instar larvae of the two insects. Results demonstrated significant differences in the mortality rates of the two insect species between different transgenic lines. The average corrected mortality rates of C. anachoreta and L. dispar varied from 5.6% to 98.7% and 35.4% to 97.2% separately. The larval mortality rates differed significantly between the lines at different ages. Up to 52.6% of the one-year-old transgenic lines and 42.1% of the two-year-old transgenic lines caused C. anachoreta larval mortality rates to exceed 80%, whereas only 26.3% of the six-year-old transgenic lines had C. anachoreta larval mortality rates exceeding 80%. The mortality rate of L. dispar showed the same trend: 89.5% of the one-year-old transgenic lines and 84.2% of the two-year-old transgenic lines caused L. dispar larval mortality rates to exceed 80%, the number decreased to 63.2% for that of the six-year-old plants. The proportion of six-year-old transgenic lines with over 80% larval mortality rates was clearly lower than that of the younger trees. In addition, C. anachoreta death distribution in different developmental stages also presented variation between one-year-old tree and six-year-old tree.

Key words: Populus tomentosa, transgenic lines, toxicity, mortality rate, tree age.

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THE RESPONSES OF DIFFERENT SOURCES OF LOW-MOLECULAR-WEIGHT ORGANIC CARBON (LMWOC) ON SOIL NITROGEN (N) TRANSFORMATION IN THREE PLANTATIONS

Xu Ye-ning¹, Tian Ye, Zhang Jia-yu and Tao Hui-ying

In order to investigate the effects of different sources of low-molecular-weight organic carbon (LMWOC) on soil nitrogen (N) transformation, glucose, citric acid, and their mixture were added into three kinds of soils collected from adjacent Liriodendron chinense, Lithocarpus glaber and Cupressus funebris plantations using one-week lab-based incubation.

The results showed that soil inorganic N decreased significantly after one-week incubation under LMWOC addition for three soils. Both net N mineralization and nitrification were inhibited when LMWOC was added, which indicated the obvious N immobilization by soil micro-organisms. The decrease of net mineralization and nitrification rate was much significant induced by citric acid addition than that by glucose in the soil of L. chinense plantation, while no differences were found between in the soils of L. glaber and C. funebris plantation. Mixed carbon sources addition showed stronger decreasing effect on net mineralization and nitrification rate when compared with each single carbon source only in the soil of L. glaber plantation, which indicated that the soils in the plantations with different tree species responded distinctively to different carbon sources.

**Key words:** Low-molecular-weight organic carbon, nitrogen net mineralization, net nitrification, carbon addition effect.

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Hybrid aspen is the most widely used Populus hybrid in the Northern Europe, even so the establishment costs of its plantations are the highest. It is crucial to achieve high productivity and minimize risks of any damages to ensure that these plantations are a financially viable investment. One of the potential risks to stem quality is sunscald injury. The aim of our study was to characterise sunscald injuries in young hybrid aspen plantations in Latvia.

The study was done in two hybrid aspen trials, both located in central part of Latvia (56°26' N; 22°52' E) on former arable land (fertile mineral soil). In both trials, 15 and 14 clones (in average 30 ramets per clone) were assessed at the age of 5 and 7 years, respectively. Sunscald injuries were evaluated in four grade scale: no injuries (0); bark crack, but wood is not visible (1); bark crack, visible wood (2); bark crack wider than 1 cm (3). The length of bark cracks was measured.

Most of the trees in the experiments (63% at the age of 5 years and 67% at the age of 7 years) had injuries, and most of the injuries (64% at the age of 5 years and 58% at the age of 7 years) were relative large (Grade 3). At the age of 5 years, wider (Grade 3) bark cracks were also significantly ($P < 0.05$) longer than the narrower ones (Grade 1 and 2). At the age of 7 years, however, no significant ($P > 0.05$) differences were observed. Clone was a significant ($P < 0.05$) factor influencing the occurrence of sunscald injuries (ranging from 9 to 100% of ramets with injuries) and their length (ranging from 6.0 ± 3.92 to 37.64 ± 13.83 cm on average). There was a strong and significant correlation at the clone mean level between these two traits ($r = 0.83$ at the age of 5 years and $r = 0.74$ at the age of 7). Stem diameter for trees without injuries was significantly smaller than for trees with injuries at the age of 5 years (32.7 ± 1.69 and 39.9 ± 2.39 cm, respectively), but not at the age of 7 years (57.2 ± 5.14 and 56.6 ± 4.25 cm, respectively). Also stem diameter and tree height was significantly related to length of sunscald injuries ($r = 0.43$, $r = 0.38$ and $r = 0.44$, $r = 0.50$; all $P < 0.05$, respectively). However, at clone men level correlation between stem diameter and proportion of trees with sunscald injuries was week and negative ($r = - 0.08$ in the youngest and - 0.31 in the oldest trial), but correlation between diameter and length of injuries - stronger and positive ($r = 0.29$ and 0.78, respectively). The results indicate, that a notable proportion of trees could be affected by sunscald injuries and larger damages are found for faster-growing trees at younger age (presumably due to characteristics of bark), that might lead to fungal infections. Selection of faster-growing clones might not affect the occurrence of cracks, however, might lead to larger size of them and consequently affect the probability of fungal infection. This aspect needs to be addressed in the further studies to determine if sunscald injuries (occurrence and/or size) had to be included into selection index for hybrid aspen clones.

**Key words**: Stem cracks, frost crack, southwest injury, stem quality.

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4. WORKING GROUP ON SUSTAINABLE LIVELIHOODS, LAND USE, PRODUCTS AND BIOENERGY

A SALIX SPP. SHORT-ROTA TION COPPICE SYSTEM IN BUENOS AIRES, ARGENTINA: EFFECTS OF CLONAL COMPOSITION, PLANTING DENSITY AND DRIP IRRIGATION ON BIOMASS PRODUCTION.

Fabio G. Achinelli1,2, Guillermo Doffo2, Pablo Etchevers3 and Virginia M. C. Lúquez2

In Argentina, renewable sources represent 9.4% of the primary energetic matrix, of which only 5% correspond to bioenergy sources. During the last decade, the country needed to increase fossil fuel imports due to a pronounced fall in national reserves. As a consequence, there is a growing interest from government and companies about the use of wood biomass to produce energy through firing or co-firing processes. One obstacle for the development of these projects is the scarcity of information about the local productivity of dendroenergy crops, and about the suitability of this biomass to produce energy. We established a tree-factor factorial field trial with a willow (Salix spp.) short-rotation coppice system (SRC) to evaluate the effects of drip irrigation, genotype and planting density on the yield and quality of the biomass. The eight treatments were arranged in a split-split plot design and replicated in three complete blocks. The trial was planted on an agricultural soil in September, 2012 and harvested every year from 2013 to 2015. The variables determined for each treatment were yield (t/ha dry mass at 105°C), upper heating value (UHV, cal/g) and total ash content (TAC, %).

During the first season (September 2012-April 2013) drip irrigation was not applied because soil was saturated or at field capacity for most of the growing period. Clone Salix alba `Yaguarete INTA-CIEF’ had significantly higher yields than clone Salix matsudana x S. alba `Barrett 13-44 INTA´ (11.94 ± 0.88 t/ha vs. 9.49 ± 1.14 t/ha). The increase of plantation density from 13333 plants/ha to 20000 plants/ha correlated with higher yields, but the effect was statistically significant only in plots of clone Barrett 13-44. In the two following years, drip irrigation was applied to irrigated plots, with resulted in the addition of 543 mm (2013-2014) and 843 mm of water (2014-2015) to rainwater. In both seasons irrigation was the only factor with statistically significant effects on biomass production, where irrigated plots produced higher yields compared to non-irrigated ones (21.76 ± 0.98 t/ha vs. 16.94 ± 1.07 t/ha during 2013 – 2014 season; 19.03 ± 1.48 t/ha vs. 11.99 ± 1.22 t/ha during 2014 – 2015 season). UHV and TAC were determined on 2013-2014 harvest only. The mean UHV for all samples was 4654 ± 25.5 cal/g, with no significant differences between treatments, while for TAC marginally significant differences (0.05<p<0,1) between clones (2.15 ± 0.095 % for Yaguareté vs. 1.95 ± 0.1 % for Barrett 13-44), and between irrigated and non-irrigated plots (1.96 ± 0.15% vs. 2.13 ± 0.15 % respectively) were found.

So far, the best combination in terms of yield, quality and implantation cost would be a drip irrigated, low density (13333 plants/ha) short-rotation coppice with clone Barrett 13-44.

Key words: Salix spp., short-rotation coppice, bioenergy.

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This study analyzes the impacts of smallholder plantations on the households’ cash income, modern agricultural input use, education and health care spending of 300 sampled households (of which 153 were planters and the remaining 147 were non-planters) in Fagta Locuma and Lay Gayint districts of Amhara National Regional State of Ethiopia. A multistage sampling technique was used to select sample respondents.

In this study, both descriptive analysis and econometric model have been used to analyze the data. The t-test (mean difference test) result shows that there is a significant mean difference between planters and non-planters in terms of family size, land holding in hectares, livestock holdings, extension service provision and distance to the nearest market center measured in kilometers. The econometric estimation result also shows that the probability of participation in plantations is significantly and positively affected by nursery ownership, land holding size, land productivity measured in terms of monetary unit per hectare, and household head education. These results are significant at 1%, 1%, 5% and 5% probability level, respectively. Likewise, it is negatively affected by distance to the nearest market center which is significant at 1% probability level. The propensity score matching analysis result also revealed that, participation in plantations had a significant impact on farm households total cash income, education and health spending. However, it does not have a significant impact on the use of modern agricultural inputs.

The findings of this study calls for the scale up of best smallholder plantation practices in Amhara region and in Ethiopian at large. In addition, concern has to be given in improving the land productivity, educational level of farm households, creating and increasing market access and linkages, value addition of plantation products, expansion of infrastructures, especially road and telecommunication networks in the rural parts of the sampled districts to raise the plantation participation.

**Key words:** Plantation, propensity score matching, planter, non-planter, impact analysis.

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USING STEM ANALYSIS RESULTS FOR DETERMINATION OF THE ECONOMIC ROTATION AGE OF PINUS BRUTIA IN SOUTH WESTERN IRAN

Kamran Adeli¹, Javad Soosani² and Samaneh Namdari³

Pinus brutia is one of the most important multipurpose species representing high ecologic flexibilities and economic values.

This study aims to determine the optimal harvest age of Pinus brutia in southwestern Iran; that is, the age in which marginal revenue will equal marginal cost. Data of increment of a 33 years stand, stumpage price in a 33-year period (1978-2012), interest rate and stand establishment cost was used for determination of the optimal rotation age. Data of the current annual increment and volume stock (per ha) from stem analysis table for various ages were extracted for a number of 31 trees. Then, stumpage price of Pinus brutia was estimated using an autoregressive model. Finally, by applying increment data and stumpage price, the maximum land expected value (per ha) was obtained using Faustmann criterion.

Results showed that the optimal harvest age of Pinus brutia with interest rate 6% and establishment cost of 500,000 RLs ($15) per ha, was determined to be 18 years when the maximum expected value (per ha) in this age is 47,355,478 RLs ($1443).

Key words: Pinus brutia, increment, stumpage price, optimal rotation age, Faustmann model.

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In the present paper, the financial maturity and optimal rotation age of poplar species in Kurdistan Province was studied. At first, the growth data of poplar species were extracted from poplar planting plans of Research Center of Sanandaj city. Then, stumpage price data, fixed and variable cost per hectare, were collected by filling out questionnaires and interviews with local people and poplar farmers. Finally, the age which farmers achieve maximum net present value was determined using the expected value of land model (Faustmann).

The findings showed that optimal rotation period occurs at the age of 12 years old where the marginal revenue curve cuts the marginal cost curve. However, the local farmers cut poplar trees at the ages of 6-7 years old and prematurely and also ignored higher profits. The results obtained can be attributed to the risks of poplar market in this region and risk aversion of farmers.

Key words: *Populus deltoides*, Faustmann model, net present value, financial maturity, length rotation.

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WOODFUELS AS ALTERNATIVE SOURCE OF ENERGY IN RURAL AND URBAN AREAS IN THE PHILIPPINES

Romulo T. Aggangan

Woodfuel continues to be a major component of the energy supply mix of the Philippines due to increasing demand for energy that are not adequately met by decreasing supply and increasing prices of fuel oil such as liquefied petroleum gas (LPG) and kerosene.

The Development Academy of the Philippines projects that the demand of woodfuels in 2016 will reach 28.3 million metric tons in the household sector and about 105.4 million metric tons combined supply potentials of both forest and non-forest lands. However, the Revised Master Plan for Forestry Development plans a demand of about 50 million cubic meters of fuelwood in 2016 but the capability to supply this product from local sources is only about 28 million cubic meters, indicating a 44 percent deficit. Household demand constitutes 82% while industries demand is 18%. Domestic household demand for energy is for cooking needs while the industrial demand is for steam power generation, curing barns of tobacco: brick, ceramics and pot making; bakery; lime production; and small-scale food processing. Factors that favour increased use of wood-based energy include the relatively low prices (increasing oil-based fuel prices), availability of efficient wood-based energy utilization technology, increasing supply, and increasing population that cannot afford conventional fuels. Moreover, innovations in combustion technology and cogeneration of heat and power from biomass for modern applications favour biomass energy development.

This paper recommends policies and strategic directions for the development of the woodfuel industry with the twin goals of sustainably supplying the energy requirements of households and industry.

Key words: Fuelwood, supply and demand, innovations in combustion technology, biomass energy development, households and industry.

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PROPERTIES AND UTILIZATION OF SELECTED FAST-GROWING TREE PLANTATION SPECIES FOR WOOD-BASED INDUSTRIES IN THE PHILIPPINES

Romulo T. Aggangan¹, Dwight A. Eusebio¹ and Robert A. Natividad¹

Log production from tree plantations now account for 80% of the country’s total log production. These tree plantation species are Paraserianthes falcataria, Gmelina arborea, Swietenia macrophylla, Eucalyptus deglupta and Acacia mangium. In addition, establishment of forest plantations provide environmental benefits. However, only a few of these planted fast-growing tree species are known to our wood processors.

The basic properties (anatomical, physical, mechanical, chemical and pulping) of each species were established. Working and other technological properties such as sawing, seasoning, preservative treatment and finishing were investigated for end-use evaluation. Also, new processing systems must be continuously developed to optimize the use of plantation timbers. Development of new, profitable wood products encourage the establishment of new plantations ensuring sustainable supply of raw materials. Likewise, there is a great need in developing cost-effective technologies in harvesting, retrieval and utilization of logging and wood processing wastes and in enhancing information, technology transfer, and marketing capability in terms of plantation forestry.

**Key words:** Anatomical, physical, mechanical, chemical, sawmilling, seasoning, preservative treatment and finishing.

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HEDGEROW INTERCROPPING OF *POPULUS ALBA* AND ALFALFA IN WEST AZARBAYJAN PROVINCE, IRAN

F. Asadi and A. Khodakarimi

In order to produce a great quantity of wood, selection of suitable tree spacing and cultivation of different crops between tree rows, especially at the early stage, would increase productivity and poplar cultivation area.

In the study *Populus alba* seedlings were planted in a randomized complete block design with three replications and four mixed poplar and alfalfa treatments with tree spacing including 3x4, 3x6.66, 3x8, and 3x0 m, and also two control treatments - namely pure alfalfa and pure trees. We investigated some important attributes during the years 2009-2013. Tree diameter, height and alfalfa dry weight were recorded during the time of the study. Data were analyzed using combined analysis of variance.

Results showed that mixed 3*4 treatment showed highest wood volume growth. Also the major amount of dry weight production of alfalfa was belonging to pure alfalfa, 3x10, 3x8, 3x6, and 3*4 m treatments respectively. All attribute amounts that revealed differences among treatments were significantly different at 5% level of probability. For some attributes there were significant differences among years and interaction between treatments and years. As a final result until now, the suitable planting spacing of tree in Poplar/alfalfa intercropping system in Azarbayjan province is 3*8 m according to the site conditions.

**Key words:** Agroforestry, intercropping, poplar, alfalfa, spacing.

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INVESTIGATION OF GROWTH VARIATIONS OF POPLAR (*POPULUS NIGRA*)
PLANTATIONS IN RIVERBANKS OF KERMANSHAH PROVINCE, IRAN

F. Asadi¹ and F. Nouri²

This study was conducted to evaluate the amount of poplar wood production in traditional poplar farming. Therefore, calculation of annual growth in different stands is necessary.

In this study 8 *Populus nigra* stands were selected in margin of different rivers of Kermanshah province, taken by systematic random method, 102 variable sample plots. In each sample plot growth attributes were measured. Data were studied by analysis of variance and Duncan method. Soil sample was measured and soil data were analyzed by correlation and PCA analysis method.

Results showed that annual growth for 4th and 6th stands was between 10.3 and 38m³ so that the annual growth for the 6th stand was three times more than the 4th stand. Differences in amount of volume growth, height and diameter between stands were observed. According to soil analysis, there was no significant correlation between wood volume growth and soil characteristics, but according to PCA analysis, there was a small difference between them. For example decreasing EC and pH improved the volume growth. But, increasing the Clay, N and OC increased the volume growth. On the other hand, previous research results showed high genetic similarity between trees of the eight stands. Thus, it seems that the main affecting factors on poplar growth could be a suitable management in farm.

**Key words:** Growth variation, poplar stands, wood production, Kermanshah.

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² Agricultural and Natural Resources Research Center of Kermanshah, Iran.
Agroforestry is being promoted and popularized in India to fill the gap between wood requirements and supply. Poplar (Populus deltoides), a native tree of the USA introduced in India during 1950s, is widely grown in northern India as an agroforestry tree because of its fast growth, straight growing stem, short rotation, quality wood production and less adverse effect on associated agricultural crops. The average production potential of poplar plantations is 35-40 m$^3$/ha/year, whereas the maximum production potential is up to 65 m$^3$/ha/year. Commercial-scale plantations of poplars have been expanding since the WIMCO-sponsored Farm Forestry Project promoted the poplar-based agroforestry plantations by providing technical know-how for planting and care of poplar trees and buy back guarantee with a fixed support price. Poplar replaced Eucalyptus tereticornis when the latter's market prices declined in the 1990s. The poplar based agroforestry plantations had been very profitable since the beginning and increasing at a very faster rate all over northern India till 2000. Ten million trees used to be planted annually in 0.02 million ha with an average density of 400-500.

But poplar was no more popular among farmers, particularly during 2003-2004, because the prices of their produce reached an all time low. Farmers were forced to sell their produce at throwaway prices anywhere between Rs.700 (10.5 US$) and Rs.1550 (23 US$) per ton during 2003-2004 as compared to Rs.3500-5500 (52.0-82.0 US$) per ton till 2000. Farmers were compelled for pre-mature felling of poplar trees. Sale price of 6-8 years old poplar tree with a girth of 1 m was lower down to about Rs.500-600 (7.5-9.0 US$) per tree in 2004. The low market price of poplar wood discouraged the farmers with the result the farmers were compelled to deviate from poplar-based agroforestry plantations. Consequently nursery growers also reduced the production of poplar saplings in their nurseries. Rates and demand of poplar wood started increasing again by the end of 2004 and the farmers were again attracted towards poplar-based agroforestry plantations. Poplar tree attains a girth of 1 m at breast height (1.37 m) after an average age of 6-8 years and such a tree was used to fetch an average of Rs.4500 (67 US$) till the end of year 2014 and the net income from poplar plantation was about Rs.300000 (4480 US$) per hectare per year (more than three times in comparison to crops alone). But in 2015, the sale price of poplar tree with a girth of 1 m at breast height (1.37 m) after an average age of 6-8 years was decreased to Rs.2000 (30 US$) which ultimately reflected during February 2016 when sale of poplar saplings decreased significantly. Production potential, market trend and economic return of exotic poplar in India have been reviewed.

**Key words:** Agroforestry, poplar, Populus deltoides, commercial plantations, market price.

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Currently, Extremadura Region has got the largest water reserves in Southwestern Spain, which allow large areas to be irrigated. This fact gives the region a high potential to get energy from biomass production. Our goal is to know the production of Paulownia crops in order to get biomass or timber in the “Vegas Bajas” area, next to the Guadiana River. For this purpose, different clones are being studied to find which one is the best suited to our environmental conditions with a high production.

In April 2012, four different clones of Paulownia, selected from the available ones in the Spanish market (112, COT2, L1 and X1), were planted in two plots. In February 2013 all the trees in both plantations were cut down, to obtain more homogeneous and straight trunks in the future. The plot allocated for timber production, with an estimated growing period of 10 years, had got 156 plants with a planting pattern of 4x4m. The plot bound for biomass production, where harvesting was done every three years, comprises 264 plants in a planting pattern of 3x2m. Both plots were surrounded with 67 and 76 paulownias, respectively, to minimize the edge effect.

Along these years of the project, we have dispensed all the required needs of water and nutrients to avoid any lack that could cause a growing decrease. So we have provided a maximum of 24 liters of water per day and tree (five days per week). In turn, plots have been slightly fertilized to avoid any growing reduction due to nutrient shortcoming. In addition, competing vegetation was eliminated. Growth was monitored in both plots, diameters were measured in both plots and heights were only measured in the plot allocated for timber production.

In February 2016, after a three years growing cycle and along the dormant period, we proceeded to cut down the trees intended to biomass production in the first of the seven production cycles expected for this species. Thereafter it has been shown that the clone X1 has had a significantly lower dry matter production, being its diametric and height growth also lower than the other studied clones. Between the other three clones, no significant differences were observed.

The total production in the plot intended to biomass production was 24,280.1 kg of dry matter per ha. That means 8,093.4 kg (dry weight) per ha and year for the whole plot considering the four different clones.

**Key words**: Biomass, fast-growing trees, *Paulownia*, timber, full random blocks.
HORIZONTAL PLANTING OF POPLARS IN SRC TRIALS: FIRST RESULTS WITH DIFFERENT CLONES

Sara Bergante¹ and Gianni Facciotto¹

A reduction in energetic and economic costs is key to the sustainable development of Short-Rotation Coppices (SRC) for energy purposes. During their cultivation, the highest costs are incurred in the course of the planting and harvesting phases. Currently, the SRCs are established with 20-30 cm long cuttings and with a diameter above 1-1.5 cm; for each cutting we could obtain one or more sprouts. Considering the high density of SRCs (5,000-20,000 trees ha⁻¹), labour and time for cuttings preparation and planting, reached a very high cost. Taking advantage of poplar and willow rooting ability, in the last years a part of experimentation has been addressed to evaluation of another plantation method, which involves the horizontal disposition of 120 cm long stems or cuttings, at a depth of 5-10 cm. It could provide energy and cost savings during planting.

The results of three experimental plots - in Casale Monferrato (sandy soil), in Cannara (clay soil) and in Chioggia (peat soil) - are shown: horizontal stems and long cuttings were able to produce from 1 to 5 sprouts per meter (sp m⁻¹), depending on the genotype and environmental conditions. Willow was able to produce on average from 2.1 to 4.8 sp m⁻¹ and between poplars, the species P. ×canadensis produced more sprouts than P. deltoides (3.9 sp m⁻¹ compared with 1.9 sp m⁻¹). Yields reached a maximum in a Casale Monferrato trial with 12.7 oven dry tons per hectare (Odt ha⁻¹) for poplar ‘Orion’ and 12.3 Odt ha⁻¹ for willow ‘Levante’ at the end of the first year. For poplar and willow, that show a very high sprouting ability in vegetative reproduction, this method may represent a valid alternative, specially for nursery and Short-Rotation Coppice with very high density model (vSRC).

Nevertheless, we must emphasize that the final density of the plant is only predictable and not safe and depends on many factors. In fact, it is the authors' opinion that different species and clones respond differently, and generally the genotypes showing high rooting values with normal cutting, show also high sprouting ability with this method. Furthermore, it seems that the water soil conditions and rains, associated with the type of soil, affect the sprouts emission. In addition, considering the lower cuts and the lower time to insert the rods in the soil compared to traditional plantations, it is possible to assert that this planting method allows to reduce time and costs for material preparation and for planting.

Key words: Short-Rotation Coppice (SRC), poplar, willow, planting.

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GROWTH POTENTIAL OF FIRST GENERATION HYBRID ASPEN PLANTATIONS IN SOUTHERN FINLAND

Egbert Beuker, Anneli Viherä-Aarnio and Jari Hynynen

During the end of the 1990’s a series of field trials with hybrid aspen (P. tremula x P. tremuloides) were established in southern Finland. The aim of these trials was to study commercial pulpwood production of first generation hybrid aspen plantations at different initial spacing (400 to 1600 trees/ha) and using different clones.

The results show that the most dense plantations (1600 trees/ha) had the highest production, reaching over 20 m³/ha/year over a period of 18 years. Besides for initial spacing, there is also a significant effect for site as well as for clone.

With such growth rates, first generation plantations of hybrid aspen could be grown in southern Finland with rotation periods of 20 years, or even less, without any commercial thinning. It is assumed that the next generation plantations, which are grown from root suckers, have an even higher production rate. Compared to other tree species that are commonly planted at the same type of site in Finland, the results show that the growth rates of hybrid aspen during the first 20 years can be up to 40% higher than of silver birch (Betula pendula Roth.) and 50% higher than of Norway spruce (Picea abies Karst.).

Although during recent years there have been hardly any activities concerning development of hybrid aspen cultivation in Finland, it is expected that in the near future hybrid aspen may become increasingly important as a resource of biomass in the Finnish bioeconomy.

Key words: Hybrid aspen, initial spacing, clonal variation, pulpwood production, growth rate.
CONTRIBUTION OF POPLARS AND WILLOWS FOR RURAL LIVELIHOODS AND SUSTAINABLE DEVELOPMENT IN ARGENTINA

E.D. Borodowski¹,²

Poplars and willows belong to the Salicaceae family. They are selected species for forest production in Argentina because of its rapid growth, the ability of spreading vegetatively, its resprouting capacity and the possibility of consociation with other crops and other productions in agroforestry systems.

Argentina does not have native species of Salicaceae, except for *Salix humboldtiana* Willd, known as "sauce criollo". The cultivated species are exotic, being mainly poplar, *Populus deltoides*, *P. × canadensis*, *P. nigra* and several hybrid willows (*Salix sp.*).

Willows and poplars represent about 10% of the planted forest in Argentina. They are the third group of important forest species in growing forest plantations, after pines and eucalyptus. The main growing areas are Paraná Delta and Cuyo regions, Valles del Río Negro and Neuquén, as well as Buenos Aires and Santa Fe provinces. The adaptability to a wide range of climatic and soil conditions in Argentina, allows its implementation in marginal soils for other productions, becoming preferred species in various agro-climatic conditions.

Its timber has various industrial uses, suitable for pulp wood, reconstituted boards, sawn timber, plywood, and veneer. Besides Salicaceae can be used as bioenergy crops, for environmental services (shelter, shade and protection of soil, water, crops, livestock and dwellings) and have a positive role in rehabilitation of degraded lands, forest landscape restoration, climate change mitigation and livelihood generation in Argentina.

Argentina has an important potential Salicaceae growing area. Within it there are areas with potential for the production of quality wood and as bioenergy crops. Considering that the current demand for Salicaceae timber exceeds the supply, it is important to increase the forest area with this family, as well as increased productivity of these species and silvicultural practices that prioritize the timber production destined for sawing and unwinding wood.

There are also alternatives for producers, such as the possibility of combining these crops with agricultural crops or silvopastoral production by rapid growth (compared with other forest species used in other provinces) and the favorable forestry promotion carry by the government.

Salicaceae cultivation and all its value chain can produce a high impact in terms of social, economic, environmental and quality of life of people living in the places where these species are implanted.

**Keywords:** Salicaceae, *Populus sp*, *Salix sp*, Argentina.

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BIOMASS PRODUCTION OF THE *POPULUS* x *CANADENSIS* ´CONTI 12' CLONE, IN DIFFERENT PLANTING DENSITIES

J.A. Bustamante, E.M. da Silva, L. López and J. Llera

Argentina has no data on biomass production that could be obtained in cultures of poplar clones planted at high densities, under short rotation turns. The aim of this study is to quantify the biomass resulting from an energy crop of the *Populus* x *canadensis* ´Conti 12’ poplar clone, in two planting densities; through four biannual turns of harvest.

The experimental plot was installed in 2006 in a rural property irrigated with treated residential wastewater, located approximately 20 km north of Mendoza city. One year old wood cuttings of approximately 30 cm in length were used as plant material, which were placed into two planting frames: in a double row with a distance of 75 cm, then an inter-row of 150 cm, with a distance between cuttings of 90 cm in the direction of the row, and a double row with a distance of 60 cm, then an inter-row of 120 cm, with a distance between plants of 55 cm in the direction of the row, obtaining a density of 10,000 and 20,000 plants.ha$^{-1}$ respectively. Randomized block design was used, with 3 replications of 100 plants each for both densities.

The first year the plants were cut at 15cm from soil surface; then the biomass produced in each plot in the years 2009, 2011, 2013 and 2015 was harvested. Given the weight of each plant, the number of live plants in plot on each harvest turn and the planting density, the biomass produced, expressed in tons of fresh matter per hectare, is as follows:

- To 10,000 plants.ha$^{-1}$; the results were: 21.75; 17.25; 10.50 y 5.40 Mg.ha$^{-1}$.year$^{-1}$ on each harvest turn.
- To 20,000 plants.ha$^{-1}$, the results were: 32.70; 28.30; 19.2 y 22.8 Mg.ha$^{-1}$.year$^{-1}$ on each harvest turn.

The biomass obtained in each harvest turn was higher in the density of 20,000 plants.ha$^{-1}$; this is because the average weight per plant was similar in both densities, and this density showed, besides a greater amount of plant, a greater amount of living plants. It can be considered that after 9 years and four harvest turns, the biomass production of this crop is maintained at acceptable levels mainly in the higher density of plants per hectare.

**Key words**: Biomass, *Populus*, short-rotation coppice.

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ALTERNATIVE MODELS OF SILVOPASTORAL SYSTEMS IN POPLAR FORESTS FOR IRRIGATED AREAS OF MENDOZA, ARGENTINA

A.D. Calderón, C. Rébora, J.A. Bustamante, F. Tacchini, S. Robledo1, M. Ochoa, M. Tondi and O. Araya2

Forest activity, as with poplar species in irrigated areas, demands long periods (10 or more years) to recuperate the investment. One alternative to generate incomes is livestock production that needs the incorporation of forage production to the system. The main objective of this project is to evaluate alternative models of silvopastoral forestation of *Populus* ssp in areas under irrigation in Mendoza. This main objective implies three other specific ones: 1) to evaluate the response of poplars to different alternative models of silvopastoral systems, 2) to evaluate the response of pastures under the influence of forest, and 3) to estimate the potential of meat production indirectly based in the quantity and quality of forage.

The project is located in two different places in the Mendoza area: one in Tunuyán and the other in San Rafael. In Tunuyán, the trial was installed in a forest of *Populus x canadensis* 'Conti-12', at a distance of 5 x 4 meters; three treatments were evaluated: witness without pastures (traditional farming), spontaneous vegetation and implanted polifitic pasture (*Trifolium repens, Festuca arundinacea, Dactylis glomerata and Bromus unioloides*). In San Rafael, the test was developed in the experimental field of INTA Rama Caída, in a forest of *Populus x canadensis* 'Conti-12' at a distance of 6 x 4 m; three treatments were evaluated: witness without pasture (traditional farming), pure pasture of *Medicago sativa* and polifitic pasture (*Dactylis glomerata, Lolium multiflorum, Festuca arundinacea, Medicago sativa and Trifolium pratense*).

This project is under way and at present gives information about poplar growth during the first cycle of implementation of the pasture, the volume and quality of pasture produced. The production of dry matter per hectare ranges from 3,800 to 19,500 kg., equivalent to 250 to 1400 kg of meat per ha. There are significant differences between treatments in the growth of poplars; the average growth of poplar in all cases was higher in the witness. A notable difference can be observed in the total dry matter production according to the site - the production of San Rafael was very higher than Tunuyán.

The result is supposed to be due to the different ages of forest, planting densities and environmental conditions for each site. It is planned to continue with measurements and calculations in the next growing seasons in order to understand and evaluate the silvopastoral system throughout the forest cycle.

**Key words:** Silvopastoral systems, *Populus*, forage, irrigated areas, Mendoza.

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ESTABLISHMENT OF SILVOPASTORAL SYSTEMS IN THE DELTA OF THE PARANA RIVER:
ROOTED AND UN-ROOTED POLE CUTTINGS WILLOW AS PROPAGATING MATERIAL

Edgardo Casaubon and Teresa Cerrillo

Willow (Salix spp.) plantations in Argentina concentrate mainly on the Delta of the Paraná River. The propagation material used consists of cuttings (of variable length), rarely un-rooted pole cuttings, and never rooted pole cuttings. Although grazing under willow plantations is not common in this area, willow trees can be used on Silvopastoral Systems (SPSs). The few examples of this show that livestock entry starts between the fourth and the sixth years, depending on trunk diameter (DBH), thus minimising plant loss due to knock-down, breakage or bark-stripping by cows.

With the aim to generate information in order to bring forward livestock entry into the silvopasture, two trials were established assessing the rooting capacity of pole cuttings (T1) and of rooted pole cuttings (T1, R1) for three recently recorded improved willow trees: S. matsudana x S. alba “Agronales INTA-CIEF”; S. matsudana x S. nigra “Lezama INTA-CIEF”; S. matsudana x S. alba “Los Arroyos INTA-CIEF”, and two others in an advanced stage of selection, “98.11.01” and “94.08.43”, in the Experimental Field of the Instituto Nacional de Tecnología Agropecuaria’s Estación Experimental Agropecuaria Delta (Delta Agricultural Experimental Station). The genetic material used is characterised by fast growth, straight shafts, and narrow crowns. Even if the rooting percentage for all five clones was 100%, “Lezama INTA-CIEF” planted from un-rooted pole cuttings showed the lowest percentage of sprouting along the pole, as opposed to 100% when planted from rooted pole cuttings.

On the basis of these preliminary assessments, the use of un-rooted pole cuttings and rooted pole cuttings for S. matsudana x S. alba “Agronales INTA-CIEF”; S. matsudana x S. alba “Los Arroyos INTA-CIEF”, 98.11.01 and 94.08.43, and of rooted pole cuttings for “Lezama INTA-CIEF” should be a good option for the establishment of a SPS.

Key words: Silvopastoral systems, Salix spp., propagation material, Delta of the Paraná River.

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PROPOSED MANAGEMENT FOR WILLOW AGROSILVOPASTORAL SYSTEMS IN THE DELTA OF THE PARANÁ RIVER (ARGENTINA)

Edgardo Casaubon, Teresa Cerrillo, Laura Gurini and Mauro Fernández

In the last years, the quantity of beef cattle in the region has led to the need to move from the traditional plantation system to a more intensive production system with the aim to achieve a comprehensive production of wood, grasses, beef and bee products. Willow agrosilvopastoral systems (AS) currently focus on wood production for various uses in an environmentally-friendly fashion. The new willow silviculture is designed to produce a higher percentage of wood for solid uses (sawn wood and veneers), in addition to crushed wood, wood pulp and/or wood for energy uses. In the case of plantations under AS particularly, it is designed to produce high-quality beef, forage and/or bee products (honey, bee pollen, propolis) according to the demands from both the domestic and international markets.

This silvicultural management demands organisation of the plantation area, identifying the most suitable sites for the clones to be cultivated. Predominant plantation frame plots are square-shaped, such as 4x4 and 5x5 m. It is essential to implement good water management, which requires proper land systematisation facilitating river water movement through the use of drainage networks. In order to yield quality materials, nurseries require planting greater spacings than traditional ones, such as 1x1 m, as well as excellent sites and more intensive nursery management. In the most adapted plantation sites, there have been good experiences of planting one- and two-year old, 3.5- to 7-m long, rooted and unrooted pole cuttings, especially in Salix babylonica x Salix alba ‘Ragonese 131/25’ and ‘Ragonese 131/27’, and Salix matsudana x Salix alba ‘Barrett 13/44’ willow cultivars, obtained from nurseries specially designed to that end. This silviculture accelerates AS establishment, with livestock entry at the first, second or third year of plantation, facilitating natural grass consumption and the simultaneous production of beef, bee products and wood for various uses. It also favours individual plant growth with a higher percentage of cylindrical shafts, as well as augmenting planting period (May-August), spontaneous forage and wood quality by reducing dark stains and standing tree death due to excess water. There is less competition among plants and a lower risk of surface and forest fires, since dry grass volume is smaller, and water is always present in drainage networks and available for livestock. In addition, willow leaves are very palatable and nutritious for livestock, and thus a good complement to livestock feed.

Key words: Salix spp, agrosilvopastoral systems, delta of the Paraná river.

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POPLARS IN THE KYRGYZ REPUBLIC

N. Chyngozhoev¹

The forests of the Kyrgyz Republic are located in a mountainous area and have water and soil protective, recreational and scientific value. A large number of different species grow there (wood and shrub). The forests are rich in wild-growing products: berries, fruits, walnuts, medicinal herbs. There is a sufficient number of tilled fields, hayfields, pastures, facilitating the development of animal husbandry, grain growing, and they constitute wildlife habitats. Rivers of Central Asia cross the forests of the Kyrgyz Republic and their waters are used for irrigation of lands, not only in the Republic, but also abroad, in Uzbekistan, Tajikistan, Kazakhstan and the People’s Republic of China.

On the territory of the country sixteen species of poplars are widely known, nine of which represent the local wild-growing wood and shrub flora. They grow in the valleys of the mountain rivers or watered slope aprons. These are swamp, blue, Bolle’s, Tien Shan, Uzbek, densely-leaved, Talas poplars and trembling poplar. Others relate to foreign species introduced into the culture at different periods. As a rule, they are not demanding to soil conditions, but require scheduling irrigation. They propagate by seeds, cuttings and rootstocks. Poplar wood is white, light, and machinable. In the national economy it is used for paper and veneer manufacture, manufacture of rayon, match splints, packing cases, dry distillation, cold building construction, as well as manufacture of household items (shovels, dishes, utensils, toys, etc.).

Poplars are of great value for landscaping. They are characterized by rapid growth, crown form, color of leaves, bark, branches and, to some extent, aglets of staminate flowers. Furthermore, poplars are of high value by the fact that they clean the air. Their opening buds and juvenile leaves scatter fragrance with detrimental effect on malignant bacteria, including influenza virus. Among the growing wild species Bolle’s poplar is widely used for housekeeping needs of the population, and among introduced poplars - pyramidal and black. Until recently, these poplar species are the main construction material for residential units and other household premises.

Considering the importance of poplar wood for partial covering the population needs, creating a basis for social forestation, support for socio-economic development of regions and conservation of natural forests by sustainable multifunctional use of existing potentials, the Government of the Kyrgyz Republic has entrusted local administrations to start poplar plantations and implement annual planting of fast-growing woody species culture on agricultural lands not suitable for agriculture. However, a topical and important issue is in the regularity of local residents training, as well as scientific approach in mechanisms of planting and growing.

Key words: Poplars, wood, shrub flora, Bolle’s poplar, local residents training.

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NEW CLONES WILL LET FARMERS INCREASE VARIABILITY AND SUSTAINABILITY OF POPLAR PLANTATIONS IN ARGENTINA

Silvia Cortizo¹, María Silvana Monteverde² and Nora Abbiati³

Poplar plantations in the Paraná River Delta area, which currently cover 14,508 hectares, began in the late 19th century with the introduction of *P. deltoides* subesp. *angulata* cv. *Carolinensis*. These and willow plantations are the main economic resource of the region. Maintaining the quality and health of commercial plantations greatly depends on the continuous supply of genetically improved clones and a suitable silvicultural management that allow to obtain wood of adequate quality for the industry. To meet this requirement, the National Agricultural Technology Institute (INTA) leads a poplar-breeding programme since 1960, the main objective of which being the selection of superior genotypes based on the concept of comprehensive quality of the tree to improve industrial performance.

As Argentina does not have any native poplar population to establish the basis of the programme, it was necessary to introduce *Populus deltoides* and *P. xcanadensis* improved clones, mainly from Italy and the United States. Some clones, once their adaptation tested, were commercially widespread and included in the schedules of controlled crosses. Seeds belonging to *P. deltoides* trees that had shown good behavior in areas ecologically similar to Paraná River Delta within the natural range of this species were also introduced. The outstanding genotypes were selected using the method of independent culling levels for variables: fast growth, rooting ability; straight and cylindrical stem; tolerance to rust and *Septoria* canker; tolerance to flooding during the establishment period and physical and mechanical properties of the wood.

In this paper the technical characteristics of four new clones of poplar (Guayracá INTA, Ñacurutú INTA, Paycarabí INTA and Hoyvû INTA) submitted for registration in the National Register of Varieties are presented. All of them originate from seeds of *P. deltoides* collected in Stoneville, Illinois and Tennessee (United States) and introduced by Celulosa Argentina in 1977/1979. Part of this collection was donated to Ing. Abelardo Alonzo in 1982, who installed them in the A.E.E. ‘Delta del Paraná’. The four selected clones have a similar or better performance than commercial controls, excellent health, straight and cylindrical stem with thin branches suitable for mechanical harvesting. Their wood presents technological characteristics suitable for the sawmilling and unwinding. Before the commercial release, all of them were characterized by the DESCRIPTOR approved by the National Institute of Seeds (INASE) and by SSR markers, to facilitate traceability through the process of diffusion from our nursery to commercial plantations.

**Key words:** *P. deltoides*, clonal selection, Guayracá INTA, Ñacurutú INTA, Paycarabí INTA Hoyvû INTA.

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VARIATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF FOUR NEW POPLAR CLONES SELECTED IN ARGENTINA

Silvia Cortizo¹, María Silvana Monteverde², Mercedes Refot³ and Gabriel Keil⁴

In spite of the physical and mechanical properties of poplar clones which largely determine their suitability for various end-uses, especially for high value-added applications, they have not been included as a selection criterion in most of the breeding programmes.

Recently the National Agricultural Technology Institute submitted to the National Register of Varieties four new clones (Guayracá INTA, Ñacuturú INTA, Paycarabí INTA, Hovyů INTA). These clones were selected from seeds of P. deltoides collected in Stoneville, Illinois and Tennessee (United States) using a combination of nursery and clonal tests planted at high density, laboratory tests and multi-site field plantations. For each clone, six trees from 13 to 15 years old and circumference at breast height between 25.8 and 44.4 cm were selected before their commercial release. Second logs were sawn in lumber of 50 x 50 mm, 20 x 150 mm and 20 x 40 mm, transported to the LIMAD and stacked until the samples reach the equilibrium moisture (HEH) of 12%. Moisture content and density were determined on 30 specimens of 20 x 20 x 20 mm free of defects from each tree, following the protocol defined by the IRAM 9532 and 9544 standards. Dimensional changes were determined in 120 clear specimens of 20 x 20 x 50 mm perfectly radial and 120 ones perfectly tangential from each tree according to IRAM 9543. Janka hardness, static bending, cutting parallel to the fibers, compression perpendicular and parallel to the fibers were established in specimens of 50 x 50 x 150 mm (30), 50 x 50 x 200 mm (30), 20 x 20 x 300 mm (60), 50 x 50 x 65 mm (30), 50 x 50 x 150 mm (30), 50 x 50 x 200 mm (30). These tests were performed on universal testing machine following the protocols established by the IRAM 9570, 9542, 9596, 9747 and 9551 respectively.

According to its physical characteristics, the wood of these clones was classified as light (density: 370 to 470 kg/m³) and stable to moderately stable (Anisotropy coefficient: 1.96 to 2.03). Regarding the mechanical characteristics, the wood was soft to very soft (Janka hardness: 20.1 to 50.0 MPa), the compressive strength perpendicular was medium to high (6.52 to 9.71), the resistance to compression parallel was medium (32.6 to 37.9) and the shear strength was medium (8-12 MPa). Finally, the modulus of rupture was low (52.9 to 79.2 MPa) and the wood was very elastic, according to the modulus of elasticity (5402 to 6652 MPa). These results suggest that all the clones are suitable for various end-uses of high value-added applications.

Key words: P. deltoides, physical properties, mechanical properties.

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POPLAR AND WILLOW WOOD AS A MULTI-USE, LOCAL, RAW MATERIAL FOR A BROAD SPECTRUM OF GREEN CONSTRUCTION PRODUCTS WITHIN THE EUROPEAN FORESTRY WOOD CHAIN

Lieven De Boever¹ and Joris Van Acker²

During a ten-year research into more than 60 different poplar and willow clones, the potential of a broad range of construction products was assessed. Their density ranged as from 250 to 650 kg/m³ (oven dry). The outcome of the study describes the inherent properties of poplar and willow wood with special emphasis on assessing their variability and the possibility to select, control and improve the properties of interest. This immediately demonstrates the potential to use poplar and willow wood for almost all types of construction products.

The often large variability of the macroscopic material properties had to be understood, suitably described and linked to the impact on specific constructive building stones in order to prevent the need for exaggerated safety factors which result in an uneconomic over-dimensioning when designing timber members. Furthermore, the study evaluated the inherent wood features with respect to the impact on transformation processes (primary processing and drying). Solid wood members or components in reconstituted engineered materials were classified with regard to their mechanical performance. Also the possibilities of chemical preservation and thermal modification were envisaged for product types as window joinery and cladding.

Poplar and willow wood was evaluated as an additional source of raw material. The objective of this work was to compare the low-density hardwood species with the currently used (low-density) softwoods for load-bearing applications. Therefore, different product types as sawn solid timber or laminated timber were assessed using European standard codes and building regulations and calculations (Eurocode V, CPR). Moreover, the use of reconstituted materials (glulam, LVL and plywood) allowed to reduce or redistribute the number of wood defects (strength reducing factors), as such enhancing the yield of timber for value added construction products with prolonged service life. Adding or shifting raw material flows within the European integrated forestry-wood chain does induce questions on economical feasibility (quality vs. quantity) and environmental restrictions (sustainable and durable production systems). Therefore, the study handled on the impact on the forestry side as well as the wood column demonstrating the important potential of environmental friendly and local wood resources with an additional social impact due to local employment and a wide range of niche products.

The concept of this research demonstrated an overall approach to assess rapidly growing low density hardwood species for load-bearing applications. Although this work specifically focuses on poplar and willow, the methodology will be transferable to fast-growing low-density hardwood species growing worldwide (e.g. eucalyptus, limba, alder) as well as to other product groups (energy resources).

Key words: Poplar, willow, construction products, economical drivers, environmental impact, European forestry wood-chain.

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HOW TO RUN A BIOMASS GROUP-HEATING ON SRC BASIS

Hans-Georg von Engelbrechten

The Agraligna GmbH started their business with the idea to produce the raw material directly where it is used. As a provider of planting material for short-rotation coppice (SRC) as well as for planting and care service, the target was not only to plant SRC, but also to give advice and to develop local small- or medium-scale heating-projects. Using the domestically produced woodchips for the domestic heating system and also to sell heat to neighbor households, the farmer realizes the positive effect of upgrading his special crop from his field.

This case was developed in 2008 in the Village of Beuchte near Braunschweig, Lower Saxony, Germany. A heating grid was established in Beuchte with two woodchip heating systems generating the necessary heat for 65 households. The heating grid was established in a way enabling additional households to be added later without having to change the construction of the existing network. In order to establish a project of maximum total CO₂ mitigation efficiency, the aim was to make the system independent from any foreign raw material so that the SRC plantations were planted very close to the village, avoiding additional energy for transportation.

So far, Agraligna planted 15 hectares on fields owned by the operators for operating the grid with an average biomass potential of 10 to 14 t (DM)/ha*a. For purposes of extension as well as for other already existing local heating projects, more plantations have been established on other farms. Within 10 km distance there are more than 30 hectares of SRC. The heat is being delivered to the households based on 12-year-contracts by means of hot water which is pumped through the grid with transmission stations installed in the customer houses. The fields which are used for fuelwood production are smaller than the average field size of the farm so that the economically important large fields remain for the production of wheat, sugar beet, or oil seed rape. Apart from the fact that the system becomes independent from foreign fuelwood the operator can also guarantee a price for the heat delivered to the customers, as the price of acquisition of energy wood from SRC can be fixed over a long period of time. Therefore, the business model can be adopted elsewhere as long as there is interest from a sufficient number of local households to agree to long-term contracts. The advantage for the households consists of savings compared to fossil sources of energy (10%) and savings on maintaining fossil energy combustors (10%) so the average advantage is 20% in total depending on current prices.

Key words: Heating grid, biomass group heating, SRC.

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POPLAR SHORT-ROTATION COPPICE GROWN IN MARGINAL ENVIRONMENTS OF SOUTHERN ITALY

Gianni Facciotto¹, Sara Bergante and Giuseppe Nervo

With the aim to extend short-rotation coppice (SRC) for bioenergy purposes with poplars in Southern Italy and to verify the biomass production of poplar clones in these environments, characterized by low water availability, five trials were established in the frame of the FAESI Project funded by the National Ministry of Agricultural, Food and Forestry Policies during the last seven years. Due to the extreme poplar plasticity, and with the interest on SRC cultivation on marginal soils, these plantations may represent a valid alternative or an additional income also in South Italy areas, that have social and economic problems due to lack of work and cultivation difficulties related to the conformation of the territory.

The fields are plowed until 30 cm and refined by harrowing just before planting. Unrooted cuttings of different genotypes of Populus spp were planted in single rows with densities ranging from 1667 to 5000 trees per hectare and harvesting cycle ranging from two to five years. Chemical weed control with a pre-emergence herbicide was applied after planting. Mechanical control of weeds was carried out between the rows during growing seasons while manual hoeing on the rows in the first year. Pest control (poplar borer) with a synthetic pyrethroid was required in the three trials. Two trials are not irrigated, two trials are irrigated only in the first year and one is drip irrigated with low volume of water during each summer.

The experimental design was randomized complete blocks with three replications in all the trials. Data collection concerned: direct observation during growing season, survival rate, dendrometric recording (diameter at breast height, total height) and above ground biomass weights of the inner part of each plot at the end of the harvesting cycle. The aboveground biomass production of the best poplar clones (‘Neva’ in Apulia and ‘Dvina’ in Sicily) in three sites is under 5 oven dry ton (odt) ha⁻¹ year⁻¹ while in the other two sites, both in Calabria, is over 10 odt ha⁻¹ year⁻¹.

The overall sensitivity of poplar to drought represents a severe limit to the future development of its cultivation in Southern Italy. Poplar SRC is possible with good results only in limited areas characterized by high rainfall or by the presence of a constant water table at depths accessible to the roots, as in the Apennine valleys, or alternatively using waste water as irrigation. Considering the present economic situation and the looming global warming, selection criteria of commercial poplar clones need to be reoriented in order to take into account resistance to abiotic stresses in general, and to drought in particular in addition to a maximum biomass production.

Key words: Poplar, SRC, biomass production.

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BIOMASS PRODUCTION WITH POPLAR AND WILLOW IN ALLEY COPPICE SYSTEMS IN PIEDMONT (ITALY)

Gianni Facciotto¹ and Sara Bergante¹

Alley coppice is an innovative production system that combines the growth of trees for valuable timber (as *Prunus avium*, *Sorbus torminalis*, *Quercus* spp. and others) with poplar (*Populus* spp.) and willow (*Salix* spp.) Short-Rotation Coppice (SRC) in the same land. The advantages are: more protection of the valuable timber trees from atmospheric events, rapid coverage of the ground, apical dominance and reduction of pruning intensity of timber trees. In addition farmers can sell SRC biomass every 2-5 or more years obtaining an income when timber trees are in the juvenile phase (10-15 years). This model has been introduced in Italy, in the recent past, and this work refers growth and production results of two trials situated in Brusnengo (BI) and Casale Monferrato (AL) Piedmont.

The first trial, planted in Spring 2005 on a *inceptisol* soil, covers an area of approximately 1.5 ha, contains 4 poplar and 4 willow genotypes and different timber species: *Acer* spp., *Prunus avium*, *Quercus robur*, *Carpinus betulus*, *Pyrus communis*. The planting layout is: 12 × 6 m for timber species, with a distance from SRC double rows of about 4 m; the SRC double rows have a spacing of 4 × 0.70 m. The final density is about 2380 trees ha⁻¹ for SRC and 139 tree ha⁻¹ for timber species. The second trial covers a total area of 1.5 ha on a flat agricultural field with alluvial soil (*fluvisol*). Experimental plots were established to compare pure plantation of *Sorbus torminalis* and *Pyrus communis* with the mixture of these timber trees with 3 poplar clones under SRC management. One year rooted seedlings were planted at a spacing of 8 × 8 m. The distance between poplars and timber trees was 3 m. The final density for poplar was variable from 1000 to 5000 trees per hectare due to method of planting (poplar was planted as un-rooted stem cuttings, 120 cm long, placed horizontally on the soil surface with an inter-row distance of 2 m) and depending on genotype; 156 tree ha⁻¹ for timber species. Poplar and willow genotypes were tested with Randomized Complete Block Design, with 3 replications.

In Brusnengo, average yield of SRC reach 6 oven dry tons per hectare per year (Odt ha⁻¹ y⁻¹) in the first and second harvest cycle (5-7 years); the timber trees showed a mean annual increment of diameter at breast height (dbh) ranging from 1 to 2.3 cm in the last years. In Casale Monferrato, average yield of poplars ranged from 2 to 5 Odt ha⁻¹ y⁻¹ with biennial harvesting. The timber tree species showed a continuous growth; dbh reached in average 50.4 mm for *Pyrus* and 39.2 mm for *Sorbus* with a maximum growth in pure stand.

The fast-growing species tested in these trials show large potential as energy crops in marginal lands. They can supply woody biomass to produce renewable thermal energy and/or electricity for a farm plant. Alley coppice design could be an innovative mixture in relation to its management simplicity, especially concerning the mechanization of cultural operations and marketability of final and intermediate products.

**Key words:** Poplar, willow, biomass, alley coppice.

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GROWTH PATTERNS OF SEVERAL POPLAR CLONES FOR PLYWOOD PRODUCTION IN SPAIN

P. Garnica¹, Pedro Romero², Oscar Crespo³ and J. Garnica⁴

“Bosques y Ríos” manages around 1.800 ha of poplar plantations in Spain, located mostly around the Duero and Ebro river basins. These plantations are sustainably managed, certified under PEFC standards and nearly half of them are FSC-certified as well. The destination of the timber is rotary cutting for obtaining plywood.

Traditionally Spanish poplar cultivation has been based on the Italian clone I-214. This variety provides excellent and white veneers; however, because of its tension wood, it sometimes splits when felled, making it useless for plywood production and it is sensitive to some pest and diseases as well. In order to widen the genetic pool and identifying the most suitable poplar varieties for Spain several experimental plots have been established in the last 16 years. More than 50 clones are being currently tested, coming from several research centers in Europe. Once the trees are felled studies about their quality for peeling are carried out as well. Some clones that obtain excellent growth results have been rejected for future plantations because of their affection by certain pests and diseases.

In this study several clones are indentified as potentially interesting from the growth perspective. Future monitoring of these plantations and testing their quality for peeling will determine in the future if they can be considered as viable alternatives for poplar plantations in Spain.

Key words: Poplar, clones, growth, plywood.

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ECONOMIC ANALYSIS TOOL FOR SRWC-BASED FEEDSTOCK PRODUCTION IN THE SOUTHEASTERN U.S.A.

Solomon B. Ghezehei¹, Elizabeth Guthrie Nichols¹, Robert Bardon¹ and Dennis W Hazel¹

The importance of woody feedstock for future renewable energy production and the potential of poplars and other short-rotation woody crops (SRWCs) as sustainable feedstock have been recognized. Economically viable SRWC production is particularly significant in the southeastern U.S.A. due to prominent wood pellet exports to Europe and evolving bioenergy markets, and depends on minimizing costs and maximizing economic returns and productivity. Major renewable energy policies including the 2007 Energy Independence and Security Act in the U.S.A. and the European sustainability guidelines discourage the use of productive lands for bioenergy production necessitating substantial non-contentious lands for bioenergy production. Hence, questions regarding the effects of marginal land types, species and stand management decisions on economic returns should be addressed.

A robust and user-friendly economic analysis tool was developed for SRWC-based feedstock production based on enterprise budgets required for best management during establishment and maintenance of stands on marginal lands. It can be used for assessing economic feasibility of growing woody feedstock based on land type or previous land use, species, stand management, rotation length and feedstock prices, and determining feedstock prices or productivity on a particular land required to achieve a target return (e.g. breakeven). Further development of the analysis tool into a web-based application is underway using BlueGriffon™ to ensure extensive accessibility and application in southeastern U.S.A.

Key words: Bioenergy, investment analysis, marginal lands, poplars, sustainability.

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POST-HARVESTING EMISSIONS OF CO2 AND BIOGENIC HYDROCARBONS FROM WOODCHIPS PRODUCED BY A POPLAR SHORT-ROTATION COPPICE

Andrea Ghirardo¹, Karin Pritsch² and Jörg-Peter Schnitzler¹

Due to the increasing demand of renewable and sustainable energy, short rotation coppices (SRCs) of hybrid poplars or other fast-growing tree species (e.g. willows) are becoming an important source for biomass production. To assess their sustainability, a comprehensive analysis of greenhouse gases (GHG) and reactive volatile organic compound (VOC) emissions along the overall production chain is essential. Up to now, less attention was paid on post-harvesting processes. Poplar SRCs are commonly harvested by chipping the woody biomass, and the woodchips are accumulated as piles and let drying outdoor to reach water content (WC) of ~30% before they can be used for energy production. However, how and to which extent the storage of woody biomass releases GHG (i.e. CO₂, CH₄, N₂O) and VOCs into the atmosphere remains unexplored.

Here we demonstrate how storage temperature and microbial activities affected the C-loss of freshly harvested poplar woodchips. Immediately after harvest of a SRC plantation, wood chips (average size 16 mm; piles ~ 63 Kg fw) were placed in gas-tight enclosures in phytotron chambers at 3 constant temperatures (15, 20, 25 °C). During the drying process, emissions of CO₂, H₂O and VOCs were recorded online over 6 weeks by infrared spectroscopy, proton transfer reaction mass spectrometry (PTR-MS), and gas chromatography (GC-) MS.

From a biological perspective, woodchipping represents a severe mechanical stress, which induces a broad range of stress-related responses in the living wood. The C-loss as CO₂ was high at the beginning of the storage (~ 10 g Kg⁻¹ dw⁻¹ day⁻¹) and decreased within the following two weeks to ~ 2 g Kg⁻¹ day⁻¹, a rate almost stable until the end of the experiment. The C-loss correlated positively to temperature. Overall, the woodchips lost 13, 17, 18 % of carbon (respectively to storage at 15, 20, 25 °C) of its initial dry masses. We observed a conspicuous release of different VOCs following different time gradients. Methanol was emitted in large quantities during the initial heat of the heap possibly due to degradation of plant material. After few days, monoterpenes, sesquiterpenes and benzenoid emissions increased in concert with microbial activities.

We clearly demonstrate that freshly harvested woodchips from poplar SRCs (i) were a source of both CO₂ and VOC emissions during the drying process, and (ii) a significant proportion of C was lost due to microbial activity. Because VOCs are highly reactive with trace gases (OH, O₃) of the atmosphere, the high VOC emission rates originating from woodchip piles might impact local air chemistry. Beside the unavoidable emissions of VOCs and CO₂ during the production and transportation of biomass, the technical processes of making and storing woodchips needs to be taken into account when assessing the benefits of poplar SRCs, in terms of carbon dioxide neutrality, global warming potential and air chemistry.

Key words: Woodchips, greenhouse-gases, C-loss, CO₂, H₂O and VOCs emissions, biomass.

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Since the Romans introduced poplar in Spain as a crop on family-run farms to be used as fences, windbreaks, firewood etc., this crop evolved very little until the XIX century, when the first native or foreign selected clones were introduced. However, the creation of the National Poplar Commission in 1952 marked the beginning of substantial improvements in both plant material and cultivation techniques, which would lead to increased production and improved wood quality. Between 1972 and 1982, the average annual standing wood volume for poplar was around 500,000 m³. This figure has continued to rise and now stands at over 700,000 m³ per year. The increase in production over recent decades is not due mainly to an expansion in the planted area, which has slowly increased from 100,000 ha in the seventies to 116,000 ha today, but rather to genetic improvement and higher plant quality used in plantations, the potential benefits of deep-root plantations, especially relevant in Mediterranean conditions of low rainfall, and current high-tech cultural management.

Additionally, the quality of the wood produced has improved in the newer plantations, with the consequent increase in price. For example, in the province of León, an average price of 58.6 € / m³ was reached at public auction last year. Bearing in mind that the rotation cycle is normally 15 years, it can be affirmed that intensive poplar plantations are a very promising option as a forestry crop for rural forest development. From the point of view of environmental protection, poplar plantations make an important contribution to the fight against climate change thanks to their ability to capture carbon. One hectare of poplar fixes 12 tonnes of CO₂ per year, which means 1.4 million ton in Spain.

Over the last decade (2006-2016), interest in obtaining biomass for energy purposes has led to SRC cultivation. This activity has mainly been established on surplus agricultural land and always under irrigation. Cultivation is based mainly on hybrid poplar clones, with ongoing testing of clones used for traditional wood production as well as new clones developed in Europe for this specific purpose. To a lesser extent, trials have also been established with other fast-growing species.

Heat generation using biomass has a promising future in Spain. However, the prospects for electricity production from this resource have weakened considerably due to regulatory rules introduced in 2014 (RD 413/2014). On the other hand, the production of biomass for second-generation biofuels is hotly debated and it is necessary to settle the question of the type of land to be used. Moreover, the development of a bioeconomy in Europe has led to biomass production being considered within a broader framework in which not only energy but also other new higher value-added bioproducts are under development.

Today, both forms of crop coexist, albeit with a far greater area in the case of traditional crops. The evolution of the situation over coming years will be strongly influenced by the development of enterprises demanding the product and the price of the raw material.

Key words: Poplar cultivation, wood, biomass production.
BIO-ETHANOL FROM HEMICELLULOSES WASTE OF LIGNO-CELLULOSIC BIOMASS – A SUSTAINABLE FUTURE BIO-REFINERY PROSPECT

P. K. Gupta\textsuperscript{1} and Vikas Rana\textsuperscript{1}

Hard wood tree species such as Poplar and Eucalyptus are grown on large land areas to meet requirement, particularly of Plywood Industry and Pulp and Paper Industry besides others. Bio-energy industry particularly with technological advancement in production of bio-ethanol from ligno-cellulosic biomass may raise the future demand for these biomasses, and due to this additional application the existing industries may face competition to meet their requirements, resulting in low-availability and price hike. In countries where land is limited and required more for agriculture and other purposes, there will always be constrain in the availability and growing more of such plant species.

The Plywood Industry uses raw wood and the side waste as well as fresh material is used by Pulp and Paper Industry, where the biomass is processed and a pulp yield \(~55\%\) is achieved on dry matter basis. The remaining \(~45\%\) of the plant material, which is a substantial quantity if total paper produced is considered, go as waste in the form of black liquor comprising mainly lignin and degraded hemicelluloses sugars. These leftover degraded hemicelluloses sugars waste is converted for bio-ethanol production without requirement of fresh biomass leading to future green economics, and in the presentation achievements made and challenges ahead is discussed.

**Key words**: Bioenergy, black liquor, hemicelluloses, bio-ethanol.

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WIMCO - a privately owned match splint manufacturing company - introduced *Populus deltoides* clones from Australia in the 1980s. Under field trials, clones G-3 and G-48 outperformed all other clones and laid the foundation of poplar-based agroforestry plantations in north Indian states of Punjab, Haryana, Uttar Pradesh and Uttarakhand. The National Bank for Agriculture and Rural Development partnering with WIMCO and 13 commercial banks under PPP model financed a big poplar-based agroforestry project from 1985 to 1995 which was a huge success.

The author undertook a case study in Punjab in 2010 to ascertain the management practices, planting materials, yield, income and marketing. It was observed that G-48 clonal plantations were raised under intensive culture with 5m x 4m spacing which attained an average height of 18 m and 90 cm girth by 6th year, yielding 180 tons of wood per hectare, earning INR 0.72 million (1 EURO= INR 70) income with initial investment of INR 0.1 million and at a sale price of INR 4000 per metric ton. Marketing was no problem since in Yamunanagar, Haryana large numbers of plywood industries were established. Wheat and sugarcane were intercropped only for three years. Again in 2014, a field study was undertaken in Uttarakhand, which confirmed the high growth and yield of poplars that enhanced purchasing power of the farmers and changed the weak rural economy into strong green economy, thus uplifting the rural livelihoods on sustainable basis.

Poplar changed the rural landscape of these states and is now totally integrated in social, environmental, agricultural, silvicultural, ecological, industrial, economical and financial applications of the region. Since poplar wood was treated as cash crop, many growers earned INR 0.25 million income per ha per year when timber prices touched an all time high of INR 13000 per MT in 2012. Due to monopoly of plywood manufacturers, price has come down recently and hovering around INR 10000 per MT. Today, the world’s largest manmade, renewable poplar plantations are in India and are even harvested during the 4th year because of a very fast growth. With India’s population touching beyond 1300 million, demand for wood would remain high. The current annual turnover of this market is INR 10 billion, and is growing. Since poplar plywood is mainly used for furniture making, it will act as carbon sink to mitigate climate change for a long period.

**Key words:** Poplar agroforestry, high income, green economy.

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FERTILIZATION AROUND POPLAR STUMPS WITH ESTABLISHED SPROUTS

Birger Hjelm¹, Tord Johansson², Per-Ove Persson³ and Theo Verwijst¹

Landowners with harvested poplar plantations are currently facing the choice to replant or establish new populations based on sprouts production. To enhance the stump shoot production by fertilizing around stumps is an unproven method. An earlier project established fertilization experiments in three felled poplar stands in southern Sweden with two-year old sprouts 2012 in order to evaluate the short-term fertilization effects (two growth seasons) on sprout development. The poplar stands were 20-year old when they were harvested in 2011. The number of stems per hectare was 1250, 707 and 707 with a mean diameter at breast height (DBH) of 24.6, 25.1 and 25.1 cm respectively. The average diameter at 0.1 m height above stump for the sprouts was 7.5 mm in trial no.1 and 11.1 and 13.2 mm respectively for trial nos. 2 and 3 the first season after sprouting. Around the stumps with a radius of 5 m the ground was fertilized in autumn 2012 with a dose of 75 and 150 kg N per hectare. Totally 30 stumps were included in each trial: 10 as a control, 10 fertilized with 75 and 150 N ha⁻¹ each. Next year in spring five of the fertilized stumps where given a repeated dose. The number of sprouts stump¹ three years after treatment ranged between 9 and 17 for trial no. 1. For trial nos. 2 and 3 the number ranged between 9 and 14 and 12 and 15 respectively.

There was a short time effect of fertilization during which the fertilized stumps produced taller sprouts with larger DBH than unfertilized after three sprouting seasons. Mean sprout DBH was 20.7 mm for trial no. 1 and 29.9 and 33.4 mm respectively for trial nos. 2 and 3. In trial no. 1 sprouts with a repeated fertilization of 150 kg N ha⁻¹ were tallest, 415 cm, compared with unfertilized, 335 cm. In trial no. 2 and 3, sprouts with repeated fertilization (150 kg N ha⁻¹) were tallest, 592 and 584 cm compared with 516 and 548 cm for non fertilized sprouts.

In the current project, the experiments will be revised in spring and autumn 2016 and in autumn 2017 to evaluate the long term effects of fertilization on sprouting performance. In addition, based on the results of this follow up study, calculations of financial outcomes of different fertilization options will be made.

Key words: Poplar, forest management, second generation, sprouts, fertilization.

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A PILOT STUDY OF POPLAR PLANTATIONS OPTIMAL ROTATION PERIOD AND ITS GROWTH DYNAMICS UNDER DIFFERENT PLANTING DENSITIES

Birger Hjelm¹, Tord Johansson², Per Ove Persson³ and Theo Verwijst¹

Biomass production of poplar plantations in Scandinavia is known to be high, but knowledge of management practices is lacking for Nordic conditions. Individual landowners have little help or guidance in selecting the optimal planting density or optimal time for harvesting when establishing new plantations. To be able to target markets for specific diameter assortments with a poplar management system, knowledge of growth dynamics and diameter development under different planting densities is crucial for economic optimization. Short-rotation poplar plantations thus far have mainly been established for bioenergy purposes. Poplar plantations aiming to produce other assortments than biomass for energy need to take into account the diameter requirements needed for the pulp and timber industry. When the rotation period, for a given high planting density, is found to be appropriate in the short term (10-12 years), the resulting management system will primarily produce biomass for energy. For longer rotation periods (20-30 years) management systems using a lower planting density could also be designed to produce pulpwood and other assortments with larger diameter requirements. Stakeholders can with this knowledge be guided in plantation management and provide forecasts about yield depending on site conditions and management method, which includes planting density, thinning and length of rotation period.

This project is therefore divided into two sub-studies:

1) Study the growth of twelve poplar stands (7 to 23 years old) in three regions (in South, South West and Central Sweden) where height and diameter growth to date has been measured 3 to 6 years for the calculation of the mean annual increment (MAI) and the current annual increment (CAI). Some additional relevant allometric tree data will also be recorded to detect stem form variations within and between plantations, which can influence the increment estimations.

2) Study the growth dynamics under three different planting densities in two research trials, one in Västra Götaland and one in Uppsala län, established in May 2016. The design is: Three different spacing densities (625, 1 111 and 2 500 trees per hectare) with seedlings/cuttings on individual squared plots (30 x 30 m) with respective density planted within the plots. Each trial will have three replications of each density, altogether nine plots with a total area of 90 x 90 m. Both studies will be conducted with clone OP42 (P. maximowiczii x P. trichocarpa) in plantations established on farmland in southern and central Sweden.

The two studies will be revised annually during the project which ends in autumn 2018.

Key words: Poplar, bioenergy, forest management, rotation period, planting density.

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DIAMETER GROWTH AND WOOD PROPERTIES OF NEW ZEALAND POPLAR CLONES

Trevor Jones¹ and Ian McIvor

A demonstration planting of commercial and experimental poplar clones, at Palmerston North in the North Island of New Zealand, provided the opportunity to compare the diameter growth and wood properties of a wide range of poplar species and hybrid clones on one site at age 12 years. The trees were planted at 3 m spacing within the rows, and 6 m between rows, in a silt loam soil on a flat alluvial site at 37 m altitude, 12.8°C average annual temperature, 1080 mm average annual rainfall. One tree per poplar clone was selected with good form and evaluated for wood properties using two breast height pith-to-bark cores. The acoustic velocity of the ethanol-soaked and air-dried cores was measured from pith-to-bark using ultrasonic transducers (500 MHz), the wood density at 12% moisture content was measured from pith-to-bark using SilviScan-3 at CSIRO. The acoustic modulus of elasticity was calculated from the values of acoustic velocity and wood density.

There was no relationship between the diameter growth of the poplar trees and the wood density, and acoustic modulus of elasticity of the breast height cores, making it possible to select poplar clones that combined fast diameter growth and high wood density and acoustic modulus of elasticity. The wood density of the poplar clones ranged from 308 to 456 kg m⁻³, average 387 kg m⁻³, and the acoustic modulus of elasticity ranged from 4.0 to 5.9 GPa, average 5.0 GPa. The poplar clones with greater than average diameter growth, wood density and acoustic modulus of elasticity at age 12 years were ‘Dudley’, ‘Eastwood’, ‘Henley’, ‘Margarita’, ‘Veronese’ (Populus deltoides × P. nigra), ‘Kawa’ (P. deltoides × P. yunnanensis), and ‘Yeogi 1’ (P. alba × P. glandulosa). Of these, ‘Veronese’ and ‘Kawa’ are the two most widely planted poplar clones in New Zealand, accounting for 64% of the poplar poles planted in 2015.

Key words: Poplar, wood density, modulus of elasticity.

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ESTABLISHMENT OF POPLAR PLANTATIONS IN SCANDINAVIA AND THE BALTIC SEA REGION

Almir Karacic¹, Anneli Adle², Mindaugas Silininkas³ and Audrius Gradeckas⁴

In recent years the interest for fast-growing Populus species has increased rapidly in countries around the Baltic Sea. However, the introduction of poplars in harsher, northern climate conditions implies slower growth and tough browsing pressure from an abundant wildlife population. In addition, poplars in this region are often intended for planting on forestland and different types of marginal land that are known to be highly demanding in terms of early plantation management. Here, we present the results from a series of establishment trials in Sweden, Lithuania and Estonia testing mainly different types of plant material. Dormant cuttings of different lengths were tested along with the rooted bare-root and containerized cuttings (seedlings), and one- and two-year old poles planted to a depth of ca 60-70 cm. A range of soil treatments, weed management practices and clones were applied in these trials.

In a large “Eurostar” trial (11 trials on 9 locations) with identical trial design, the two-year old poles resulted in significantly higher plants compared to all other types of plant material two years after planting. However, the bare-root and containerized seedling, and 80 cm long cuttings had equally high survival rate on most of the sites. On lime bedrock and shallow soil, heavy clay and deep organic soil the poles had lower survival rates compared to rooted cuttings. The lowest height and survival rate had short cuttings (30 cm) and seedlings planted at the end of the first growing season representing the completion treatment. The robust two-year old poles had almost 100% survival on an organic soil in a trial at 60°N latitude in central Sweden. Such a high survival rate and very strong increment was achieved in combination with ditching and mounding without the use of herbicides. The trial was not fenced and the plants were successfully protected using four different chemical repellents and two mechanical stem protection devices. The initial length of the poles was positively correlated with both plant height and height increment after the second growing season. At a trial on wet organic soil with a constantly high vole population only two-year old poles had satisfactory survival rate (85%) in comparison with one-year old long cuttings. On this site, the mechanical vole protection in form of plastic spirals was crucial for the survival rate for all types of cuttings, while the type of weed management (milling or grass trimming) had little effect. At a trial on forestland containerized seedlings planted at different dates in a growing season had a significantly higher survival rate (80%) compared to 40 cm long cuttings (70%) and 20 cm long cuttings (25%).

The use of rooted cuttings in form of bare-root seedlings is recommended for the establishment of poplars under most of combinations of site conditions and weed management practices in the Baltic Sea Region. The two-year old poles are a viable solution on some organic sites and at extreme vole population pressure.

Key words: Baltic, establishment, poplar.

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FAST-GROWING TREE CULTURE OUTSIDE FOREST: 
EXPERIENCES FROM INDIA

Dinesh Kumar1

Plantation forestry outside the forest in India is largely based on fast-growing trees. This is particularly true for agroforestry which is practised by individual growers in their farmland and wasteland. Trees are systematically planted in farmland as block plantation or boundary plantation, or maintained as scattered trees for various tangible and intangible benefits. The Forest Survey of India has estimated the growing stock of trees outside forest at 1573 billion cubic metre (27.3% of total growing stock). However, the annual wood production of trees outside forest is about 13 times more than the forest, suggesting the popularity of fast-growing trees outside the forest.

The boost to tree planting outside the forest was provided by the National Commission on Agriculture, 1976 and the National Forest Policy, 1988. *Eucalyptus, Casuarina, Populus, Dalbergia, Tectona*, etc. are among the most popular plantation trees. Genetic improvement programmes on plantation species promise to increase the plantation productivity.

Despite this, several policy interventions are adversely affecting the interests of tree growers. Difficulties in obtaining felling and transit permits, absence of a favourable minimum support price mechanism, non-availability of soft bank loans, absence of agroforestry cooperatives, inadequate availability of superior planting material, etc., pose serious challenge to the grower. *Populus deltoides*, in particular, witnesses large fluctuations in the price of wood which renders the planting rate of this species highly variable from year to year. A low level of technical knowledge about tree cultivation too sometimes results in losses to growers. Insufficient research grant is also proving a handicap in technical innovations in plantation forestry.

Experiences from different countries may help in addressing policy issues inimical to the interests of growers.

**Key words:** Trees outside forest, challenges, policy.

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THE JOURNEY OF POPLAR CULTIVATION UNDER AGROFORESTRY IN INDIA - RESPONDING TO DRIVERS OF CHANGE.

Gulshan Ahuja Kumar¹

Poplars belonging to family Salicaceae provide an array of wood products viz: plywood, veneer, reconstituted boards, furniture, packing boxes and small timber besides fuel wood for bio-energy. It has tremendous role in forest landscape restoration, climate change mitigation and livelihood generation in temperate and sub-tropical regions of the world. As per Country Report on Poplars and willows in India (2012), the area under Poplars and willows is 5,05,000 hectares till 2012, of which 3,12,000 hectares is under *Populus deltoides* species grown on farmlands. This has been due to expansion of Poplar based Agro-forestry from mere 60000 hectares area in 2004 to 3,12,000 hectares on India’s farmlands. Thus the Country has tremendous potential of bringing the farm areas under Poplar Agro-forestry plantations. Thanks to India’s National Forest Policy 1988, wood based industries viz. Plywood, Veneer, Paper-pulp etc. are largely dependent on farm grown Poplars and Eucalypts. Expansion of agro-forestry plantations and their utilization in wood based industries is critically important for meeting the national needs of timber and non timber forest products and conservation of bio-diversity. Technology based innovative farm forestry plantations with genetically improved, high yielding and fast growing clonal planting stock of poplars coupled with production, marketing and export of value added products made from poplar wood have tremendous potential for diversification of agriculture, meeting the growing needs of industrial timber on sustainable basis and creating ample employment opportunities for the rural poor. Poplars are, therefore, grown in India as an integrated rural development program. The added advantage to the farming community of growing Poplars under Agro-forestry systems in India is that the income generated from Poplar plantations on farmlands doesn’t attract tax liabilities. However, of late the Poplar Agro-forestry has found itself at cross-roads in India.

This paper traces the journey of poplar cultivation in India, particularity under Agroforestry from 1978 till date and describes prospects and problems in the course of its journey of nearly four decades.

**Key words:** Agroforestry, rural livelihoods, farmlands, socio-economic, wood-based industry.

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EVALUATION OF GROWTH AND BIOENERGETIC POTENTIAL OF FAST-GROWING TREES
(*POPULUS* AND *SALIX*) FOR SHORT-ROTATION PLANTATION

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In Ukraine poplars were planted for centuries as timber, ornamental and windbreak plants. Unfortunately, due to the lack of knowledge for fundamentals of cultivation, forests were frequently planted with no commercial success. In the years 1950-70, poplar and willow clones were crossed, selected and evaluated by Ukrainian breeders. But short rotation forestry was not established yet, and only recently few companies started to cultivate willows, but currently no commercial poplar short-rotation plantations (SRP) are planted in Ukraine. Taking into account many benefits which we may obtain from SRP as renewable bioenergy source, leading to country’s energy independence, this sector should be developed. It is therefore necessary to estimate for the first time present clones for their suitability for SRP, as the requirements for SRP plant material are different from those for traditional forestry.

Last spring (2015), we have established fast-growing tree collection at the National Botanical Gardens. It includes 21 *Populus* and 10 *Salix* clones, many of them were provided by the Institute of Forestry and Forest Melioration, they are mostly hybrids of Ukrainian origin. Cuttings of 20-25 cm length were planted very densely and plot was watered every week through spring and summer, which was very important because of extreme summer drought. At the end of the first growing season the height, base diameter, number of branches per each plant and biomass weight were measured, and biomass calorific values was determined by calorimeter (IKA C-200, Germany).

Poplar and willow clones were much different by growth and energetic parameters. Average height of the best clones reached more than 2 m while the lowest were around 1 m height and less. Diameter variations ranged in 4–19 mm, by numbers of branches per plant clones varied between 1.00 and 2.22, and by fresh weight – between 23–341 g. By the caloric value of firing the biomass of different clones varied between 17.9–19.4 kJ/g. Comparing to others, willow clone Zhytomyrska-1 was the most intensively growing during the first planting season. Other perspective clones of poplar and willows were also determined, they may be recommended to Ukrainian farmers for creating the SRP.

This study was carried out in the framework of bigger cross-institutional research supported by the Ukrainian Academy of Sciences grant. Authors addressed their appreciation to Prof. Tkach V.P. and Dr. Los S.A. from the Institute of Forestry and Forest Melioration for providing poplar and willow cuttings for collections.

**Key words:** Short rotation plantations, *Populus*, *Salix*.

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CASE STUDY OF HYBRID ASPEN, POPLAR AND WILLOW YIELDS DURING FIVE-YEAR ROTATION

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Popularity of Salix and Populus as the short rotation coppice (SRC) energy crop is increasing in Latvia. Aspens and poplars (Populus spp.), as well as willows (Salix sp.) and grey alder (Alnus incana) are accepted as agriculture energy crop with rotation period of up to 5 years since 2011 (the Cabinet Regulation No 173, March 21, 2011). Changes made in law “On Agriculture and Rural Development” on 1 January 2015 provides definition for the fast-growing energy wood tree plantations - agriculture crop with rotation period of up to 15 years; despite the definition the SRCs are eligible for the area payments only if the rotation period is no longer than 5 years (Cabinet Regulation No 126, March 10, 2015). During 2015 in total 1882 ha of SRCs were accepted for area payments.

Clones of hybrid aspen (Populus tremula x tremuloides) No 4 and 28 (2 000 trees ha⁻¹), commercial clones of Poplar No AF2, AF6, AF7 and AF 8 (6 000 trees ha⁻¹), several clones of willows Sven, Klara, Inger, Gudrun, Lisa, Tora, Stina, Torhild, as well as the candidates of willow clones Salix burjatica, Salix viminalis, Salix smithensis, Salix purpurea (10 000 cuttings of willows ha⁻¹), were planted in Latvia, Vidzeme region in May 2011. Before planting fields were fertilized with wood ash (6 tonnesDM ha⁻¹), waste water sludge (10 tonnesDM ha⁻¹) and fermentation residues from biogass plants (30 tonnes ha⁻¹). Soil type in the experimental fields is Luvic Stagnic Phaeozem (Hypoalbic) and Mollic Stagnosol (Ruptic, Calcaric, Endosiltic) according to FAO (2006); dominant soil texture is loam (at 0–20 cm depth) and sandy loam (at 20–80 cm depth). Five years after planting trees were harvested and above-ground biomass was determined by weighing.

Hybrid aspen clone No 28, produced in average 1 tonne of above-ground stem biomass per ha during 5 years rotation, while clone No 4 produced in average 2.9 tonnes of dry mass per ha. The most effective fertilization method was treatment with biogas fermentation residues – in plantation of clone No 28 – 25% more biomass, but in plantation of clone No 4 – 38% more biomass in comparison to average values. The most productive clone demonstrated better response to fertilization. The clones of poplar had lower survival rate in the fertilized fields and in average 7.4 tonnesDM ha⁻¹ of above-ground biomass were harvested in these fields (in control plot for comparison – 9.03 tonnesDM ha⁻¹). Rotation period of 5 years is too short for biomass production in Populus SRC plantations in Latvia. Above-ground biomass of the commercial clones of willows at 5 years age in average was 20.9 tonnesDM ha⁻¹ (the value is close to the average yield in large scale commercial willow plantations in Nordic countries), while “candidates” produced only 12.6 tonnesDM ha⁻¹. The treatment with wastewater sludge increased the yield by 18 % in plantations of the “candidate” clones. The productivity of the commercial clones was increased by 10% by treatment with wood ash.

Key words: Poplar, aspen, willow yield.

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CAN RESULTS FROM ANALYSIS OF ASH CONTENTS BE USED FOR DETERMINATION OF
MASS LOSSES DURING STORAGE OF WOOD CHIPS?
A COMPARISON OF RESULTS FROM 9-MONTH STORAGE OF POPLAR

Hannes Lenz¹, Ralf Pecenka¹ and Christine Idler

Cost efficient harvest of short-rotation coppice as well as high dry matter losses during storage are still matters of much concern. Equipment and techniques are being developed and some are commercially available. However, it does not necessarily work efficiently for farmers. For resource efficient use of wood chips in local heating plants as well as from an economic point of view storage loss, ash and water content, and heating value are key factors. For the evaluation, comparison and improvement of different storage techniques at practice moisture content and mass loss have to be measured over storage periods of more than 6 months. However, practice scale storage piles with typical volumes of 200 m³ and more are very inhomogeneous and therefore precise measurements are very labour intensive. Therefore, periodical sampling with focus on ash and moisture contents only would reduce work and costs. Mass losses could be determined indirectly from the trend of ash contents over storage time due to the fact that dry matter losses are caused by bio-chemical conversion of organic matter in a storage pile only. Therefore, the aim of this work was to investigate if such an indirect method is adequate for a reliable prediction of mass losses during 9-month wood chip storage.

Two practice scale storage piles (volume 500 m³ each) have been built up using fine and coarse wood chips from poplar (P31 resp. P45). The raw material has been produced during harvest of a 10 ha SRC plantation (4 and 5-year old poplar from first rotation – clone Max) in the north-east of Germany in February 2014. The development of moisture contents, temperatures, dry matter losses (using sampling bags), ash contents (using pre-processed samples of separated bark, bark-free wood as well as natural mixtures of wood and bark) and heating values have been analysed during storage to evaluate differences in the storage behaviour of fine and coarse wood chips from poplar. These results have been also used to compare the two most common methods for the determination of mass losses at practice scale: the sampling bag method and the ash content method (indirect determination of mass losses by analysis of the development of ash contents over storage time). The comparison has shown that the ash content method supplies only a qualitative accurate picture of the development of mass losses during storage. Furthermore, a separate ash analysis of wood and bark is an unavoidable prerequisite for reliable qualitative conclusions regarding the development of mass losses over storage time. But even than, the difference to the results from the sample bag method is e.g for fine chips (P31) higher than 10% in dry matter content with a total error of more than 30%. Due to the results of this storage experiment, the sampling bag method should be used if more precise results for the analysis of the trend of mass losses during storage are required.

Key words: Poplar, wood chip, ash content, storage, dry matter loss.

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POPLAR WOOD IN THE MANUFACTURE OF PROSTHESES

Annabell v. Limburg¹, Falk Berster¹ and Georg v.Wuehlisch²

Already in the mid-age wood was used as an aid in different shape, size, and design of the supply of amputees. For centuries, wood played besides metals, such as bronze or iron, and animal products, such as leather or horsehair, the most important role in the development and reproduction of artificial limbs.

At the beginning of the twentieth century wood was introduced as the main element and shaping material for the entire unit with a new processing technique, the so-called sleeve technique. Especially suitable for the milling machines was the wood of hickory (Carya), yellow poplar (Liriodendron) and especially poplar (Populus). For prosthesis, skin friendliness, moisture absorption, no slivering, easy machineability, odorlessness, few allergic substances, little or no secondary substances like resins, tannins, terpenes, form stability, no cracking, and low weight are important wood characteristics, which are fulfilled especially by poplar wood.

The period following the 1st World War was particularly crucial for the production of a high diversity of prostheses to replace lost limbs. The wooden product was considered a resource guarantee and for prefabricating stock products, customized in size, shape and volume. Compared to other former processing options such as leather, wood offered a weight reduction for the prosthesis wearer and the wearout of clothing was minimized. In 1919 the enterprise Otto Bock was founded, taking up the concept of wood use from the past, developing and optimizing it. The wooden prosthesis production is still carried out presently by the company, although more efficient production methods for prostheses using modern materials, such as carbon, fiber glass, various resins as well as plastics have replaced wood widely. However, during 2015 a total of 104 custom made wooden shafts were produced at the headquarters in Duderstadt, Germany.

Key words: Prostheses manufacture, wood use, wood characters.

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BIOMASS PRODUCTIVITY AND MUTUAL RELATIONS BETWEEN TREE GROWTH AND SOIL NUTRIENT STATUS IN SHORT-ROTATION HYBRID ASPEN PLANTATIONS IN HEMIBOREAL ESTONIA

Reimo Lutter¹, Arvo Tullus², Tea Tullus¹ and Hardi Tullus¹

Short-rotation forestry (SRF) with hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) for the intensive production of energy wood, aspen pulpwood and logs is a new silvicultural approach in hemiboreal Estonia. However, knowledge about hybrid aspen growth potential in different soil types, nutrients longevity and the impact of soil physico-chemical properties on tree productivity in the long term is still scanty in hemiboreal region.

To cover this gap, we used repeated soil and tree growth monitoring in 51 permanent sample plots in young (5-yr-old) and midterm (15-yr-old) hybrid aspen plantations. Growth and productivity of 15-year-old hybrid aspen plantations exceeds most of local tree species forestland stands at this age. Hybrid aspen plantations on former agricultural fields had significantly altered soil reaction (pH<sub>KCl</sub>), but did not show significant depletion of primary macronutrients (NPK). Available water content in soil, rather than nutrient concentrations and stocks from past fertilization of abandoned agricultural soils, has been decisive for the growth rate of the trees.

To conclude, former arable soils provide sufficient supply of major macro- and micronutrients to ensure high productivity of hybrid aspen plantations during the first half of the rotation period.

**Key words**: Biomass, hybrid aspen, *Populus*, short-rotation forestry, soil nutrients.

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INTRODUCING TREES INTO CULTIVATED FIELDS TO REDUCE THE FRENCH SHORTAGE OF POPLAR WOOD: AGROFORESTRY AND WOOD QUALITY

Rémy Marchal¹, Serge-Stephane Kouakou¹, Loïc Brancheriau¹ and Kevin Candelier¹

In France, the poplar sector provides 20 000 jobs, in both forestry and industry. Since 15 years, plantations of poplars have been decreasing regularly. Today, 30 to 50% of the poplar surfaces are no longer re-planted because of the low resiliency of monocultural systems, the competition between poplar and food production, the low market prices of wood, etc. This situation becoming risky for poplar wood economic sector, different strategies have been undertaken to resume poplar production such as encouraging farmers to reintroduce trees inside their crops. The design of poplar-based agroforestry system is under progress. How poplar wood quality would be influenced by low plantations density and by trees x crops interactions? Some preliminary results of comparative study between trees coming from an agroforestry plot and others from an adjacent forest control plot are here presented. Wood construction sector being growing fast in Europe, we have mainly considered wood mechanical properties.

Trees from agroforestry growing faster and being more exposed to wind are supposed to contain: (i) higher proportion of juvenile wood into the stems; (ii) higher proportion of reaction wood; (iii) higher growth-stresses level into the logs, and (iv) higher rate of lignin. In order to check these hypotheses, we have sampled and measured 20 poplars (19 years old, cultivar I214) in Restinclieres Domain, Montpellier: 10 agroforestry trees (120 trees/ha) and 10 forest control trees (400 trees/ha). The mechanical properties were estimated by measuring Modulus of Elasticity (MOE) on standing trees in the three orthogonal directions using “Wood In Situ Inspection System” (WISIS). The growth constraints level inside the trees was estimated by measuring the longitudinal residual deformations of maturation (DRLM). For each tree, we have measured microfibril angles (MFA) on increment cores for each ring by X-ray diffractometry. The lignin content was measured using Klason lignin method.

Dendrometry data show that agroforestry trees are significantly less slender than forest trees because of their feature bigger diameters while total heights remain unchanged compared to forest trees. There was no effect of the plantation density on the ovality – agroforestry trees remaining closed to a cylindrical shape. Concerning wood quality, there is no significant effect of “sylvicultural” treatment on wood density, green moisture content, longitudinal MOE, growth stresses, MFA and lignin content.

The trends seem consistent and explainable in the case of cultivar I214. But the low number of samples and the observation of a significant interaction sylvicultural treatment x distance to the river invite us to be careful regarding the conclusions drawn here and to repeat similar tests in other locations.

Key words: Agroforestry, wood quality, poplar.

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WOOD AND TREE-RING ANATOMICAL TRAITS FOR PHENOTYPING POPLAR CULTIVARS

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Poplar (Populus spp.) breeding is important in order to meet the changing requirements that result either from changing pathogens and climate or from changing needs in industrial utilization. At present for instance, research on short rotation poplar plantations managed solely for bio-energy purposes seem to become of minor political interest in Germany. Their possible benefits for agricultural managed landscapes and for sustainable bio-energy supply chains on a regional scale are well documented but short-rotation systems have not become a major bio-energy crop in Germany. With that background, the combined industrial timber and bio-fuel or cascade utilization of poplars grown in longer rotation cycles may be of higher importance in the future. Hence, the characterization of wood traits like specific gravity, heating values or wood anatomical characteristics can contribute significantly to appropriate phenotyping.

The presentation will focus on the usability of the juvenile tree-ring archive and selected wood traits for investigating the trees’ early development in a retrospective manner. On one hand, these traits can help to compare eco-physiological interrelations of the cultivars with site conditions. On the other hand, the traits are often also related to usability because the xylem of the stems is both, the primary merchantable product as well as an important tissue for the hydraulic architecture of poplars. Examples of the work on characterizing different clones tested by partners in a collaborative German project (www.fastwood.org) will be presented. The value of vessel cross-sectional characteristics, wood density or fuel characteristics as supplementary traits for phenotyping will be discussed.

Key words: Phenotyping, xylem, hydraulic architecture, heating value, ash content.
Poplar is a fast-growing tree with high industrial demand for its timber which can be allocated to different uses such as plywood, sawwood, particle board, bioenergy, etc. Poplar adequacy as component of silvoarable practices is based on the reduced amount of light it intercepts when compared with other tree species, the great knowledge about its silviculture and decades of genetic improvement, its integration in the agricultural landscape and its shorter rotation.

Agroforestry practices with poplar in Europe include alley cropping to produce biomass as renewable energy and silvoarable practices. The use of poplar as part of an agricultural plot increases productivity but also promotes environment protection and carbon sequestration while enhancing social benefits.

This paper aims at reviewing the main poplar plantation areas in Spain, Italy and France and the potential of combining it with crops and also identifies the main drawbacks to implement agroforestry with poplar from a policy point of view.

**Key words:** Timber, silvoarable practices, renewable energy.
GROWING POPLAR BIOMASS IN SHORT ROTATION: LIGNOCROP PROJECT

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The project started in 2010 as an initiative of the Spanish government to promote the economy and employment in the field of energy. The main objective was to promote a national biomass market, based on knowledge of the entire process embracing implementation, monitoring and development of forestry crops for energy. For this purpose, it is necessary to identify the most appropriate crops with the highest energy potential as well as to define and develop the conditions to be met in the technical, economic and environmental aspects in order to enable sustainable implementation of energy crops in Spain.

It is necessary to understand the different stages comprising the biomass cycle, which are basically: implementation of crops, their management, harvesting and transportation, storage and finally the characterization of biomass along with the assessment of the environmental effects of the entire cycle. These steps must be analyzed on a national scale. To achieve these objectives, a leading energy company, different research institutions as well as companies involved with forest crops are working together. Experimental plantations with different poplar and willow hybrids under irrigation along with black locust on non-irrigated land were established in order to determine their suitability in different areas of the territory. These areas were Castilla y León, and two different locations in Andalusia. The planting density was 6,666 trees per hectare in a rotation of three-four years. We assessed the plant material adaptation as well as the growth and production at the end of the first rotation (3 or 4 years). The process of biomass harvesting was also analyzed. Three different strategies were compared, manual and two mechanical with different equipments, a biomass baler harvester and a standard forage harvester fitted with a special short rotation forest headed. The analysis was based on the study of the process efficiency and the labor quality.

The thermo-chemical and physical properties have been determined in order to select the most suitable species in terms of their behaviour for combustion but also the effect of site on these properties. Experimental tests to quantify the moisture content, particle size distribution, bulk density, heating value, ash content and composition as well as the volatile matter have been performed. In addition, natural air-drying of the poplar clones as collected (branches) was analyzed in two of the four sites to determine the humidity loss during raw storage.

A white paper is currently being developed in which the crop details are collected. The aim is that this will be a ‘living document’ in which information on the successive rotations will continue to be included as well as their economic viability in our country, based on the information generated.

Key words: Short-rotation coppice, yield, management, biomass characterization, harvesting.

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POPLAR AS A RAW-MATERIAL FOR MATCH STICK MANUFACTURING INDUSTRIES IN INDIA

Dinesh Babu Paulrajan¹

Poplar is used as one of the raw-material by several match stick manufacturers in India. Every month around 3000 to 4000 cubic metres (depending on the demand) of Belgian poplar clones are imported in Tuticorin port which is located in southern India. These stems are peeled for production of matches.

In trade terms, the logs are named as old and new generation Poplar logs in which Robusta clone falls under old generation category where the stem has thicker bark. New-generation logs are the plantation logs which has a thinner bark. The consumers prefer to use 80% of plantation logs since they give more out-turn while peeling and hence the yield. There are many exporters from Belgium and France who supply these logs based on the customer’s requirement.

Each customer requires certain quality factors and specifications of the product which includes straight and cylindrical logs, minimum diameter of 30cm and maximum of 70 cm and minimum length of 5.2 m (+30cm free trim). Root ring, rot, cracks, iron and knots bigger than 15 cm diameter are not permissible. Match industries produce safety matches with these specifications and supply them not only within the Indian market but also export them to African and South American countries.

Key words: Poplar, Robusta clone, new generation, safety matches.

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EFFICIENT HARVEST AND STORAGE OF WOOD CHIPS FROM POPLAR IN PRACTICE

Ralf Pecenka¹, Hannes Lenz¹ and Christine Idler¹

The use of plant biomass for energy is increasingly more on the focus of public interest, due to limited fossil energy resources and an increasing awareness for global warming. Wood from short-rotation woody crops (SRWC) such as poplar and willow is a promising option for sustainable production of biofuels and biomaterials. Provided that production technologies, logistic chains and end user structures are well designed in farmers’ regional structures, these cropping systems may provide a secure source of income. However, after more than 30 years of practice experience in cropping of SRWC there are still several problems in the production chain. In particular, cost-efficient harvest and high dry matter losses during storage are still matters of much concern. Although a lot of harvest machines were developed and tested, only a few have exceeded prototype stage. Analysing the process chain for SRWC, it can be concluded that high investment costs for suitable harvest equipment, low flexibility of harvest solutions regarding variety and cultivation scenario, limited trafficability of the fields for heavy harvest equipment during winter as well as dry matter losses of up to 25% during storage are some of the most important obstructions at present.

As a result, approx. 40% of the total production costs are located in the process steps of harvest, transport and storage alone, assuming optimal harvest conditions. Therefore, the Leibniz Institute for Agricultural Engineering (ATB) has developed a simple and low weight tractor-mounted mower-chipper for medium sized standard tractors (150-200 kW) for a more flexible harvest of poplar with a max. stem diameter of 15 cm to take advantage of longer rotation cycles. For the evaluation of this new harvest system, machine and harvest data from several poplar harvest campaigns with the ATB mower-chipper (Kluge KL-ATB 130) and two forage harvesters (New Holland FR9060/KUP130 and Claas Jaguar/HV1400) have been analysed and compared. All machines reached a comparable performance at harvest. But harvest with the ATB mower-chipper showed several advantages such as lowest harvest and investment costs, a higher flexibility due to a much lower machine weight, an adjustable chipping length for improved wood chip drying and reliable harvest of poplars with bigger stem diameters.

Previous small-scale investigations of wood storage have shown that bigger particles can be advantageous for long term storage due to improved drying by natural air ventilation. The mower-chipper has been designed to produce wood chips of an adjustable length from 20 to 120 mm. On this basis it was possible to conduct a storage experiment to evaluate the influence of the chips size on the storage behaviour at practice scale. In March 2015 three 500 m³ piles of wood chips with 30, 75 and 120 mm chipping length have been built up and equipped with measuring columns to monitor the development of temperature, dry matter loss, moisture content and gas concentrations over a period of 8 months. Wood chips with a chip length of 75 mm showed the best results with a dry matter loss of 17% and a moisture content of 26% at the end of storage. However, the in principle assumed favourable storage properties of coarse chips have been smaller than expected at practice scale.

On the basis of the experiences from practice scale harvest of more than 150 ha SRWC and associated storage experiments general advices for the design of optimised harvest chain as well as the design of storage piles in dependence to available harvest equipment can be given.

Key words: Poplar, harvest, wood chip, storage, dry matter loss.

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OPTIMUM STORAGE TECHNIQUES FOR POPLAR WOOD FROM SHORT ROTATION – A COMPARISON OF WHOLE TREE AND WOOD CHIP STORAGE

Ralf Pecenka¹, Hannes Lenz¹ and Christine Idler

Relative to storage time and chip size determined by the technology used for harvest of short rotation coppices such as poplar and willow, the common production lines supply woody biofuels of very different quality. In general, two different harvest lines are available at practice scale: the cut-and-chip and the cut-and-store line. Whereas the cut-and-chip line provides wood chips which have to be stored until the next heating season (commonly for more than 6 months), the product for intermediate storage of the cut-and-store line are whole trees. However, due to the high moisture content of the harvested wood dry matter losses are inevitable during storage in non-ventilated piles.

The main aim of this study is to provide comprehensive information about the development of moisture contents and dry matter losses during storage of poplar wood to evaluate possible advantages of whole tree storage in comparison to wood chip storage. Two storage piles have been built up after harvest of 4-years old poplars (Clone Max 4) in March 2014. For the determination of dry matter losses in the whole tree pile 80 trees have been weighted before building the pile and equally distributed in the pile for later analysis of changes of dry matter and water content over storage time. Dry matter losses and moisture contents of wood chips in the chips pile have been analysed on the bases of 144 sample bags equally distributed in 4 different layers in the chip pile. At the beginning every two weeks and later every four weeks sample trees resp. sample bags have been pulled out from the piles for comprehensive analysis. Physical, chemical and microbiological parameters were determined for the description of the trend during the 7-months storage: temperature in the piles, dry matter content, pH, ash, the elements C, N, S, CO₂ and O₂ concentrations, calorific value and number of thermotolerant mould.

In spite of the high volume of the storage pile in this experiment comparable to practice storage, the assumed advantages of storing wood as whole trees instead of chips could not be confirmed in all facets in this experiment. The final moisture content of whole trees has reached 43% and dry matter losses of approx. 10% have been measured at the end of the experiment in October 2014. In contrast, wood chips reached moisture contents of only 29% and dry matter losses of 24%.

To choose the appropriate storage technique not only optimum natural drying of the storage pile but also dry matter losses have to be taken into consideration. Whereas whole tree storage shows significant advantages regarding low dry matter losses, wood chip storage ensures much better drying. Furthermore, for the evaluation of total costs of bioenergy supply from short rotation coppices the whole process chain has to be analysed with special focus on harvest, required comminution processes as well as transport operations.

Key words: Poplar, wood chip, storage, dry matter loss.

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EVALUATION OF POPLAR GENOTYPES UNDER MEDITERRANEAN CONDITIONS:
GROWTH AND WATER USE EFFICIENCY IN THE FIRST VEGETATIVE PERIOD

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Two experimental plantations were established in order to evaluate the behaviour of different European poplar genotypes under Mediterranean conditions. Both sites had very similar climate characteristics but different soil types. The management was also similar and was characterized by the application of drip irrigation throughout the growing season. These two trials form part of a network of poplar clone trials at European level within the framework of Project EW13/14.

The plantations include the following sixteen genotypes belonging to different taxonomic groups: AF2, AF8, AF34, Brenta, Delrive, Dellinois, I-214 (P. deltoides x P.nigra) Antonije (P. deltoides x P.nigra x P. deltoides), Koreana (P.trichocarpa x P.koreana), Baldo (P. deltoides), SV-490 (P.trichocarpa x P. deltoides), Max-4 (P.nigra x P. maximowiczii), Matrix-21, Skado (P.trichocarpa x P. maximowiczii), Grimminge (P.trichocarpa x P. deltoides), and Hybride 275 (P. maximowiczii x P.trichocarpa).

At the end of the first vegetative period, growth parameters such as dominant height (Ht), base diameter (D₁₀ cm) and diameter at breast height (D₁₃₀ cm), number of shoots and number of branches were evaluated. The production was evaluated as an index of volume (Ht x (D₁₀)²). Gas exchanged variables were also recorded over the vegetative period in order to infer intrinsic water use efficiency (IWUE). Several morphological variables such as specific leaf area (SLA, cm²) were also measured.

Growth parameters and production (volume) in the 1st year differed significantly between the two sites. These differences cannot be attributed to differences in weather or management conditions as both were similar. Soil differences between the two sites account for the differences in production and these were largely attributed to the organic matter content and to the electrical conductivity using a generalized linear mixed model in which the different soil traits were considered fixed effects. Additionally, the genotype*site interaction was significant, revealing that some of the genotypes improve their production under specific soil conditions. These associations are presented in a biplot graph. The difference in the number of shoots was not significant between the sites but there was a significant difference in the number of syleptic branches, this number being higher in the most productive site.

The seasonal patterns for IWUE for the set of clones were analysed. Additionally, genotypic variation in gas exchange parameters was detected, with A and gs varying by as much as 19% and 32% respectively among the genotypes. Hence, these exhibited differences in IWUE under suitable irrigation.

Key words: Short-rotation coppice, genotype x environment interaction, genotypes characterization.

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BIOMASS PRODUCTION IN AN IMPROVED SUSTAINABLE MIXED SHORT-ROTATION WOODY CROPPING OF *POPULUS*-HYBRIDS AND *ROBINIA PSEUDOACACIA*

Jessica Rebola-Lichtenberg\(^1\) and Christian Ammer\(^1\)

The rising demand on bionenergy leads to a necessity for optimization of biomass production. Hardwood short-rotation coppice crops are used as a source for carbon-neutral energy. The intensification of land use systems means a decreasing number of species, which in return has the effect of higher dependence on external inputs as a result of lower ecosystem resilience and subsequent autonomous reduced production of biomass. The biological simplification drives to a lack of self-regulation functions like nutrient recycling and regulation of microclimate and hydrological processes.

Mixed cropping is seen as an improvement towards higher ecological complexity. Intercropping - the cultivation of different crops on the same land at the same time - may lower the dependence on additional input by recovering the internal regulation of a natural ecosystem and enhancing the crop systems stability. Intercropping systems can be optimized through targeted selection of mixture components turning them into economically feasible and practical systems. Searching for the traits that make crop diversity enhancement practical and sustainable in an ecologically sensible frame is essential to achieve the benefits of a more balanced crop ecology.

Due to their rapid high woody biomass production the fast-growing *Populus* hybrids are particularly used as elements for bioenergy production in monocropping systems. *Robinia pseudoacacia* L. is a lesser known species for energy plantations, but has promising characteristics like drought tolerance and the ability to fix nitrogen.

This study aims to throw light on a potential facilitation and complementarity between the N-demanding species Poplar (*Populus* spp.) and the N-fixing species black locust (*Robinia pseudoacacia*) on biomass increment. Tree measurements, crown structure analysis, leaf-area-index, competition analysis and biomass functions will be used to characterize the biomass increment of the different. The poplar hybrids that benefit most from this type of crop mixture will be identified.

**Key words**: Biomass production, mixed culture, *Robinia pseudoacacia*, *Populus* spp.

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Though the time scale gives reason for some debate, it is considered a fact that fossil fuels are inevitably becoming scarce. One of the alternative and most promising pathways to provide future society with energy and platform chemicals is the use of lignocellulosic biomass. Therefore, the separation of lignocellulose into valuable compounds for further conversion is one of the key challenges of valorizing biomass, preferably while keeping the chemical structure intact. The separation of lignin, cellulose and hemicellulose from lignocellulose biomass consequently builds the foundation of a wood based future green economy.

The pulp and paper industry mainly processes lignocelluloses by Kraft pulping to generate pure cellulose paper. Here, apart from cellulose, black liquor accrues as byproduct which consists of lignin, hemicelluloses and degradation products. The process uses aggressive chemicals and the produced lignin contains sulfur, which impedes many chemical applications. Because of these disadvantages, the Organosolv-process is being investigated at the Fraunhofer ICT. Here, water, an organic solvent (e.g. Ethanol) and optionally a catalyst (e.g. acid or base) is used. The produced lignin stays close to its natural structure and is suitable for further processing.

For the optimization of lignin extraction from the softwood Populus balsamifera without bark, screening experiments on the Organosolv-process have been conducted in a 500 ml autoclave using design of experiments (DOE) to give a systematic overview of the correlation between reaction conditions and experimental results. The reaction conditions have been varied in temperature T, reaction time τ and content of organic solvent $w_{\text{EtOH}}$, and the results being parameters such as yield, purity and molar mass of the given lignin, respectively the yield and purity of the carbohydrates have been investigated. The range of parameters was chosen to be 120°C–220°C for temperature T, 120 min–240 min for reaction time τ and 0,25–0,75 wt. % for ethanol content in the solvent $w_{\text{EtOH}}$. A Box–Behnken-design was used as experimental design, to reduce the amount of experiments from a full factorial design by nearly half while remaining a high validity. The statistical analysis allows predictions about optimum conditions for any material stream (hemicellulose, lignin or cellulose). To meet demands specifically, reaction conditions can be changed to achieve maximum yield of lignin, cellulose or hemicellulose.

By evaluation of the regression curves gained from this screening, the optimum parameters could be defined and experimentally confirmed. This lead to a yield of 88% lignin extracted from Populus balsamifera without bark with the potential for a yield increase in a cascade setup to over 90%. The purity of the residual cellulose fraction reaches up to 85% with remaining impurities consisting of lignin only. The Organosolv process shows to be disadvantageous for the extraction of the temperature sensitive hetero-oligosaccharides hemicellulose with only 40% yield. Optimization according to several variables in one experiment is viable, which shows an 82% extraction of lignin while gaining an 82% purity of cellulose. The determination coefficients $R^2$ show high consistency between data and statistical model with $R^2=0,976$ for lignin yields and $R^2=0,971$ for cellulose yields. Lignin was characterized by GPC, analyzed for impurities by ThermoFlash EA and IR-spectroscopy, the fibre fraction was analyzed by HPLC according to NREL 42618 and monomeric- as well as oligomeric sugars in the washing solution were quantified with HPLC.

**Key words:** Organosolv-process, DOE, poplar without bark, *Populus balsamifera*. 

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Next to cellulose, lignin is the second most abundant natural biopolymer. Based on its phenolic structure it offers a variety of material applications. Numerous industrial processes (sulfite, sulfate, alkaline, etc.) are known to extract lignin out of lignocellulose for pulp production. However, besides the botanical origin the pulping processes itself have the strongest effect on the structural variety of segregated lignin. An alternative and environmentally friendly process for the generation of sulfur-free lignin out of hard wood is the acid-catalyzed Ethanol/Water-Organosolv process. The pulp quality is comparable with that of hard wood Kraft-pulps. Using fast-growing lignocellulose material from short-rotation coppice (SRC) e.g. “Poplar with bark” for the generation of biogenic intermediates, appears useful for material applications and provides several decisive advantages. (i) it saves an additional mechanical step, (ii) it saves energy to remove the bark, (iii) a significant part of the lignin is located in the bark, and (iv) the investigated lignocellulose is a fast-growing forestry source, harvested after 3 to 5 years with high mass yield per hectare, important for the allocation of feedstock for biorefineries.

However there are no detailed results available regarding an acid-catalyzed E/W-Organosolv on yield and quality of the fractions (lignin, cellulose, hemicellulose/ hydrolysate) out of the SRC feedstock “Poplar with bark”. A parametric study (supported by DoE; Box-Behnken-model) was realized. The objectives of the study are to evaluate the effect of process parameters on yield and structural features of the lignin, as well as to evaluate the yield, composition and quality of the polysaccharide fractions (cellulose, hemicellulose/ hydrolysate). The evaluation of structural features and functionality of lignin (M_N, M_W, M_W/M_N, aliphatic, phenolic, carboxylic OH number) is one of the main objectives. The functionality of the lignin is important for the development of strategies within the generation of so called low emission, bio-based building blocks for material applications. According to the DoE-model, 15 experiments with randomized parameter combination were realized. Variable process parameters were T: 160, 175, 190°C; t: 120, 180, 240min; and w_{EtOH}: 35, 55, 75%. The solid/liquid ratio with 1/7 and the acid concentration (0.5% sulfuric acid) were constant. The feedstock as well as the generated fractions (lignin, raw fiber, hemicellulose/hydrolysate) of each experiment were characterized by several methods (gravimetry, ash, moisture, NREL-TP-510-42618ff, EA (CHONS), M_W & M_N of lignin by SEC etc.). The complex data set was evaluated using the software Statgraphics Centurion®.

The statistical analysis shows an increase in lignin yield with rising process intensity with an optimum for precipitated lignin yield of 42% at the combination T: 190°C, t: 205min and w_{EtOH}: 59%. With the same parameter combination 59% cellulose remained in the raw fiber and 13% hemicellulose was found in the watery solution. A high amount of soluble lignin was also determined in the watery solution (33%). Moreover molecular weight (M_w) and molecular number (M_n) of lignin were affected by the process parameters. M_w values of the lignin samples decrease from 4000 to 2000 g/mol with rising T. It is likely that the process parameters affect the phenolic, aliphatic as well as the carboxylic OH number of the lignin samples, though ^31P-NMR-analyses are planned to confirm this.

**Key words**: Ethanol-Organosolv-process, short rotation coppice, poplar with bark, lignin.

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GREY ALDER (ALNUS INCANA (L.) MOENCH.) – A COMPLEMENT TO OTHER FAST-GROWING TREE SPECIES IN NORTHERN EUROPE

Lars Rytter¹ and Rose-Marie Rytter²

Biomass from woody crops is regarded as a future major source of renewable energy in northern Europe. Wood production has therefore to be enhanced to meet an increasing population and the need for more renewable energy. The requirements can be satisfied by using fast-growing tree species. Grey alder (Alnus incana (L.) Moench.) is an indigenous and fast-growing species, which is well adapted to the harsh climate of northern Europe. It is also comparably unattractive for browsing animals and has the capability to fix atmospheric nitrogen, thereby being more or less self-supporting in N and also a contributor to soil improvement. In the light of increased interest for other fast-growing tree species outside the Salicaceae family grey alder probably has an opportunity to complement the fast-growing and biomass-oriented species mainly used today.

A study was implemented aimed to assess the potential for wood production and carbon (C) sequestration in biomass and soil of grey alder plantations under north European conditions. Estimates were based on literature data on above- and belowground biomass production, including fine roots, biomass allocation patterns and litter decomposition.

By applying functions on reported production figures, and adding an estimated breeding response, grey alder would be able to produce on average 6–7 Mg ha⁻¹ y⁻¹ of above ground woody biomass during a 20–25 years rotation period. This would significantly contribute to increased biomass availability in the north European countries when applied on agriculture land. By assuming that grey alder probably will be most used on areas suitable for the species, e.g. sites with harsh climate or moist conditions, an estimate of 560,000 ha of newly abandoned agriculture land could be available in the Nordic and Baltic countries. Thus, afforestation of those areas with grey alder has a potential, with the assumptions set, to increase the annual supply of woody biomass with 3.6 Tg, corresponding to 67,000 TJ y⁻¹.

Grey alder would also be an efficient C sink when used on newly abandoned agriculture land. Using the same productivity level as for biomass the annual C sequestration in biomass and soil would reach 4.6 Mg ha⁻¹, or 2.6 Tg C in total over the estimated available area. The figures presented show that grey alder has a potential to be a significant contributor for increasing biomass supply and C capture in northern Europe.

Key words: Biomass, C sequestration, productivity, renewable energy, soil organic carbon (SOC), fine root production.

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NEW POPLAR GENOTYPES FOR SHORT-ROTATION BIOMASS PLANTATIONS IN THE MEDITERRANEAN ENVIRONMENT: PRODUCTIVITY AND QUALITY OF BIOMASS FOR BIOREFINERY

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Short-rotation woody crops have been recently included in the latest guidelines on the EU’s “greening” of the new Common Agricultural Policy (CAP). For the implementation of this measure it is necessary to identify species adapted to different climatic conditions to be evaluated for the production and quality of their biomass. For this purpose, an experimental poplar plantation (1.5 ha) was established in 2009 near Viterbo with a density of 6060 cuttings ha\(^{-1}\) and three-year rotation. Eight new poplar genotypes were compared with Monviso, AF2 and AF8, already in use in commercial plantations. The drip irrigation, conducted in the summer period with irrigation volumes of approximately 100 mm\(^{-1}\) has covered the 30-60% of the optimal water demand of the culture.

At the end of the second three-year rotation dry biomass production was evaluated into its component (branch and stem) and qualitative biochemical analyses were conducted to highlight the potential for biorefinery. The dry biomass production was not significantly different between the clones under investigation, with an average production of 13.7 Mg ha\(^{-1}\) in three years. The best clones were AF24 and AF17, with a higher productivity on the average of about 20%. AF24 has allocated in the stem the largest amount of biomass (14.5 Mg ha\(^{-1}\)). The biomass of the branches was on average equal to 16% of that total, with the bark representing about 40% of this segment. Also interesting is the variability observed for the survival of the sprouts at the end of the second rotation, with average values at clonal level from 1.9 (AF19) to 5.3 (AF16) shoots per stump. Differences in the allocation of the biomass on the different diameter classes (CD) affected the percentage of bark (Bark%) on the total biomass and, therefore, its qualitative characteristics. In the stem Bark% was variable, from 50% for the 1 cm CD (DBH) up to 20% for the CD over 6 cm. There were not significant differences among clones in Bark%.

The qualitative analysis of biomass highlighted significant differences among genotypes in the composition of ashes, total extractives, lignin, and non-structural carbohydrates. The obtained results will be discussed to improve the selection of poplar genotypes for different traits in the Mediterranean environment.

Key words: Biomass production, poplar, short-rotation forestry.

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THREE-YEAR SURVEY ON GROWTH PERFORMANCE OF VARIOUS SALT CEDAR POPULATIONS ON SALINE-ALKALINE SOILS OF IRAN CENTRAL DESERT

Mohammad Hosein Sadeghzadeh Hallaj¹, Davood Azadfar² and Rasoul Mirakhorli³

Salt cedar (Tamarix aphylla L.) is a rapid growth and salt tolerance species which has been considered as suitable tree for wood production in arid and semi-arid lands of southern Iran in addition to its common usages in desertification and sand fixation programmes.

In order to study the possibility of development of this tree in saline-alkaline soils of central desert boundaries of Iran, this research was carried out on stem cuttings of six different population of salt cedar from Sistan va Balouchestan (Khash and Zahak townships), Yazd (Yazd township), Qom (Qom township), Isfahan (Kashan township) and Semnan (Garmsar township) provinces at Garmsar Research Station of Desert (EC=68.5 ds/m, SAR=103.26) in a CRBD experimental design with three replications, 25 cutting in each plot and 3*3 plantation density. Produced seedlings were irrigated weekly through growing seasons For 3 years. Shooting, survival, number of sprouts (NS), mean of sprouts collar diameter (MSD), height and vitality of trees were measured at the end of every growth season (autumn). Statistical analysis consisted of evaluation of correlation between variables using Pearson coefficient, ANCOVA analysis using soil EC as covariate and mean comparisons using LSD test.

Results showed that there is significant negative correlation between soil EC and shooting, EC and survival as well as between shooting and vitality of Salt Cedar trees. Also, significant positive correlation between number of sprouts and tree survival was noticed. Overall, Salt Cedar Populations showed high growth and adaptation to harsh environments of Iran central deserts (mean shooting=72.67%, mean survival= 67.11%, mean MSD=51.17 mm and mean height= 299 cm). However, ANCOVA results showed non-significant impact of populations on majority of measured variables. Just weak significant difference between population was noticed for MSD and vitality (P<0.1). Considering shooting, survival and biomass production of Salt Cedar planting this species in arid regions of central Iran on saline-alkaline soils is recommended. For this purpose domestic populations of central Iran have higher priority than those from lower latitudes considering their great adaptation to cold winter weather of these regions.

Key words: Salt Cedar, genotypes, saline-alkaline soils, central Iran.

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Currently, much of the focus in short-rotation forestry is on selecting species with high biomass production and specific traits that allow for easier conversion of lignocellulosic raw material into biofuels or biopolymers. In this work, we present a comparative study of a set of traits related to lignocellulosic biomass productivity of sixteen genotypes and some related hybrids genotypes among the most commonly used in Short-Rotation Coppices (SRC) with the main purpose of selecting suitable species to be grown in lands of the Campania Region, in southern Italy.

Sixteen species and hybrid genotypes (six hybrid poplars, four native black poplars, four eucalypts, black locust and one ash) frequently used in high-density SRC plantations were planted on a lowland area in southern Italy. With an overall extension of 5 ha, the SRC plantation was characterized by two harvesting regimes differentiated by the length of the single-stem rotation. A portion of the stand was coppiced for the first time after three years (model A) following the establishment, whereas the remaining part of the stands was coppiced after five years (model B). Annual stand volume, obtained by applying the tree-felled method, was converted to lignocellulosic biomass using specific density. To assess both energetic power and biochemical conversion aptitudes, physical and chemical characterization of wood and bark was carried out on three species, selected among the three groups (eucalypts, hybrid and native black poplars).

Under model A, the eucalypt species and related hybrids exhibited the highest biomass production with a mean annual increment (MAI) of lignocellulosic biomass of 15.4 Mg ha\(^{-1}\) yr\(^{-1}\). Instead, hybrid poplar genotypes and native black poplar provenances showed lower production rates with an average MAI of 8.0 Mg ha\(^{-1}\) yr\(^{-1}\) and 7.5 Mg ha\(^{-1}\) yr\(^{-1}\), respectively. Conversely, under model B, native black poplar exhibited the highest MAI with 12.2 Mg ha\(^{-1}\) yr\(^{-1}\), followed by hybrid poplar genotypes with 9.2 Mg ha\(^{-1}\) yr\(^{-1}\). Overall the analysis of biomass collected in the SRC plantation showed a high content of bark in the range of 20% to 35% of total weight but, when compared with the wood portion, we found a low cellulose content and higher lignin and ash content, respectively of 26%, 22% and 6% of the total dry matter.

Therefore, in order to provide better feedstock in terms of both biochemical conversion and energy power, it should be useful to explore in more detail the role played by both genetic, environmental and management factors. Physical and chemical properties of wood and bark tissues strongly differ, and their relative quantity play a crucial role in determining the quality and the aptitude of woody biomass to different conversion procedures.

Key words: Bioenergy crops, bio-based products, *Populus nigra.*
DEVELOPMENT OF POPLAR CLONES FOR SRC IN AN EU-WIDE TRIAL

Randolf Schirmer¹ and Daniel Glas²

The importance of SRC for wood chip production is increasing, as it is an additional possibility for farmers in the EU to produce energy and generate income on agricultural land. There are two possibilities to obtain clones suitable for SRC: Starting breeding programmes to cross and select new clones, or the testing of already available clones for their SRC suitability.

After the 24th IPC session, the ASP organized a workshop with European poplar breeders, nurseries and FRM testing authorities to exchange experiences with poplar clones considered to have a high potential for productive SRC. In spring 2014, 50,000 cuttings of 30 clones were aggregated in Teisendorf (Bavaria) and distributed to 12 European countries. In total 22 trial sites with a total acreage of 21 hectares were established. The aim of the project is to compare the productivity of poplar clones under different European site conditions, determine and exchange existing SRC-suitable clones between partner countries and therefore save money compared to costly breeding programmes.

Our presentation compares the height ranking of clones at different European wide locations after the 1st and 2nd vegetation period and analyzes their suitability in regard to the climate conditions of the site. It becomes obvious that black poplar crossings are growing faster under warmer site conditions, while balsam poplar clones perform better under middle and north European climates. For example, when comparing the average height of black poplar and balsam poplar clones in Germany and Spain after the first growth period, the results show significant differences in height growth. On a testing field in central Spain Black Poplar clones reached an average of 3.52 m, while Balsam Poplar clones gained an average 0.50 m less. The development on a testing field in Southern Germany showed an inverse result: Balsam Poplar clones reached heights of 2.89 m while the same Black Poplar clone as in Spain stayed an average 0.72 m under the Balsam Poplar clone level. Additionally, the height performance of the German standard clones Max1/Max4 (P. maximowiczii x P. nigra) and Hybride 275 (P. maximowiczii x P. nigra) after the first year, and their suitability to use them in other countries is discussed in detail. Correlations between mean temperature of vegetation period, precipitation and growth are analyzed. For instance, clone Max1/Max4 shows average height ranging between 364 cm in Spain and 72 cm in the Czech Republic with survival rates between 100% in Spain and 43% in the Czech Republic. Clone Hybride 275 reaches average heights between 224 cm in Spain and 63 cm in the Czech Republic, showing survival rates between 96% in Spain and 19% in Italy. Finally clones with SRC potential for South Germany are presented.

Key words: Poplar clones, clone recommendations for SRC.

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BASE CATALYZED DEPOLYMERIZATION OF ORGANOSOLV-LIGNIN FROM POPULUS BALSAMIFERA – EFFECT ON YIELD AND STRUCTURAL FEATURES OF CLEAVAGE PRODUCTS

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Energy use, mobility, chemical industry, commodity setting, private household of a sophisticated, industrialized society depend on fossil resources. One of the alternative and most promising pathways to provide future societies with energy and platform chemicals is the utilization of fast-growing lignocellulose biomass. Therefore, the separation of lignocellulose and conversion of its fractions into valuable compounds is one of the key challenges of valorizing biomass to a future green economy. Under economic considerations a future, integrated, lignocellulose biorefinery is only profitable in case of valorizing all fractions, including the lignin and its derivatives. Isolated lignin, as one relevant biogenic source for aromatic compounds, offers a high potential for material applications and in the energy sector. During the last decade new application fields for lignin-based products were developed. A suitable way to activate lignin for material applications is the economic generation of monomer and oligomer building blocks. The activation way opens an implementation in the chemical industry sector with high quantity applications (e.g. epoxy and formaldehyde resins, polyurethanes).

A parametric case study for the conversion of S/G-Organosolv-Lignin (hardwood (Populus balsamifera) by base catalyzed degradation (BCD) was realized, according to a statistical design of experiments (Box-Behnken), in a continuous high pressure, plug-flow reactor. To overcome the bond dissociation energy of selected bond types, specific process parameters (Temperature (T): 300°C–350°C, reaction time (t): 5–15min, Sodium hydroxide concentration: C_{NaOH}: 1-3%) were adjusted. Practically, the hydrolysis of macromolecular lignin takes place on the remaining Organosolv-pulping-resistant ether bonds (e.g. -O-4) as well as on methoxyl-groups at high T in alkaline water. The yield, the composition of monomer cleavage products (primary and secondary) as well as the yield and structural features of oligomer cleavage products depend on the lignocellulose pretreatment process, botanical source of lignin & BCD-process conditions. The starting material as well as cleavage products of the hard wood -lignin were characterized in more detail by gravimetric analysis, moisture and ash, EA (CHONS), SEC, GC-MSD/FID, FT-IR, 2D-NMR (HSQC), ^31P-NMR & HPLC.

Based on the results of the complex data sets, the following conclusions are available: The primary, monomer cleavage products are syringols and guaiacols, secondary cleavage products are methoxy-catechols and catechols. The highest yield of the BCD-Oil, with 21% of lignin, could be reached at the combination: T=350°C, t=6,8min & c_{NaOH}=2%. Its composition is not affected by process parameters and contains approx. 62% dimeric/trimeric compounds, 25% syringols, 8.5% guaiacols, 2% catechols and 2.5% phenols. The oligomer cleavage products (yield: 60-35%) show a significant reduction in average molecular weight (M_w) decreasing from 1100g/mol (starting material) to approx. 680g/mol - 400g/mol. Ether bridges (e.g. -O-4), present in the starting material & the aliphatic OH-groups are completely removed after 5min of BCD process time. The phenolic OH-number increases. BCD-Oligomers are poly phenolic building blocks, showing fast reactivity with epoxy groups.

Key words: Populus balsamifera, lignin, base catalyzed degradation, oligomer building blocks.

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POPLAR PLANTATION - A BOON TO RURAL LIVELIHOODS AND ECOLOGICAL RESTORATION IN NORTH INDIA

S. K. Sharma

Increasing population has been causing a serious problem of unemployment and poverty in India. Agriculture is the major source of livelihood in rural areas but heavily dependent on rainfall, surrounding forests and ecosystem. As a result of denudation of forest resources, there has been an acceleration in soil erosion and floods. As an effect of change in climate, farmers all over the country have been experiencing erratic and scanty rainfall more frequently than before. This has been suppressing agricultural production directly. Such lands are suitable for introducing tree based farming. Among the tree species, farmers have a wider choice for selection, but profitability and market demand is the most important factor for cultivation.

The present study through interviews with representatives from civil society organizations shows that the fast-growing hybrid poplars G48 variety or poplar (Populus deltoides), are grown commercially in the plains of north India, namely, Punjab, Haryana and Uttar Pradesh because of market demand and high returns. These states have fertile alluvial soils that can hold adequate moisture with pH less than 8 which is very conducive from growing the sugarcane as well as high breed poplar. The poplar trees are also very easy to care and their plantation with sugarcane are found to give luxuriant growth and excellent results. Poplars are also planted for windbreaks and shelterbelts.

The study revealed that the fast-growing poplars thrive well in warm conditions of north India and thus grown commercially, as a part of agro and social forestry. Poplars have wide industrial use in the manufacturing of paper, matchbox, and plywood among others thus enhancing the rural livelihoods. The state of Haryana has a large plywood industry reliant upon poplar. The poplar biomass can be harvested again in another two to three years as sprouts emerge from cut root stalks (coppice), forming new stands of poplar. This pattern can be repeated several times before replanting is required. The trees are fast growing and able to produce large quantities of biomass in a short amount of time, easy to propagate and cultivate. Raising poplar trees in these states is also rendering outstanding services for maintaining the ecological balance. On the basis of recent research, the planting of poplar trees (Populus deltoides) is expected to alleviate sodicity in soils with a high pH (>8.5) due to the presence of excessive sodium carbonate (Na₂CO₃) on a long term basis. The activity of raising fast-growing poplar trees by the farmers and their marketing has not only taken employment to the very door-steps of the unemployed but also contributed to the reduction of poverty in the poor areas of north India. Poplars are an important component of the twenty-first century renewable resource portfolio and can be farmed as short-rotation woody crops, harvested every two to five years. Therefore, due to their fast growing nature, they serve as renewable resources for future green economies.

Key words: Ecosystem, renewable, woody crop.

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PERFORMANCE OF VARIOUS WHEAT VARIETIES AND SOIL FERTILITY UNDER DIFFERENT SPACINGS OF POPLAR-BASED AGROFORESTRY SYSTEM IN NORTHERN INDIA

Chhavi Sirohi¹ and K.S. Bangarwa¹

Five wheat varieties viz., WH-1105, WH-542, HD-2967, HD-943 and DPW-621-50 were grown under 5 m × 4 m, 10 m × 2 m and 18 m × 2 m × 2 m spacings of 7 and 8 year old Populus deltoides plantation during winter season of 2013-14 and 2014-15 in the research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar.

In the present study, the various growth parameters of wheat crop like total tillers/m², number of spikes, number of grain/spike and 1000-grain weight contributed significantly towards higher yield in wheat variety HD-2967. The grain yield was significantly higher in HD-2967 (3.00 t/ha) closely followed by WH-542 (2.60 t/ha), DPW-621-50 (2.00 t/ha), HD-943 (1.80 t/ha) and WH-1105 (1.40 t/ha) in paired row spacing (18 × 2 × 2 m) than 10 × 2 m spacing. However, the maximum grain yield reduction was found in wheat variety WH-1105 (59.2%) and it followed the order: HD-943 (48.7%) > WH-542 (44.6%) > DPW-621-50 (42.8%) > HD-2967 (27.9%) under seven-year old poplar plantation.

The similar trend was also observed in eight-year old plantation. There was significant reduction in grain yield production of all the wheat varieties under the poplar plantation in comparison to control (crop varieties with no tree). The variety HD-2967 out yielded the rest of wheat varieties under different spacings of poplar plantation. Thus adoption of HD-2967 under poplar plantation would substantially improve the overall productivity of the system without any additional input cost. Soil parameters (organic carbon, available N, P, and K) were also assessed to quantify the effect of this system on nutrients, which were significantly influenced by different spacings of poplar plantation. Availability of macro-nutrients (N, P and K) and organic carbon were determined under 5 m × 4 m, 10 m × 2 m and 18 m × 2 m × 2 m spacing of poplar plantation of surface soil (0-15 cm depths). The organic carbon (0.77%) and N (234.3 kg ha⁻¹), P (20.1 kg ha⁻¹) and K (241.3 kg ha⁻¹) contents were recorded maximum under closer spacing at 5 m × 4 m of eight-year-old poplar based agroforestry system after the harvesting of wheat crop as compared to other spacings and sole crop (April-2015). The macro-nutrients tended to increase with time due to higher inputs of organic matter with the age of tree. Under this study, the overall growth pattern of poplar under different spacings generally followed a rising trend with age. After 8 years of plantation, paired row planting (18 × 2 × 2 m) of poplar resulted in significantly less dbh (22.5 cm) than planting of poplar at 10 × 2 m (25.9 cm) and 5 × 4 m (25.8 cm) spacing.

Key words: Agroforestry system, growth parameters, macro-nutrients, organic matter, Populus deltoides, productivity, spacing, variety and wheat crop.

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Fast growing hybrid poplar trees can be cultivated in agricultural areas for rapid biomass production under coppice management systems as block plantations or strips alternated to herbaceous crops (alley cropping). In Mediterranean conditions, irrigation is a necessary practice in poplar plantations for bioenergy purposes. Its usefulness is to balance out the precipitation shortcomings and implementing the plantation management properly, thus ensuring adequate biomass production. The main aim of the study is to quantify the biomass productivity and the economic sustainability of subsurface drip irrigation (SDI) practice in a Mediterranean poplar coppice plantation located in southern Italy (Montenero di Bisaccia). SDI is an advanced and efficient irrigation system; however, its high installation cost may be unprofitable when used for bioenergy production. The study plantation was established by using the hybrid poplar clone “AF2” under single row design, with overall plantation density of 6,060 trees ha$^{-1}$. We collected the experimental data within two sub-plantation plots, the first under growing conditions of S2R4 (i.e., stem aged 2 years and roots aged 3 years); and the second under S3R5 (i.e., stem aged 3 years and roots aged 5 years). Every sub-plantation plot was divided into two equal parts, the first was subjected to subsurface drip irrigation; the second was rainfed, without irrigation. Measurements were taken at the end of the second and third growing seasons. The total irrigation water volume was 4831 m$^3$ha$^{-1}$year$^{-1}$. The results showed that the fresh biomass yield, in the irrigated plots, increased by 79% compared to the non-irrigated plot, in the S2R4, while this difference increased up to 118% in S3R5.

Considering the economic cost of SDI in relation to the variation of the sale price of woodchip and the production increase, an analysis of the economic sustainability of SDI on poplar SRC for different growing seasons was made. A financial evaluation via Net Present Value method (NPV) was carried out on a 10-year cycle. The initial cost of SDI, with technical materials, machines and workers included, was 1,280 € ha$^{-1}$. Considering the biomass production obtained in the two different plots and the actual selling price of woodchip, the economic analysis shows that the farmer obtains a little economic loss in relation to the S2R4 plantation, while, a little economic advantage is obtained in the S3R5 plantation. To recover the investment cost of SDI during a period of ten years, the increase in biomass production should reach at least +90% in the irrigated plot compared to the non-irrigated ones.

**Key words:** AF2 clone, Alley cropping, NPV, *Populus* spp., SRC.
FARM WOODLOTS OF POPLAR AND OTHER FAST-GROWING INDUSTRIAL TREES IN SMALLHOLDER FARMS OF BUNDELKHAND REGION OF CENTRAL INDIA


Bundelkhand Region of Central India is the most backward and downtrodden region of India. Water is a scarce natural resource. The average rainfall is less than the national average, i.e. 800-900mm. A once food secure zone has now become a symbol of insecurity and migration due to climate change. The industrial trees such as *Tectona grandis*, *Eucalyptus tereticornis*, *Populus deltoids*, etc. are the second choice for the farmers, mainly due to non-availability of market, lack of wood-based industries and available markets at far places.

Poplar is a prominent exotic species farmers like to plant along with crops. *Populus deltoides* Bartr is the most widely planted species in India. It has huge market in plywood and paper industry. Generally it prefers irrigated and sandy soils. It is planted in plains of North-West India, i.e., Western Uttar Pradesh, Punjab and Haryana and to some extent in the outer plains/valleys of Uttaranchal and Himachal Pradesh. It has very high growth rate (mean annual increment of 20 to 25 m$^3$/ha/year). One smallholder farmer named Pankaj Nemani who hails from Dohar-Jouniya village of Dabra tehsil in Datia district of Madhya Pradesh, had succeeded in introducing poplar for the first time in his farm which is non-traditional poplar growing region. Initially the Forest Department helped him in technical knowhow and provided the planting material. ICAR-CAFRI (Central Agroforestry Research Institute, Jhansi, India) helped him in analysing his soil properties at varying depths and assessing growing stock of the plantation. At present he has 1000 Poplar trees of three years old. Every year he is extending the plantation by planting the seedlings obtained through suckers and cuttings prepared from his own trees. He has cultivated vegetables in the initial years and *Stylosanthes amata*, *Trifolium alexandrium* grass as fodder for his livestock. The trees are healthy and the growth rate is totally comparable with the traditional poplar growing areas. At present, the average gbh of trees is 16 cm and height is around 15 ft. The tree is deciduous in nature and the litter fall plays a major role in improving soil carbon. It was observed that as the age increased, the organic carbon content of the soil increased up to (0.405%) when compared to control (0.363%). At the current rate of growth, basal area of the stand comes to be at 0.0221 and the total tree volume stands to be at 0.0443m$^3$ at three years after plantation. In addition he has 3-year old well established plantation of *Tectona grandis*, 1-year old plantation of *Eucalyptus tereticornis*, 4-year old plantation of *Ceiba pentandra*. The main purpose of establishing these woodlots is raw material for plywood, match, paper and pulp and timber industries.

In an experiment to determine the bioethanol content of *Tectona grandis* and *Eucalyptus tereticornis*, the total sugar yield at 1 gm and 5 gm yeast used for fermentation was found to be 15.06 and 12.87 gm in *Tectona grandis* (15 years) and 21.67 and 40.88 gm in *Eucalyptus tereticornis* (4-year old). Farm woodlot-based agroforestry systems is very much new to this region. In the next season CAFRI is planning to procure ETPs of poplar from nursery and planning to establish the plantation. Now this is high time that the industrial species can be very much propagated and promoted in large scale in non-traditional growing region.

Key words: Woodlots, industrial trees, exotics, growth rate, soil carbon.

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BAMBOO-BASED AGROFORESTRY IN VINDHYAN REGION OF INDIA

Anubha Srivastav¹, Anita Tomar , V.P. Pandey and S. D. Shukla

Bamboo is known as poor man's timber and companion of the rural masses is one of the most important renewable resources; capable of producing maximum biomass per unit area and time as compared to other forest species. The proper management and attention has degraded the bamboo wealth considerably in Vindhyan region of India. Though there are over 100 species of Bamboos which are found in India, Bambusa arundinacea, B. tulda, B. polymorpha, Dendrocalamus strictus, D.hamiltonii, Melocanna baccifera and Ochlandra travancoroca are more important from the point of view of availability. However, Dendrocalamus strictus and Bambusa arundinacea are the two principal economic species, of which the former occupies the largest area and is the most common.

The study is intended to develop suitable demonstration agroforestry models of Bamboo on farmer’s land so as to motivate them for adopting Bamboos in agroforestry. The two bamboo species, namely Bambusa arundinacea and Dendrocalamus strictus, were planted at different spacing on field bunds in combinations of traditional agriculture crops on degraded alkaline land of farmer. The results indicated that growth performance of Bamboos in respect of survival (75%), number of branches (30), number of culms (16) and plant height (6.5 m) were superior in large spacing of 6 m x 6 m than lower spacing in all the agroforestry models. There was not much variation in the yield of wheat and paddy between treatment of different spacing of Bamboos and control plot.

On degraded land of Vindhyan region where agriculture production is less, adoption of bamboos in the long run may be a viable option to address ecological as well as economic problems of degraded land. Large-scale adoption of Bamboo plantations under agroforestry system would help increasing the bamboo stock over degraded land. These plots can be utilized for inter crops like wheat, paddy, vegetables, pulses etc., in combination with different species of Bamboos for a period of 3-5 years till first harvest. In the later stages, these plots can be managed only for Bamboo stands for small land holdings as agriculture production will be severely affected due to shade effect of dense crown. Shade loving underground crops/ medicinal plants and spices can be grown as intercrops with Bamboos. Further, commercialization of bamboo-based handicrafts and articles bear great potential of generating income and employment for rural masses.

Key words: Bamboos, agroforestry models, degraded land, Vindhyan region.

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A profound estimation of yield potentials for a given set of cultivars based on soil and climatic properties of a site is of central importance for a prospective grower of short-rotation coppice (SRC) plantations. One way to enable such assessments is by supplying a model that estimates the effects of genotype by environment interaction, based on data from multi-environment trials. While this has been implemented in some countries for their respective growth conditions, approaches in Germany have mostly been conducted on a smaller scale. The comparison of results from different experiments is often limited by differing management choices, like selection of clones, spacing or rotation cycle for example.

The ProLoc Joint Research Project aimed to close this gap, by initializing a network of 38 trial sites with a standardised experimental design in 2008, of these remain 27 active at the end of the second project phase in 2015. Sixteen additional sites with a different rotation length and spacing have been established in 2012, the main focus is on the trial series from 2008. Sites were distributed across the area of the Federal Republic, including differing physical and chemical soil properties as well as diverse climatic conditions. Three poplar and 2 willow clones representing different hybrids and being the most common clones in German SRC cultivation were selected for testing. The rotation length has been fixed to a 3-year cycle, measurements regarding growth and vitality have been carried out annually, biomass yield was assessed at each harvest.

Different approaches have been tested for suitability of modeling the relationship between soil conditions and yield potential. Mixed-effects models offer an adequacy for explaining variance of yield on plot level by taking random effects into consideration that have been introduced by the hierarchical and longitudinal structure within the data from the trial series. Second rotation yields are significantly influenced by yields after the first rotation cycle. Climatic variables like sum of precipitation during the vegetation period and the length of vegetation period described by the sum of growing degree days show a differing impact between rotation cycles. Physical soil properties, like soil texture and type, as well as variables like soil class indicate a plausible influence on yield potential. Furthermore German soil quality indices, as a conventional instrument of assessing arable land, show a considerable suitability for estimating yield.

An outlook is given on the possibilities of shifting the focus of analysis from stand to the single tree level as well as implementing this approach into a growth simulator.

**Key words:** Short-rotation coppice, forest growth modeling, yield estimation, clone-site-interaction.
THE HISTORY OF BLACK COTTONWOOD IN ICELAND

Halldór Sverrisson¹ and Thorbergur H. Jónsson¹

The first individuals of *Populus balsamifera* ssp. *trichocarpa* arrived to Iceland in the winter 1943-1944. A young student in forestry, Vigfús Jakobsson, sent some poplar cuttings to the Icelandic State Forestry. He collected them in the autumn 1943 in Copper Landing, near Lake Kenai on the Kenai Peninsula in Alaska. The director of the State Forestry at that time, Hákon Bjarnason, wrote in the annual report for the year 1944 that the plants were doing well so far but he would wait to give this new species an Icelandic name until more was known about its hardiness in Icelandic environment. In the following years the poplar got the name alaskaösp (Alaskan poplar). Jakobsson went to Alaska for the second time in 1947 to collect more cutting material. Poplar material has been collected in Alaska in five more expeditions, 1950, 1952, 1963, 1985 and 1994. The 1963 expedition was made after a very bad frost damage on poplars in the southern part of Iceland in the spring of 1963. The aim was to get material from the south coast of Alaska where the climate is more oceanic compared to the inland of the Kenai Peninsula.

In 1979 the first trees of black cottonwood began to flower in Akureyri in North Iceland. Seeds were collected and sown. In 1983 seeds were collected in the south of the country and from the progeny collection some clones were selected for trials. The first controlled crossings were done in 1988 and then again in 1995. In 1999 poplar leaf rust (*Melampsora larici-populina*) was found for the first time in Iceland. New breeding programme was started in order to find clones with good resistance against the rust. The progeny of several crosses have been planted in progeny trials in different regions of the country and potential plus trees have been selected and planted in a collection of 350 clones which are tested for rust resistance, susceptibility for frost damage, growth rate and other qualities.

In the period 1992-1995 several clonal trials were established in different parts of the country. They included 40 clones. Most of them are nature clones collected in the Kenai Peninsula in Alaska and on the south coast of the country, but also a few seed plants from Iceland. Some large plantations were also established on farm land, the largest one covers 60 hectares. The research and the larger forest plantations were linked to plans for the production of wood biomass for the silicon alloy industry in Iceland. The project was financed by the Icelandic government.

One of the most important research in this field today is the poplar breeding programme. The main goal is to obtain a variety of fast-growing clones with good rust resistance and well adapted to the local climate in different parts of the country. Furthermore there are some unsolved silvicultural problems which need to be clarified. The ongoing research is partly financed by the Nordic *WoodBio project*, Wood biomass in the Nordic Bioeconomy (http://www.woodbio.com/).

**Key words:** Black cottonwood, Iceland, wood biomass.

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SEED TRAITS OF MONEY SPINNING AGROFORESTRY TREE – MELIA DUBIA

Anita Tomar¹, Kumud Dubey and Anubha Srivastava

Seeds from proven source or plus trees form the backbone of any successful agroforestry programme. Seed parameters and germination behaviour are most important for afforestation programme and these characters are interdependent and polygenically controlled. To exploit the potentiality of available resource base, variability and genetic analysis of Melia dubia trees were assessed for seed traits as a scope for further breeding programmes. Melia dubia syn. M. composita is also called as a Maha neem or Forest neem belongs to family Meliaceae. It is the fastest growing tree species, within 6-7 years the plantation is ready to harvest. An effort has been made to evaluate the extent of variation in seed parameters and germination in Melia dubia.

For the present study, the seeds were collected during January-February 2015 from an average elevation of 638 metres (2,093 feet) above mean sea level (MSL) and is situated between latitude of 12°15' N to 12°75' N and longitude of 77°5' E to 78° E. Seed collection had been done from at least 30-40 trees, 100-200 m apart from each other. The seeds then kept loosely packed in plastic sacks and kept in open place to allow for adequate air circulation. Sample of 50 seeds were drawn from the working sample and the three dimensions (length, width and thickness) were measured using vernier caliper. Seeds were measured for 1000 seed weight also using weighing balance. The highest coefficient of variation (CV) of 14.97 % was encountered in seed width. Lowest coefficient of variation (4.49 %) was observed in number of seeds per kg and the number of seeds per kg varied from 610-650 with a mean value of 630. Weight of 1000 seeds of Melia dubia is 1.47 kg. However, the seed length, width and thickness shared a variation of 7.45, 14.97 and 8.01 %, respectively. Seeds were also subjected to five pre-sowing treatments. Germination test involved 4 replications of randomly selected 25 seeds each from the working sample.

The results showed that cow dung slurry treatment for seven days had significantly enhanced germination and seedling growth. Seed germination started 35 days after sowing and continued up to 70 days. The highest germination percentage (42.3%) was observed in the soaking of seeds in cow dung slurry for five days (T₂) followed by (36.5%) soaking in cold water for 24 hours (T₅). The lowest germination percentage (19.4 %) was obtained from control (T₀). The highest germination value (3.2) and germination energy (35) was also obtained in (T₂), which was significantly (P <0.05) different from the control and other treatments.

Melia dubia is fast growing and can fulfill the needs such as timber, fuel wood and also fodder thereby farmers become self-reliant and economically stable. Apart from these benefits, the cultivation of Melia dubia increases the organic matter content of soil due to accumulation of litter which inturn enhances soil fertility. Melia dubia trees will not only contribute towards improvement of environment but can be a best environmentalist’s choice for instant greening.

Key words: Agroforestry, Melia dubia, seed parameters, germination, greening.

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SUITABILITY OF *POPULUS DELTOIDES* CLONES FOR THE INDO GANGETIC PLAIN REGION

Anita Tomar\(^1\), Anubha Srivastava\(^1\), M.K. Shukla\(^1\) and Dinesh Kumar\(^2\)

Poplars hold a great significance in India as they are among the most preferred tree species in the agroforestry systems in northern part of the country. Systematic introduction of exotic poplars took place more than seven decades ago but in the Indo Gangetic region, specific suitability of poplar clones is not much known to farmers.

Thus with a view to assess suitability of poplar clones, specifically for Indo Gangetic plain region, 50 clones were tested in Allahabad district laying at latitude 25°07’ to 25°10’N and longitude 81°54’ to 81°58’ E and at 98 m elevation. Most of the germplasm tested was brought from natural range of this species in North America and the Forest Research Institute (FRI) has been the major organization which introduced clonal material from abroad. The germplasm of *Populus deltoides* was collected from FRI and tested.

After having analysed the performance of the tested 50 clones on the basis of height, collar diameter, stem wood volume and biomass, it emerged that the highest height was recorded in poplar clone G48, Same clone also recorded maximum above-ground biomass followed by clones FRI-AM-48 and FS-223, respectively. G-48 gave higher yield also and it has been the most popular clones over the last two decades in agroforestry plantations in India. The method used for biomass estimation was destructive method of tree biomass estimation also known as the harvest method. Annual mean and standard deviation of biomass increment as well as ANOVA results showed no significant differences (p>0.005).

This paper aims to review and summarize the studies which were carried out to test the suitability of poplar clones, specifically for the Indo Gangetic plain region.

**Key words:** *Populus deltoides*, agroforestry, height, biomass.

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Aspen is a major forest-species in Russia. Aspen natural forests grow fast, have considerable volumes in stem wood, and the stems have favourable straightness. This species is sufficiently undemanding to growing conditions and shows excellent regeneration. Wood of aspen is white, odorless, easily workable and can be used in a wide range of applications. It therefore has significant resource potential.

Unfortunately, it has several disadvantages, the most significant of which being the high susceptibility to attack of heart rot caused by fungi Fomes igniarius Fr. and Phellinus tremula Bond. et Boris. Because of this, aspen is regarded by foresters as an unwanted species and many of the recommendations for forest management aim at reducing its area or complete elimination. Despite these recommendations and prohibitions, the area of aspen distribution in Russia since 1961 has increased to 65% and presently reaches about 25.8 million hectares. At the same time, especially in recent decades, a growing number of researchers came to the conclusion that aspen is a useful species, and we have to learn how to improve its resistance to phytopathogens.

Improvement of this species includes breeding, selection, introduction, hybridization, polyploidisation and transgenesis. The results described in this report were obtained in the Central Chernozem region of Russia, using selection and hybridization. In general, the survey conducted in this region revealed positive high-value stands that, at the age of 45 years, had a standing volume of 340-490 m³/ha. The number of trunks affected by heart rot did not exceed 6%. Thus, these stands displayed a high wood quality and optimal growing conditions for carbon storage.

Progeny of intra- and interspecific crossings of Populus tremula studied in the Central Chernozem region showed that the growth of aspen trees and new hybrids can be increased to 300-500 m³/ha in 30 years with no or minor heart rot infection. The best results were obtained by crossing of local forms of aspen P. tremula × P. tremula and interspecific crossing of P. alba × P. tremula. After the 2010 drought some drought-resistant hybrids were selected. All these best selected clones and hybrids can be used in its traditional form as timber, bioenergy, and also in landscaping.

Key words: Aspen, resource potential, selection.

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ASSESSMENT OF BIOMASS PRODUCTIVITY BY STUDYING SOME FACTORIAL EFFECTS ON EARLY GROWTH OF POPLAR (POPULUS SPP.) CLONES

Ivaylo Tsvetkov¹, Hristina Hristova¹, Emil Popov¹ and Tatiana Stankova¹

A field trial based on Nelder design with four different poplar (Populus spp.) clones (BL, NNDV, Agathe and I-45/5) was established in the spring of 2013 with a goal for general assessment of their biomass productivity potential and suitability for energy plantations. The experiment was aimed at following the effect of genotype, spacing (11 levels) and rotation (3 levels) on the early growth of the poplar saplings. The specificity of design allowed both genotype (the radial straight lines, “spokes”) and space (along the radial straight lines) effects to be tested on a relatively small area, with rotation period being added to the factorial set as well.

Standard biometrical parameters (survival, height (H), diameter at breast height (D₁.₃) and diameter at soil level (D₀)) were monitored during the experiment. Additional measurements of both the fresh and dry weight of experimental samples were carried out. Results from the performance of poplar clones at an early stage are presented and respectively commented.

An essential clonal effect was revealed on the average height, the diameter at breast height and the amount of branch wood biomass (clone BL being the best performer) when comparing 2-year old plants and 1-year old plants with 2-year old root system. It was found that the frequency of rotation significantly affected the amount of both total and stem biomass when comparing the same groups of plants. Based on the preliminary data obtained, no one of the clones significantly outperformed the others in its biomass potential.

Key words: Biomass, energy plantations, Nelder design, Populus spp., productivity.

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ASSESSMENT OF BIOMASS PRODUCTIVITY AND EFFECT OF PLANTING DENSITY IN A SHORT-ROTATION COPPICE POPLAR PLANTATION IN THE NORTH OF SPAIN

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In the north of Spain, during 2006, three experimental designs were established using 11 clones of Populus spp.: (i) one was designed to assess the productivity of different clones on a large scale (AF2, I-214, Monviso and Pegaso clones were used), (ii) another was established to evaluate the productivity of different clones on a small scale (A4A, Beaupré, Guardi, I-214, MC, Triplo, Unal andViriaclones); and (iii) the last one was developed to study the influence of the density on the biomass productivity in I-214 clone (15,000; 25,000 and 33,333 stool*ha⁻¹). The plants were coppiced in 2007, 2009 and 2011. Different measurements were performed between 2007 and 2011.

The objectives of the study were to assess the dry biomass produced by each clone, to compare these productions and to evaluate the effect of the planting density on the biomass of the clone I-214.

The yield for each clone was analyzed by year and rotation at stool and stand level. At the end of the first rotation the most productive clone at stool level was Viriacl (4.5 kg*plant⁻¹) and the least productive one was Unal (1.4 kg*plant⁻¹). In the case of the second rotation (values for AF2, Monviso and Pegaso were not available) the most productive was Triplo (3.2 kg*plant⁻¹) and the least productive was Beaupré (1.1 kg*plant⁻¹). At stand level, the most productive clone in the first rotation was A4A (90 Mg*ha⁻¹) and the least productive was Unal (25 Mg*ha⁻¹). In the second rotation the highest production corresponded to the clone Viriacl (76 Mg*ha⁻¹) and the lowest to I-214 (6 Mg*ha⁻¹) (values for AF2, Monviso and Pegaso were not available). Furthermore, in both rotations the most profitable clone was Viriacl (160 Mg*ha⁻¹) and the least profitable was Guardi (39 Mg*ha⁻¹). The influence of the planting density on the mean annual increment in biomass was also evaluated through analyses of variances (ANOVA’s), and Tukey’s test was used for comparison of means. In the first rotation the most productive treatment was the planting density of 25,000 stool*ha⁻¹ (43.84 Mg*ha⁻¹*year⁻¹), and in the second rotation it was the density of 20,000 plants*ha⁻¹ (37.01 Mg*ha⁻¹*year⁻¹). In addition, there were no statistically significant differences between the means for the different planting densities at the end of both rotations.

Keywords: Short-Rotation Coppice (SRC), poplar clonal characterization, two rotations.

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In 2006, three experimental trials were established in the north of Spain. Eleven poplar clones were planted (A4A, AF2, Beaupré, Guardi, I-214, MC, Monviso, Pegaso, Triplo, Unal and Viriato) at a density of 20,000 stool*ha$^{-1}$. The plantations were coppiced in 2007, 2009 and 2011. Different measurements were recorded between 2007 and 2011. The aims of this study were to develop allometric models to estimate the biomass produced by each clone and to evaluate the changes in the biomass allometry caused by age in a short rotation coppice plantation.

The study considered thirteen allometric models that included three different variables: the dominant shoot diameter at basal height, the total height of the dominant shoot per stool and the number of shoots per stool. These models were classified into two groups: models in which age was not included among the variables, and models that include it through “dummy” variables. All the variables and formulation combinations were tested, and the best model for each clone as well as for the entire data was selected. The models with dummy formulation gave high accuracy and less bias in biomass predictions. Furthermore, dry biomass measured in the field was compared graphically with estimations produced using the best model for each clone.

The influence of age on the biomass allometry was analyzed graphically by comparing different models and formulations. The models pointed to changes in the allometry with age, so that there were different parameters for each age. The influence on the model of the parameter related to the diameter increased over time, whereas the other parameters presented decreasing trends.

Our findings suggest that the inclusion of the age in the model is advisable to obtain more robust biomass predictions at different ages in short rotation coppice plantations.

**Key words:** Short-Rotation Coppice (SRC), allometric models, clone.

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INFLUENCE OF TWO CONTRASTING PLANTING SYSTEMS AND WEEDING REGIMES ON WILLOW PERFORMANCE UNDER FIELD CONDITIONS

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To assess the impact of weed pressure on survival rate and biomass accumulation of short-rotation willow, cuttings or billets (20 cm or 10 cm long fragments of one-year old shoots, respectively) of three willow genotypes (i.e. Jorr, Olof, Tora) were grown in the field under two weeding regimes (weeds or no weeds). Moreover, both cuttings and billets were produced from either cold-stored or fresh donor shoots.

Bud burst occurred 2 and 4 days earlier, respectively, for cuttings as compared with billets, and fresh as compared with stored propagation units.

Four months after planting, the cumulative mortality of billets was about twice as high as cuttings mortality. No statistical difference in survival rate was found between fresh and stored propagation units. Mortality of cuttings grown with and without weeds did not differ between willow genotypes. However, statistically significant differences existed between mortality of billets of Tora and Jorr, and Tordis. Similar trends persisted over time and were observed also for measurements performed 22 months after planting. Moreover, 22 months after planting, 4 out of 24 plots with billets presented 100% mortality in plots without weeding.

Shoot biomass accumulation was significantly affected by weeding regime. Shoot biomass was reduced by 20-80% under weed pressure as compared with weed-free plots, and biomass was consistently lower for billets. Allometric equations relating shoot diameter to shoot dry weigh revealed significant genotypic differences in yield of willows under different weeding regimes.

This field study will continue and future performance will be monitored and analysed. Thus far, we conclude that the type of propagation unit (cutting vs. billet) and weeding regime (weeds vs. no weeds) had the highest impact on survival rate and biomass accumulation of willows in this experiment. Specifically, survival rate and biomass accumulation: i) was significantly higher for cuttings than billets; ii) did not significantly differ for stored or fresh propagation units; iii) was significantly reduced under weed pressure; and iv) did not differ between willow genotypes.

Key words: Allometry, billet, biomass accumulation, cutting, field experiment, weed pressure.

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EFFECTS OF HEAVY METALS AND MYCORRHIZAL FUNGI ON GROWTH AND NUTRIENT STATUS OF *POPULUS ALBA* × *P. GLANDULOSA*

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*Populus* are important rehabilitation species heavy metals laden sites. Their existence and survival in such environment is due to their association with arbuscular mycorrhizal fungi (AMF) or ectomycorrhizal fungi (ECMF). This experiment was conducted to determine the effects of heavy metals and AMF or ECMF on growth and nutrient status of two (PCP301CGoR4 and PABC21) transgenic heavy metals (HMs) clones of *Populus alba* × *glandulosa* under glasshouse conditions. Transgenic clones are being developed at the Biotechnology Center, Korea Forest Research Institute (KFRI), Suwon, Korea for rehabilitation of mine tailings. One-month old microplants were inoculated with *Pisolithus tinctorius* (from KFRI, Seoul) or AMF (mixture of species under the genera *Gigaspora*, *Glomus* and *Acaulospora*) from mine site in Bonghwa, South Korea. AMF were isolated and mass produced for three months using bahia grass. Microplants were inoculated during transplanting into plastic cups filled with autoclaved peat perlite vermiculite (1:1:1 v/v/v) (PPV) and incubated in an acclimatization room. After one month, seedlings were transferred into bigger pots filled with non-autoclaved medium with or without a mixture of cadmium, lead, zinc and arsenic (top four HMs in Bonghwa). HMs were added separately into the PPV medium utilizing half or full of the prevailing concentrations of the top four HMs in Bonghwa mine tailings soil. The air-dried PPV medium amended with HMs was mixed thoroughly, watered to filled capacity and incubated for a week prior to plant transfer.

After four months, results showed that PCP302CGoR4 was more responsive to mycorrhizal inoculation. In no HMs medium, AMF promoted higher height, shoot and total dry weight of PCP301CGoR4 and absorbed more N, P, K and Na than that by ECMF *Pisolithus*. Control plants had the lowest total dry weight and nutrient uptake. In HM amended medium, both ECMF and AMF promoted similar growth and P, Mg, Cu and Zn, which were significant as compared with the control treatment. In PABC21, AMF promoted the highest P and Na uptakes. In conclusion, the two clones varied in response to mycorrhizal inoculation. AMF was more effective in promoting growth and nutrient uptake of PCP301CGoR4 and PABC21 than ECMF. The HMs concentration, whether half or full of the prevailing concentrations in the field, did not affect the total plant dry weight, implying that these HMs had no effect on the plant growth promoting effectiveness of ECMF and AMF on PCP301CGoR4. On the other hand, ECMF was ineffective on PABC21.

The results may also imply that a mixture of mycorrhizal fungi in AMF was more effective plant growth promoter than the single species in the ECMF. It is highly recommended that the effectiveness of the AMF and ECMF mycorrhizal inoculants should be studied under field conditions in Bonghwa mine tailings.

**Key words:** *Amanita*, Bonghwa mine tailings, heavy metals tolerant *Populus alba* × *P. glandulosa*, mixed inoculant, non-transgenic and transgenic clones.

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RESTORATION OF RIVER BANKS WITH *POPULUS ALBA* L.: A CASE STUDY IN ITALY

Pier Mario Chiarabaglio and Achille Giorcelli

In a floodplain area of the Po river subject to flooding and consequent soil erosion, in northern Italy, consolidation activities and river restoration were made using *Populus alba* L. An innovative scheme and new plantation techniques were adopted, which were able to guarantee survival of the plants on unsuitable soil, as well as water runoff, reduction of soil erosion and improvement of the landscape and of biodiversity.

We report the plantation techniques adopted and the results obtained after the first two years, with consideration to the two flood events which occurred. Furthermore, the energy balance was calculated and evaluated in comparison with that of traditional hydraulic works based on the use of concrete blocks.

**Key words:** Salicaceae, river restoration, flood.

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THE UNEXPECTED INCREASE OF WILD *POPULUS NIGRA* L. IN BERLIN AND BRANDENBURG

Achim Förster¹

Black poplar *Populus nigra* L. is a rare indigenous tree in Berlin and Brandenburg. In historical times it dominated the great river systems Havel and Spree. Seed germination of the pioneer tree black poplar depends on bare soils along river banks after flooding events. These sandy river banks were cultivated since Fredrick II (Frederick the Great 1712-1786) ordered agricultural drainage and water flow management. Remaining old trees were isolated and only cuttings were planted.

After 1800, the faster growing hybrid *P. x canadensis* (Dode) Guinier ( *P. deltoides* Bartr. from North Amerika x *P. nigra* L.) was preferred. Later on the Berlin Poplar *P. x berolinensis* Dipp. a hybrid ( *P. laurifolia* Ledeb. from Siberia and *P. nigra* L.) came up as an ornamental tree. *P. nigra* L. became very unattractive, an "ugly tree", but was not totally extinct.

In the field it is difficult to distinguish between hybrids and the wild native black poplar. So most of the botanists from West Berlin decided that only the hybrids and not *P. nigra* L. grow in West Berlin. In GDR and East Berlin botanist described old and young *P. nigra* L. trees.

After reunification, poplar seeds spread into wetlands of military and industrial wasteland, unused railways and roads etc., where they germinated, even in the center of Berlin and other cities but only a few botanists took notice of this. Black poplar was “tree of the year” in 2006; and in the following years I got the chance to collect samples from these natural poplar regeneration and also from old trees for genetic analysis (PCR). Over 95% of the samples were pure *P. nigra* L. and I had a long list with young and old individuals of this rare species.

In the last years some wasteland near Spree and Havel was re-cultivated and black poplar was the first tree species that was removed to establish the new parks. Other wasteland was reconverted for new industrial use or other buildings and all black poplars were replaced by more ornamental trees like oaks, lime, weeping willows etc.

Where did black poplar survive the last century? The study of historical maps showed that after World Wars I and II small wetland areas in and near cities were not cultivated. Temporary moderate use did not allow hard wood trees like oaks to grow up. Without competition and not threaten by other trees the pioneer species black poplar survived and wind transported their seeds into far regions for example into the city of Berlin. There it found good condition to germinate but that was possible only into the 1990s.

Raising succers from root-shoots or other parts excavated from these wild black poplars and transferring them directly in other protected sandy but wet areas was successful. That is the cheapest way to save threatened black poplar trees in the coming years.

**Key words**: Black Poplar, *Populus nigra* L., Berlin poplar, seed germination, industrial and military wasteland.

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QUANTIFYING ENVIRONMENTAL IMPACTS OF POPLAR SHORT-ROTATION-COPPICE ON MARGINAL LAND – SUMMARY RESULTS FROM THE PROBIOPA EXPERIMENT

Rüdiger Grote1, Janine Schweier2, Eugenio Diaz-Pines3, Edwin Haas1, Saul Molina-Herrera1, Klaus Butterbach-Bahl1 and Jörg-Peter Schnitzler3

Bioenergy feedstock and pulpwood for paper production can be supplied by short-rotation coppices (SRC). Compared to non-woody bioenergy crops (e.g. rapeseed or maize), biodiversity is less affected and negative environmental impacts are considered of minor importance. However, increased emissions of biogenic volatile organic compounds affect air quality and regional climate and may be important in the future considering land-use change and climate warming. Particularly on marginal sites, where the competition to food production is less expressed, SRCs are gaining an increasing importance. However, a comprehensive evaluation of the environmental impacts of SRC is demanding.

A combination of sophisticated measurements and process-based modeling has been used for a hybrid poplar SRCs established on a marginal agricultural land in southern Germany. Net emission of greenhouse gases (CO2, CH4 and N2O), carbon sequestration rates in soil and plants, and nitrate leaching were observed throughout four consecutive years. Further laboratory experiments allowed parameterizing emission models and estimating the emission of volatile organic compounds, i.e. isoprene.

It was found that net soil GHG emissions and nitrate leaching decreased considerable after the cultivation of the former crop site with poplars, particularly if no fertilizer is applied. Soil organic carbon stocks tended to increase. Based on evaluated model simulations, we furthermore conclude that the environmental benefits are likely to continue throughout the lifetime of a SRC plantation (21 years), considering multiple regrowth from stump as well as a final stump removal. Despite the overall encouraging results, it should be kept in mind that a maximum conversion of marginal lands into SRC plantations is likely to negatively affect photochemistry during heat waves in some parts of Germany.

Key words: Short-rotation coppice, nitrate leaching, greenhouse gas emission, biogenic volatile organic compounds.

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TWO *SALIX* GENOTYPES DIFFER IN THEIR PRODUCTIVITY WHEN GROWN IN MONOCULTURE AND MIXTURE

Stefanie Hoeber¹, Martin Weih¹, Stefano Manzoni² and Petra Fransson³

Species differ in their demand for resources, especially nutrients; to compete they must be able to either acquire a greater proportion of nutrients than their competitors, or use nutrients more efficiently for biomass production. These strategies are often complementary, as there are inherent trade-offs that do not allow organisms to have both high resource use intensity and efficiency. We tested the hypotheses that (i) nutrient use differ between genotypes cultured in mixture compared to corresponding monoculture due to interspecific interactions, and (ii) total biomass production is greater in genotypes cultured in mixture when nutrient resources are limited (niche complementarity).

To address these questions, we assessed productivity and nitrogen use of two genotypes of *Salix* (Tora - *S. schwerinii × S. viminalis* and Loden- *S. dasyclados*) with contrasting phenology and functional traits. Cuttings were grown for 17 weeks in a growth container experiment under two nutrient fertilization treatments in mono- and mixed-culture.

We found that Tora had higher biomass production (above-ground biomass, leaf area productivity) as well as nitrogen uptake efficiency in mixture- compared to mono-culture under low nitrogen level, whereas Loden showed the opposite pattern. In general, Loden had a higher leaf nitrogen productivity, but also lower nitrogen uptake efficiency compared to Tora.

In summary, our results indicate that young Tora plants are more successful in biomass production and nitrogen use efficiency than Loden plants when grown in mixtures, confirming our initial hypothesis. These results have been obtained from a one growing season growth container study, and thus need to be validated at field scale with mature plants that have interacted for longer periods of time.

**Key words:** Competition, biomass productivity, *Salix*, nitrogen use efficiency.

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SHORT-ROTATION COPPICE (SRC) – PLANNED AND CULTIVATED IN A MORE NATURALLY COMPATIBLE WAY

Leena Jennemann¹, Pascal Kinast¹, Wolfgang Peters¹ and Imke Hennemann-Kreikenbohm

Compared to annual crops SRC have ecological advantages, such as longer dormancy of soil, less use of fertilizer and structuring agricultural landscapes. However, SRC may also entail conflicts with environmental requirements and objectives.

The research project “Naturally compatible establishment and cultivation of short-rotation coppice (SRC)” funded by the Federal Agency for Nature Conservation, developed options for an ecologically sound site selection and an ecologically compatible cultivation of short-rotation coppice. These options have the potential to avoid conflicts and to promote synergies with nature protection and landscape conservation by cultivating SRC. The results of the research show criteria for the selection of an ecologically compatible site selection for SRC. They can serve the purpose of evaluating cultivatable areas and to identify ecologically compatible sites for both SRC-operators and environmental agencies. Potential conflicts with the requirements of ecological protection are therefore already avoided in the planning process of the cultivation of SRC. Furthermore, sites are identified which will appreciate due to the cultivation of SRC.

Further synergies with environmental protection can be promoted within the framework of the process of planting and cultivation of SRC through the procedure for the appreciation of plantations. The research project also includes a three-year field study of different cultivation procedures on their effectiveness to promote biodiversity (e.g. planting of field-flower strips). The implementation of criteria of ecologically sound site selection as well as the measures of naturally compatible cultivation of SRC is possible by means of different instruments of agricultural funding and nature protection.

The presentation’s focus lies on the methodology regarding the participative development of the ecologically sound criteria for site selection for SRC. We developed abstract criteria for naturally compatible site selection in an iterative way. Primarily the analysis of the legal framework for agricultural cropping shows plots that are not legally permissible for the cultivation of SRC. A second analysis of impact correlations allows the conclusion of criteria with information about an ecological advantage or conflict through the cultivation of SRC. To find out if these criteria are practicable, we developed GIS-analysis method. In that GIS-analysis we exemplarily identified naturally sound site potentials for SRC in the area of two administrative districts in Lower Saxony and in Brandenburg.

Therefore the presentation shows the development of the criteria of ecologically compatible site selection and the procedure of the GIS-analysis with its results. How to implement these criteria as well as measures for the ecological appreciation of SRC will also be discussed in the presentation.

Key words: Short-Rotation Coppice (SRC), site selection, environmental protection, ecological sound site selection, potential analysis, naturally compatible SRC.

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SELECTED AND USE OF NATIVE WILLOW CLONES FOR RECLAMATION IN FOREST ECOSYSTEMS IMPACTED BY ELEVATED SALT LEVELS

Richard Krygier and Martin Blank

In Alberta oil sands mine reclamation, the presence of oil sands process-affected water (OSPW) in the reclaimed landscape raises concerns based on concentrations of salts and to a lesser degree napthenic acids. Plants may be exposed to varying dilutions of these constituents within and along shorelines of water bodies, peatlands, lowland forests and seepage sites. In some cases, it is anticipated that concentrations could reach levels that are detrimental to growth of desired vegetation.

Many species of willow commonly occur in the environments most at risk from exposure to OSPW, and are frequently a major structural and functional component of lowland and riparian ecosystems. From an ecological engineering perspective, willows are often deployed early in reclamation of these areas based on their value for slope and shoreline stabilization. As such, they have the potential to play an important role in oil sands mine reclamation efforts.

Native willow clones randomly collected from the wild were tested for tolerance to dilutions of OSPW using aeroponics chambers in a greenhouse. Fifteen of the most tolerant of these clones were selected for a field trial to determine if they are also tolerant to in-situ conditions along the shoreline of an end-pit lake containing OSPW. Dormant seedlings grown from cuttings in containers, hardened off and cold stored were planted in the spring of 2014 at the edge (position 0) of the end-pit lake and 30, 60, 120 and 240 centimeters up the slope. Seedling survival, stem length and diameter, and environmental conditions (e.g. soil and water chemistry) were assessed at the end of the 2014 and 2015 growing season.

Seedling survival at the end of the 2014 and 2015 was 94% and 93% respectively. Of the seedlings that died in 2014, only one was located in the at the water’s edge (position 0). Average October exchangeable sodium concentrations in the 0-15 cm soil horizon at the 0, 60, 120 and 240 planting positions respectively was 990, 535, 390 and 380 mg/kg in 2014 and 1565, 1030, 860, 650 mg/kg in 2015. Stem length increment in 2014 season ranged from an average of 20 to 140 centimeters depending on the clone and slope position.

Based on the survival and growth results to date, OSPW in the rooting zone as represented by exchangeable sodium concentration did not impact survival and growth of the selected willows. This suggests that willows identified as tolerant to OSPW in the greenhouse trial are suitable for reclamation of salt impacted sites under field conditions.

Key words: Oil sands, end-pit lake, salt, reclamation, process-affected water.

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CHARACTERIZATION OF PM$_{2.5}$-BOUND POLYCYCLIC AROMATIC HYDROCARBONS AND ITS ABSORPTION BY POPULUS TOMENTOSA LEAVES IN THREE PLACES OF BEIJING

Chao Liu$^1$, Hailong An$^1$, Huihong Guo$^1$, Xinli Xia$^1$ and Weilun Yin$^1$

To study the correlation between the accumulation of PAHs in leaves and PM$_{2.5}$-bound PAHs concentrations, we quantified 15 kinds of polycyclic aromatic hydrocarbons (PAHs) in PM$_{2.5}$ and Populus tomentosa leaves at three sites in Beijing in 2015 non-heating period by gas chromatography-mass spectrometry (GC-MS).

The total 15 PAHs concentrations ($\sum$PAHs) in PM$_{2.5}$ were in the range of 8.14-84.58 ng/m$^3$ with an average of 31.95 ng/m$^3$ for the three sites, showing Yufa (YF) > Yanqing (YQ) > Xizhimen (XZM). The predominant PAHs in PM$_{2.5}$ were 4, 5 and 6-rings compounds. Among these compounds, BaA, Chr, BbF, BaP, IcdP and BghiP in PM$_{2.5}$ were abundant for the three sites, accounting for 64.78%-71.79% of $\sum$PAHs in PM$_{2.5}$. The mean concentrations of combustion-derived PAHs in PM$_{2.5}$ at the three sites were in the range of 18.66-38.48 ng/m$^3$ accounting for 77.37-84.87% of $\sum$PAHs in PM$_{2.5}$, indicating the leading contribution of combustion sources. Results obtained from principal component analysis (PCA) and diagnostic ratios indicated that coal combustion, vehicle emission, wood combustion and industrial processes are the main sources for PAHs in PM$_{2.5}$ in Beijing. Besides, long-range transport could contribute to the PAHs burden in the atmosphere, particularly in the southern region of Beijing (Yufa). According to concentrations of carcinogenic PAHs and BaP in PM$_{2.5}$, the potential health risk of PAHs in PM$_{2.5}$ in Beijing district should be paid attention by the local government.

Fourteen PAHs were detected in Populus tomentosa leaves, and the 3-ring PAHs were dominated, particularly for Phe. The selected five PM$_{2.5}$-bound PAHs (BbF, BkF, BaP, IcdP, and BghiP) were accumulatively absorbed by Populus tomentosa leaves, suggesting that trees can reduce the harm of PM$_{2.5}$-bound PAHs through sucking up the carcinogenic PAHs.

We would use Populus tomentosa leaves as airborne PAHs biomonitor, and pay more attention on the research of PM$_{2.5}$-bound PAHs purifying in trees.

**Key words**: PM$_{2.5}$; polycyclic aromatic hydrocarbons; Beijing; Populus tomentosa.
THE EFFECTIVENESS OF POPLAR AND WILLOW TREES IN REDUCING EROSION ON PASTORAL SLOPES IN NEW ZEALAND

Ian McIvor¹, Kerry Clarke¹ and Grant Douglas²

On the 25 April 2011 a severe storm hit parts of coastal Hawke’s Bay, resulting in major slipping, infrastructure damage, and stock and pasture losses. The effectiveness of soil conservation plantings of poplar and willow in reducing slipping in the affected areas was evaluated during the period January–May 2013. Eleven of the farms that suffered severe slipping were visited. For each farm, sites with trees (either poplars, willows or a mix) and comparable sites without trees were identified from aerial maps. The sites were visited and mapped for slipping, tree spacing and distance of slips from the nearest tree. Other data collected were aspect of the site, mean slope, number of trees, species of tree and tree size (trunk diameter). Calculations were made of the area of protection extended by the trees and the effectiveness of the conservation trees was linked with tree size, tree species, and tree spacing.

Data were collected from 86 sites with trees (treed sites) and 25 sites with pasture only (control sites). The pasture only sites were close to a treed site. Numbers of trees at treed sites were usually between 3 and 8, but ranged from 1 to 14.

Slipping was reduced by 78% on treed sites compared with control sites. Mature plantings of groups of both poplar and willow reduced slipping within a zone of ~10 m of the trees to almost zero. Where plantings had a mean DBH of <20 cm, their effectiveness was reduced dependent on spacing. For trees with a mean DBH of ~10 cm effectiveness was negligible regardless of spacing. Despite this, trees with DBH of ≥10 cm were generally able to withstand shallow slipping without being totally dislodged. Where trees were planted in gullies the same criteria applied for their effectiveness in halting the advancement of the gully upslope.

The findings strongly suggest that below a particular tree size (DBH of ~10 cm), spacing matters little since the roots are not sufficiently developed to resist the downward movement of saturated soil. However, as the trees grow their effectiveness is enhanced by their size (increase in root thickness and root distribution), and by their spacing (the intermeshing with root networks of adjacent trees, particularly the weaker extremities). The effectiveness of the trees in reducing erosion is increased when more trees are present.

Key words: Slope, erosion, tree size, effectiveness.

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POPLAR AND BLACK LOCUST YIELDS FROM SHORT-ROTATION COPPICE HEDGEROWS IN AN ALLEY CROPPING SYSTEM

J. Mirck¹, M. Kanzler¹, Christian Boehm¹ and Dirk Freese¹

Agroforestry (AF), i.e. the integration of trees with annual crop or livestock production, offers a pathway to diversifying agricultural products. Agroforestry systems have the potential to concurrently produce traditional agricultural crops and other products such as energy crops, high value timber or fruits and nuts. In addition, the combination of crops and trees is known to contribute to the control of wind and water erosion, water conservation, carbon sequestration, and increased biodiversity.

More knowledge is required on the productivity and the potentials for product diversification of AF systems under temperate conditions. Very little is known though about the behaviour and yield potentials of fast-growing woody species such as poplar and black locust when grown as short-rotation coppice systems within Alley Cropping Systems in Temperate Regions. This study has the objective to assess poplar and black locust yields during their first rotation when grown within tree hedgerows.

Data presented will come from a 70 ha alley cropping system consisting of black locust (*Robinia pseudoacacia* L.) and hybrid poplar Max1 (*Populus suaveolens* subsp. *maximoviczii* x *P. nigra*). The experimental site was planted in 2010 and the poplars were replanted in 2011. The system consists of seven tree hedgerows that are 11 m wide (four double rows) and 600 m long. The distance between the tree hedgerows varies between 24, 48 and 96 m. The alley cropping system concurrently produces a woody biomass feedstock and conventional agricultural crops.

Prior to the mechanical harvest of the first rotation allometric equations were established between diameter at 10 cm above the ground and harvested biomass for both poplar and black locust on 2 February 2015. For improved yield assessments both the border rows and the two centre rows were assessed separately and treated as separate growth forms using separate allometric equations. These allometric equations were used to calculate yields for the five growth years for black locust and four years for poplar. Average tree yields ranged between 7.2 and 9.3 Mg ha⁻¹ yr⁻¹ for black locust and 6.6 and 8.5 Mg ha⁻¹ yr⁻¹ for poplar. Maximum annual growth was measured during year 3 and 4 for black locust. Poplar did not seem to have reached its maximum annual growth yet within the 4-year rotation.

**Key words:** Agroforestry, biomass, *Populus*, *Robinia*, sustainable farming.

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Both the reuse of water resources and the generation of forests is a global challenge, especially with respect to mitigation of climate change and the preservation of water sources for human consumption, especially in desert areas. In Argentina there are successful experiences which have been afforested with different species. As an example, in Mendoza, province bordering San Juan, they have created large areas of irrigation with treated wastewater reuse “Growing Areas Restricted Special”; it has led to the modification of the provincial legislation 10 years ago. The province of San Juan, located in western Argentina, does not have this kind of experience nowadays, however, the following initiatives stand out: in 2014 the SSDFI organized the workshop "Potential of wastewater for irrigation in forest plantations use". This event was attended by national and local government officials, representatives of several national universities and public institutions belonging to National System of Innovation and private sector actors; in early 2015 INTI, San Juan Center, worked on the institutional linkage with SSDFI to submit a technological development project to be funded by the National Forest Act. At that time SSDFI and INTI join the initiative, also calling on the Government of San Juan as a strategic partner. From these initiatives the MAR Project arises, “Reuse of Municipal Wastewater for Generating Timber Species”. This project aims to implement a forest cultivation of poplars and irrigate it down with municipal sewage waters, in order to supply the unmet local and regional demand for wood. This need is based primarily on the limited availability of water resources as San Juan is characterized by a desert climate. Value chain wood industry should also be strengthened and at the same time provide solutions to environmental, productive and social problems, according to the reality of this province and its available resources.

Methods: MAR Project was outlined, then formulated in its technological, environmental, economic, financial, social and institutional aspects and submitted to several calls for national and international funding. Its implementation began in late 2015.

Results: the project is in its first year of implementation. The technical milestones are: (a) first year: construction of the environmental baseline, engineering project for irrigation and implementation of the system in 10 has (10 %); (b) second year: additional 10 ha to complete the planting of 100 has in 10 years. Moreover INTI proposed to the SSDFI the formation of an international consortium to work on the issue “Sustainable Wastewater Reuse For Generation of Timber Species for Industrial and Environmental Applications” integrated in principle by Argentina, Spain and Uruguay. In adherence to this proposed SSDFI summoned to Italy. Finally Germany and the Dominican Republic joined. The project built jointly was submitted (SUSWATER) to the call ERANet-LAC 2016.

Conclusions: it is critical to consolidate and promote institutional linkages of the executing team in the framework of the development of this project, as well as to be able to gather funding for each of the proposed stages.

Key words: Poplars, wastewater reuse.

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PHYTOREMEDICATION OF RIVER SEDIMENTS WITH THE USE OF POPLARS AND WILLOWS

Andrej Pilipović¹, Saša Orlović¹, Srdan Rončević², Nataša Nikolić², Marina Katanić¹, Danijela Arsenov² and Jelena Spasojević²

Water contamination presents one of the most significant environmental threats to the environment. In Serbia, 3.5 million m³ of wastewater is discharged every day causing decrease of the water quality in most of the watercourses. According to the estimations, about 2,000,000 m³ of sediment needs dredging, some of which must be treated. Due to the large amount of sediments and huge cost of conventional remediation, phytoremediation can present good alternative.

Poplars and willows present most often woody tree species used for phytoremediation in the northern hemisphere. This research included investigation of the possibility of application of dredged river sediment on poplars and willows used for biomass production.

The greenhouse experiment included one willow (Salix viminalis) clone SV068 and poplar (Populus deltoides) clone “Bora” were grown as pot experiment for two years and treated with different amounts of sediments (0 kg, 0.5 kg and 1 kg per pot). Dredged sediment was classified as class 4 (highly polluted) with high amounts of Cu (295 ppm) and Cr (400 ppm). During growth of plants, gas exchange and nitrate reductase activity measurements were performed, while after each year aboveground parts of plants were harvested and weighted. Results showed that there was no effect of sediment application both on growth and physiological parameters during the first, while in the second year aboveground biomass of treated poplars was greater than in control plants. Gas exchange measurements showed no change in photosynthetic activity of investigated plants, but the water use efficiency (WUE) of treated poplars was increased in the second year. Enzymatic activity of nitrate reductase was decreased in treated poplars in both years, while in willows decrease was more evident in year 2.

Results indicate that, in general, applied amounts of sediment did not affected treated plants to the greater extent and that investigated clones have the potential for use in phytoremediation of river sediments.

Key words: Poplar, willow, phytoremediation, sediment, biomass, photosynthesis.

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PERENNIAL energy crops could contribute considerably to energy security and biodiversity of the agricultural landscape. However, they also have an impact on resource use, in particular water. LUCASS (Light Use and Carbon Allocation in Salix Species) is a new process-based model, developed at Rothamsted Research, UK, which simulates biomass accumulation and water balance in short-rotation coppice (SRC) willow.

The model was calibrated for four commercially available SRC willow genotypes with different growth strategies, characterised mainly by large (Endurance, Terra Nova) and small canopies (Resolution, Tora). Experiments were evaluated in Wales (Institute of Biological Environmental and Rural Sciences, rainfall 1038 mm/year), in south-east England (Rothamsted Research, rainfall 747 mm/year), and in south-west England (Long Ashton, rainfall 854 mm/year).

The results in these three environments showed that broad-leaved phenotypes tend to produce less biomass than narrow-leaved phenotypes under drought (e.g. in the south-east of England). Water uptake data and modelling confirmed the difference between phenotypes in terms of water use efficiency. We will present results for the model upscaled for different regions in the United Kingdom, which are characterised by contrasting precipitation and soil water availability. Estimated water use and potential yields of different phenotypes should enable farmers to choose the most appropriate variety.

**Key words:** Drought, LUCASS, potential yield, *Salix* spp., water use efficiency.

**Funding support:** Institute Strategic Program Grant “Cropping Carbon”
EARLY CLIMATIC BENEFITS OF SALICACEAE PLANTATIONS ON ABANDONED ARABLE LAND

Rose-Marie Rytter¹, Lars Rytter² and Lars Högbo³

Atmospheric carbon dioxide (CO₂) concentrations have increased by ca 40% since pre-industrial time and the effect on global climate is evident. Human impact is attributed primarily to fossil fuel combustion and secondarily to land use emissions. Fossil energy sources thus need to be replaced by alternatives with no or low net CO₂ emissions. Fast-growing plantations with Salicaceae on former arable land can provide renewable bioenergy and also sequester carbon (C) in perennial biomass and soil. Arable soils have been a long-term source of CO₂ and up to 25-50% of the soil organic carbon (SOC) pools have been lost. Afforestation implies a potential to regain the SOC pools to their original levels and by using abandoned arable land for bioenergy plantations compromising with food production could be avoided. However, there are still uncertainties concerning effects on C stocks and particularly on SOC pools at land use changes (LUC).

The potential C sequestration in Salicaceae plantations on 400 000 ha of abandoned arable land in Sweden has been calculated to 1.7 Tg C y⁻¹ in biomass and soil over the first 20-22 years. However, C sequestration rates may depend on several factors like species, former land use, soil properties and climate. In 2009, fast-growing tree species were planted on five former arable sites at different latitudes in Sweden in order to increase our knowledge concerning production potentials and effects of LUC on C sequestration rates and SOC pools. The sites comprised a total area of 20 ha and included six different tree species, amongst them: willow, poplar and hybrid aspen. There were four replications of each species at each site and planting densities were 1 500 plants ha⁻¹ for poplar and hybrid aspen, and 14 800 plants ha⁻¹ for willow. Cultivation practices involved no thinning measures and no fertilization or irrigation. The SOC pools were estimated by repeated core sampling.

Changes in total standing C stocks were estimated prior to planting and after five years in the Salicaceae plantations. The general results showed that the plantations constituted C sinks after five years. Total standing C stocks, i.e. C in woody biomass above- and belowground, fine roots, litter and SOC, had increased with 13 Mg ha⁻¹ or 15% on average compared to pre-planting conditions in the willow plantations. Approximately 10 Mg C ha⁻¹ was bound in aboveground woody biomass and the rest in belowground biomass, litter and soil. The SOC-pool was unchanged for all species at all sites, except for a decrease at one willow site. However, the decrease was compensated by C stored in woody biomass, fine root standing crop and litter. After removal of stem biomass, C in other plant pools was sufficient to compensate for the SOC decrease. If 400 000 ha of available abandoned arable land in Sweden were used for willow plantations an annual sequestration of 1.0 Tg C could be reached already during the first five years. Corresponding estimates of early C sequestration rates in poplar and hybrid aspen plantations were less, 0.2-0.3 Tg C y⁻¹, primarily due to lower standing biomass. The conclusion was that Salicaceae plantations, in addition to future fossil fuel substitution, may provide an early climatic benefit when planted on abandoned arable land.

Key words: Afforestation, carbon sequestration, land use changes, Salicaceae, SOC.

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The development of the Tehran megalopolis towards large-scale urbanization and industrialization is leading to the production of huge quantities of industrial and municipal wastewater. Use of the municipal wastewater to agricultural lands for irrigation purposes creates problems such as entrance of heavy metals to food chain. So, establishment of fast-growing trees (poplars) following municipal wastewater irrigation is a suitable option for wood farming.

In this study, survival and growth parameters of *Populus nigra* trees irrigated with municipal wastewater in south of Tehran, Iran were investigated. For this purpose, two poplar stands (each with an area of two hectares and trees spacing 1.5×2m) situated in Dehkhey and Zamanabad Villages and one poplar stand (with an area of two hectares and tree spacing 1.5×1m) located in Ghaleno village were selected. In each poplar stand, 27 trees in 3 groups (3×3) were chosen using technique of systematic random sampling. At the end of growth period, survival, diameter at breast height and height parameters were measured and height growth computed. The average survival rate of poplars at three stands was 97%. The average of diameter, height and height growth of poplar trees in stand 1 (Dehkhey Village), stand 2 (Zamanabad village) and stand 3 (Ghaleno village) were respectively 2.5cm, 3.85m, 0.838m; 2.57cm, 3.72m, 0.695m; 2.41cm, 4.22m, 1.23m.

The results of this study demonstrated that poplar trees irrigated with municipal wastewater had acceptable growth in comparison of poplar trees irrigated with fresh water in the studied area. As regards lack of water resources, municipal wastewater can be used as an important source for providing required water of wood farming, especially in megalopolises of Iran.

**Key words:** Growth, municipal effluent, *Populus nigra*, Tehran, wood farming.

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LEAD TOLERANCE OF *POPULUS ALBA* AND *POPULUS NIGRA* CLONES INOCULATED WITH ARBUSCULAR MYCORRHIZAL FUNGI IN RELATION TO PHYSIOLOGICAL PARAMETERS

Azadeh Salehi¹, Masoud Tabari Kouchaksaraei², Ebrahim Mohammadi Goltapeh³ and Anoushirvan Shirvani⁴

Physiological responses of *P. nigra* 62/154 and *P. alba* 44/9 clones inoculated with mycorrhizal fungi to lead stress were investigated. The experiment was carried out as a factorial randomized complete scheme with two factors: (i) mycorrhizal fungus in 4 levels (control, *Glomus mosseae*, *G. intraradices* and *G. mosseae x G. intraradices*) and (ii) lead in 4 levels (0, 100, 500 and 1000 mg kg⁻¹) in a greenhouse for a 6-month growth period.

The results showed that at all Pb levels, root mycorrhizal colonization of two clones in fungal treatments was significantly higher than control treatment (without fungal inoculation), however without significant differences between 3 fungal treatments. In *P. alba* clone, the root mycorrhizal colonization percentage was significantly reduced by application of 1000 mg Pb kg⁻¹ in mycorrhizal and non-mycorrhizal plants. Also, in 1000 mg Pb kg⁻¹ concentration, significant reductions were observed in photosynthesis, stomatal conductance and transpiration of non-mycorrhizal plants, but the same did not observe in mycorrhizal plants. However, intercellular CO₂ concentration and water use efficiency of mycorrhizal and non-mycorrhizal plants were not different. In contrast, in *P. nigra* clone, Pb treatments had no effect on mycorrhizal colonization percentage and physiological parameters of mycorrhizal and non-mycorrhizal plants. At all Pb treatments, mycorrhizal and non-mycorrhizal plants of *P. nigra* clone had greater root mycorrhizal colonization, photosynthesis and transpiration than *P. alba* clone.

The results of the present study demonstrated that in relation to physiological parameters, *P. nigra* clone was more Pb-tolerent than *P. alba* clone. In contrast, inoculation with mycorrhizal fungi improved physiological parameters in *P. alba* clone.

**Key words**: Heavy metal, mycorrhizal colonization, photosynthesis, poplar.

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FULL LCA OF POPLAR SRC CONSIDERING ENVIRONMENTAL IMPACTS ON A MARGINAL SITE IN SOUTHWEST GERMANY

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By avoiding competition with classical agricultural production marginal land is economically and environmentally highly attractive for biomass production with short-rotations coppices (SRC) of fast-growing tree species such as poplars.

The quantification of carbon sequestration and the comparable evaluation of potential environmental impacts are based on studies using the LCA method (Life Cycle Analysis). So far, studies either focused on the evaluation of the environmental impacts of technological processes of energy wood production and supply chains, or on the evaluation of the environmental impacts of soil- and plant biological processes. Within the present study we aimed at evaluating the environmental impacts of both technical and biological aspects.

We applied a holistic LCA as a methodological framework considering different management regimes of poplar SRC on marginal land within its 21 years lifetime. Two alternative harvesting rotation cycles were analysed (7x3 and 3x7 years) as well as seven different variants of nitrogen fertilizer treatments, resulting in LCA-based evaluations of 14 different production chains. We took into account all processes associated with the cultivation of poplar SRC and the subsequent production of heat from wood chips starting with (i) initial site preparation, (ii) cultivation and repeated harvestings, (iii) chipping and heat production, and (iv) site restoration. Additionally we incorporated important soil- and plant biological processes (photosynthesis, ecosystem respiration, N\(_2\)O- und CH\(_4\)-fluxes, C- and N-household in the soil, etc.) and their environmental impacts. Model calculations were supported and validated by field data obtained from measurements during a 4-year period on a 4.5 ha poplar SRC in southwest Germany. These data were completed by biochemical and microbiological laboratory analyses, working time studies and by data taken from professional databases (e.g., Ecoinvent).

The results clearly demonstrated that the biomass yield was higher in the longer rotation cycle and in tendency increased with increasing rates of fertilization. However, the supply of fertilizer strongly influenced potential environmental impacts, in particular the eutrophication category due to significant increases in NO\(_3\) leaching and increased emissions of N\(_2\)O an important greenhouse gas. In the global warming category, results

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ranged between 17-68 kg CO\textsubscript{2}-eq.GJ\textsuperscript{-1} (22-84 kg CO\textsubscript{2}-eq.ha\textsuperscript{-1}) depending on the production chain. A 7-year rotation cycle of poplar SRC on marginal land without any fertilization would lead to a CO\textsubscript{2}-saving potential of around 114 t CO\textsubscript{2}-eq.ha\textsuperscript{-1} when produced wood chips were used to substitute an oil heating. It turned out that the biological aspects were responsible for ca. 90% of all potential impacts while it was 10% for the technical aspects.

**Key words:** Technological and biological impacts, ammonium nitrate fertilization, ecosystem respiration, GWP, EP, nitrate leaching, GHG emission, poplar SRC, LandscapeDNDC, DIN En ISO 14040-44.

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POPLAR FOR ENVIRONMENTAL RESTORATION: PHYSIOLOGICAL AND MOLECULAR APPROACHES FOR HEAVY METAL AND ORGANIC MOLECULES

Luca Sebastiani

Poplar trees have been studied in phytoremediation approaches to clean up soil or water polluted by organic and inorganic compounds. This species is known both for the ability to uptake and to stabilise several contaminants into its organs/tissues, thus reducing their mobility and concentrations in the soil profile and water.

Compared to other plant species, poplar trees have several advantageous characteristics: deeper root system, higher transpiration activity, and productivity. Moreover, biomass is economically valuable both for wood and bioenergy production. Since the availability of the genome sequence of *Populus trichocarpa* and the development of high throughput technologies, poplar has also emerged as the model system for tree biology studies.

In this talk, we will report our fifteen years experiences and approaches followed for studying poplar physiology under heavy metals (Zinc and Cadmium) and organic molecules (caffeine and erythromycin) pollution. Results from genomic, epigenetic, proteomic and transgenic studies applied on *Populus* spp. will be presented and discussed considering that deeper physiological and molecular information are key factors for improving poplar trees with traits conferring tolerance to contaminants.

**Key words:** Leaf, poplar, remediation, root, pollution.

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STUDY OF PHYSIOLOGICAL RESPONSES OF TWO POPLAR CLONES 
(Populus euramericana 561.41 and P. nigra 63.135) TO 
PB CONTAMINATED SOILS

M. Tabari Kouchaksaraei¹, A. S. Emami², N. Bahramifar³ and A. Salehi⁴

Lead tolerance of *Populus euramericana* 561.41 and *Populus nigra* 63.135 clones to high lead concentrations (0, 500 and 1000 mg Pb kg⁻¹ soil) in relation to some of physiological properties was investigated as a completely randomized design for 4 months. Physiological parameters were measured by standard methods.

The results showed that with increasing of Pb concentration in soil, net photosynthesis and transpiration of two clones were significantly decreased. The highest of total chlorophyll content of *P. euramericana* and *P. nigra* was observed in 500 and 1000 mg kg⁻¹ Pb concentrations, respectively. With increasing of Pb concentration in soil, the content of carotenoid, proline, malondialdehyde (MDA) and electrolyte leakage were significantly increased. Comparison of two clones demonstrated that in 500 mg kg⁻¹ Pb concentration, the total chlorophyll and in 1000 mg kg⁻¹ Pb concentration, carotenoid content of *P. euramericana* were greater than *P. nigra*. However, in 500 mg kg⁻¹ Pb concentration, MDA and electrolyte leakage content of *P. nigra* were greater than *P. euramericana*. Also, in 500 and 1000 mg kg⁻¹ Pb concentrations, net photosynthesis and transpiration of *P. euramericana* were higher than *P. nigra*. In contrast, no significant difference was observed between two clones with regard to proline content.

The results of the present study demonstrated that in relation to physiological properties, *P. euramericana* clone was more Pb-tolerant than *P. nigra* clone.

**Key words:** Chlorophyll, lead, *Populus*, photosynthesis, proline.

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RESPONSE OF FLOODED WEEPING WILLOW SEEDLINGS TO ZINC HEAVY METAL

Masoud Tabari¹, Azemat Hosseni¹ and Seyed Ehsan Sadati²

This study seeks to answer the question whether weeping willow (Salix babylonica L.) seedlings grow in flooded areas and are affected by the concentration of heavy metals, e.g. zinc (Zn). For this purpose, the seedlings were exposed to controlled flood-conditions at five different levels of zinc concentration (0, 100, 1000, 1500 and 2000 µm) for 120 days.

Seedling survival in all Zn concentrations was 100%. With the increase of Zn concentration, diameter growth, leaf area, specific leaf area of seedlings did not change, but at most Zn levels, shoot growth, leaf dry biomass and total dry biomass decreased. In each Zn treatment, Zn concentration was greater in roots than in shoots. The highest translocation factor (0/59) was observed at the 1000 µm concentration level. The tolerance index of shoot and root in higher Zn concentrations was > 90%. In view of a survival rate of 100%, good growth and a high tolerance index of seedlings, it can be stated that in flooded environments this species has a high ability for filtering Zn-contaminated soils until a concentration level of 2000 µm.

Thus, we recommend the ability of phytoremediation of the flooded seedlings of weeping willows at higher Zn concentrations, as well as the capacity of its root system for filtering and remediating polluted soil and water as a consequence of industrial and agricultural activities. Likewise, plantations of weeping willows appear suitable to be used for the greening of urban spaces, the restoration of coasts, plateaus, river margins and flooded environments that are polluted by high zinc concentrations.

Key words: Heavy metal, flooding, Salix babylonica, Tolerance Index, Translocation Factor.

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USING NATIVE BALSAM POPLAR (Poplar balsamifera) FOR RECLAMATION IN THE OIL SANDS REGION OF NORTH-EASTERN ALBERTA, CANADA

B.R. Thomas¹ and D.P. Kamelchuk²

Over a 2-year period, more than 150 clones of balsam poplar from a tree improvement programme were screened, in a greenhouse trial, for salt tolerance using bitumen extraction process affected water (PAW). From these screened clones, a total of 25 were selected based on superior performance from the high (50% PAW) treatment and considered ‘salt tolerant’ while another 10 clones were selected from the control group and considered to have ‘low salt tolerance’.

In October 2014, rooted cuttings from three treatment groups were identified (high salt tolerance (Treatment 1), low salt tolerance (Treatment 2), and a locally collected wild population of balsam poplar (Treatment 3)) and planted at the edge of a water extraction holding lake at the Syncrude mine site. While moving away from the lake edge, there were three blocks installed with a total of 200 trees per block in single tree plots.

Preliminary results will be presented showing the initial response differences between each Treatment group at various distances from the lake shore edge. Early indications suggest that individual clones rather than Treatment groups may be more advantages in addressing reclamation on challenging sites.

Key words: Reclamation, balsam poplar, salt tolerance.

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WILLOW AFFORESTATION FOR QUARRY REHABILITATION IN RIO NEGRO VALLEY, ARGENTINA

Esteban Thomas¹, Francisco Pili², Eduardo Pili² and Teresa Cerrillo³

A quarry is a type of open pit mine used to obtain building materials (construction aggregate, riprap, sand and gravel) and stones. This form of mining contributes to deforestation and soil degradation, causing impact on the environment. In Cervantes, Rio Negro, Argentina (39°04’09”S; 67°24’06”W) there is a case of degraded site because of quarrying. The low annual rainfall and strong windy conditions of the region are great challenges to the restoration of the ecosystem, and the forest can be useful for this purpose. Remediation strategies using tree species adapted to these soil conditions are considered valuable methods in these kinds of cases.

In order to obtain information in the site, a rehabilitation experience using willow plantations is being developed by a private local company in collaboration with the Instituto Nacional de Tecnología Agropecuaria (INTA), an official research institution. When open-pit mining was finished, a willow plantation was established in quarry site. At a first stage, 0.26 ha was established on August 2015. Density plantation was 400 trees/ha¹ (5m x 5m), planning a future silvopastoral management. The method used is known as “Deep-planting technique”, with the aim that willow material can be in contact with water table. Consequently, this practice is important when the water table depth is about 1.0m -1.5m. The willow clones tested were S. matsudana x S. alba `Los Arroyos INTA-CIEF’, S. matsudana x S. alba `Agronales INTA-CIEF’ and S. matsudana x Géminis INTA-CIEF’, from the Breeding Programme of INTA, which is being developed in EEA Delta del Paraná.

After the first period of vegetative growth, very high survival of all clone could be observed, `Géminis INTA-CIEF’: 100%, `Agronales INTA-CIEF’: 97.3% and `Los Arroyos INTA-CIEF’: 95.2%. Despite the early age of this plantation, the results already provide useful information about their rooting capacity and survival in these site conditions. Planting will continue to be evaluated in order to achieve a complete characterization of the clones on this trait of environmental interest.

Key words: Willows, clones, selection, quarrying, rehabilitation, Patagonia Argentina.

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USE OF TREATED WASTEWATER IN FOREST PLANTATIONS IN NORTH PATAGONIA, ARGENTINA

Clelia Tucat¹, Sergio Romagnoli², Esteban Thomas² and Teresa Cerrillo³

The re-use of urban treated wastewater for irrigation of forest is a valuable tool in order to prevent spills to rivers and lakes and, in this way, preserve environmental quality. As in other regions of the world, the Waste Stabilization Ponds (WSPs) system of sewage treatment is widely used in some Northern Patagonian cities.

In order to study different materials for this purpose, a trial was planted in Rincon de los Sauces, Neuquén, Argentina (37°24′25″S; 68°54′35″W). A randomized complete block was applied, with ten-tree linear plots and twenty replications for each treatment: *Salix matsudana* x *S. alba* ‘Los Arroyos INTA-CIEF’ (T1), *Salix matsudana* x *S. alba* “94.13.06” (T2), *Populus* x *canescens* (T3) and *Eleagnus angustifolia* (T4). Unrooted cuttings - 0.5m length - were planted in August 2011, with a spacing of 1.5 m x 0.5 m, and an initial density of 13.333 trees/ha.

At the end of the first year, survival rate and total height (Ht) of all treatments were measured. Willow clones showed the best values of survival (T2: 98%; T1: 97%) and height growth (T1: have reached 3.7m of mean total height and T2: 3.5m), followed by *Populus* x *canescens* (85%; 2.8m) and *Eleagnus angustifolia* (57.5%; 1.9m).

The great performance of willow clones in this initial stage evidences a very good perspective to short-rotation forestry (SRF) irrigated with urban wastewater, offering two important benefits: from an environmental perspective, a complementary treatment to improve their quality, and from an economic perspective, the opportunity to obtain a forestry product with increasing commercial demand.

**Key words**: Willows, poplars, forest irrigation, wastewater.

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ESTABLISHMENT OF HYBRID POPLAR FOR SURFACE MINE RECLAMATION IN THE SOUTHERN COALFIELD OF WEST VIRGINIA, USA

Ronald S. Zalesny Jr.¹, Amir Hass² and Dharmesh Patel³

Short-rotation woody crop (SRWC) production systems grown on marginal and disturbed lands that are otherwise not suitable for agriculture could diminish competition for the agriculture land base and other resources (e.g., water). In such cases, productive land inventory is increased and excess surface runoff associated with reclaimed mine lands is mitigated. Additionally, overall acreage of land associated with food production is maintained. The southern coalfield of West Virginia, USA is a primary example of such lands, where post-mining land use (PMLU) often leads to degradation of essential ecosystem services (e.g., water quantity and quality). Incorporating SRWC systems as a viable PMLU alternative increases the potential for biomass production and restoration of natural resources. Similarly, SRWCs may provide an economic stimulus to revitalize local economies, counterbalancing the financial impact of the declining coal industry.

To address these needs, we used phyto-recurrent selection to establish hybrid poplar biomass production farms on surface-mined lands in the southern coalfield of West Virginia. In particular, a large-scale mine reclamation study was established in 2014 at the Four-Mile Surface Mine near Charleston, West Virginia (38.2 °N, 81.7 °W) using 60 different hybrid poplar genotypes belonging to seven genomic groups (phyto-recurrent selection cycle 1). After the first growing season (126 days after planting), clonal survival ranged from 19 to 100%, that of genomic groups ranged from 56 to 100%, and stand-level mean survival was 75%. On average, height and diameter were nearly six times greater for the six most-productive genotypes relative to their least-productive counterparts. Height ranged from 6.6 cm [(P. trichocarpa × P. deltoides) × P. deltoides ‘NC13470’] to 38.3 cm (P. nigra × P. suaveolens subsp. maximowiczii ‘NM2’) and the stand-level mean was 23.1 cm, while diameter went from 0.6 mm (‘NC13470’) to 3.6 mm (‘NM2’) with a mean of 2.3 mm. In May 2015, cycle 2 was established, consisting of 32 of the original 60 genotypes.

Those data are currently being summarized and will be presented at the conference. Results from both growing seasons will be integrated to evaluate provisioning (i.e., biomass) and supporting (i.e., water) ecosystem services during the early stages of surface mine reclamation.

Key words: Biomass productivity, ecosystem services, phytotechnologies, Populus, post mining land use, forest restoration, short rotation woody crops, water quantity and quality.

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MITIGATING NONPOINT SOURCE POLLUTION IMPACTS ON NEARSHORE HEALTH IN THE GREAT LAKES BASIN, USA

Ronald S. Zalesny Jr., Joel G. Burken, Richard A. Hallett and Adam H. Wiese

Population growth and associated industrial and urban development in the last 50 years have had a large negative impact on water quality of the United States Great Lakes and their watersheds. Closed landfills contribute to nonpoint source pollution via runoff and leakage resulting in negative impacts on water quality and have related impacts on ecosystems and human health. Consequently, biological systems are needed that remediate these sites. Short-rotation woody crops such as poplars and willows are ideal for phytoremediation systems given their fast growth, extensive root systems, and hydraulic control potential as they translate wind and solar energy to groundwater impacts. The extensive genetic variability of both genera allows for selection of varieties using climate-resiliency parameters, resulting in deployment of varieties that are appropriate for both current and projected local site conditions. In addition, USDA Forest Service researchers have developed phyto-recurrent selection, a tool for choosing generalist varieties that remediate a broad range of contaminants, or specialists that are matched to specific pollutants. The ability to select varieties across contaminants allows for broad applicability of these phytoremediation systems. While the science of phytoremediation has undergone rapid growth in the last two decades, uncertainty about the efficacy of using existing forests to remediate liability sites still lingers. Recent development and patenting of phytoforensic technologies (at the Missouri University of Science and Technology) helps to use plants as not only remediation, but also as site delineation for non-point source pollutants and as monitoring tools of remediation. Phytoforensics is the use of plant sampling as a way to detect and quantify pollutants in the environment around the plants.

Currently, we are establishing a watershed-level study to integrate phytoremediation potential of existing vegetation with phytoremediation buffer systems (i.e., poplars and willows) along the western shore of Lake Michigan. The “phyto buffers” will be used to facilitate the reduction of untreated runoff and leachate plumes from landfills in the Great Lakes basin and ultimately to mitigate nonpoint source pollution impacts on nearshore health. This project integrates soil hydrology, plant genetics, and ecophysiology with surface and subsurface water quality impaired by potential leakage of pollutants in these watersheds. In addition to improving water quality, our green tool will stabilize stream banks (through establishment of willows), increase forest cover (through planting of the phyto buffers), and restore ecosystems (through filtration and remediation of contaminants). Details about site selection and establishment will be presented at the conference. Overall this approach looks to use plants to concurrently detect, remediate and monitor fugitive pollutants as well as provide ecological services in adding robust vegetation.

Key words: Ecosystem services, landfill restoration, phytoforensics, phytoremediation, phytotechnologies, Populus, Salix, short-rotation woody crops, water quantity and quality.

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