21-24 October,2015 | Zhanjiang, Guangdong, CHINA

Scientific cultivation and green development
to enhance the sustainability of eucalypt plantations

Abstracts

IUFRO Eucalypt Conference 2015

October 2015

2015年桉树国际学术研讨会论文集

二〇一五年十月

Sponsorer

Host

Organizer

Co-organizer

PART Ⅰ Oral Presentations

PART Ⅱ Posters

PART Ⅰ
Oral Presentations

Current Situation and Development of *Eucalyptus* Research in China

Yaojian Xie

China Eucalypt Research Centre
30 Mid Renmin Avenue, Zhanjiang, Guangdong 524022, P.R. China
E-mail: cercxieyj@163.com

Oral Presentation

Eucalyptus species were first introduced to China sometime in the 1890s, initially for use in ornamental and amenity plantings. Though the country's first formal eucalypt plantations were established in about 1935, it was not until the 1950s that large-scale eucalypt plantation programs began, the first of which were here in Zhanjiang in south-western Guangdong.

Large-scale expansion of eucalypt plantations through southern China started in earnest in the 1980s, and by 1986 China's eucalypt plantation resource totaled around 0.46 M ha. Since then, genetic gains from tree improvement, advances in silviculture, buoyant and increasing demands for forest products and favorable government policies have worked together to foster rapid expansion of this resource. Today China's eucalypt plantations exceed 4.4 M ha, and the country ranks third for total eucalypt plantation area, after India and Brazil.

Eucalypts are now grown in over 600 counties of 11 provinces of southern China, on sites ranging in latitude from 18^0 to 32^0 N, longitude 100^0 to 122^0 E and altitudes of up to 2000 m asl or more. However, the two southern coastal provinces of Guangxi and Guangdong account for around 75% of the country's total eucalypt plantation area. The most commonly planted varieties in China are hybrids with over 50% of the total area being planted with *Eucalyptus urophylla* x *grandis* clones. Also of major importance here in China, as either pure species or hybrid parents, are *E. camaldulensis, E. tereticornis, E. globulus, E. maidenii, E. dunnii* and *E. smithii.*

China's eucalypt industry now comprises a complex, multi-faceted industrial chain including seedling propagation, fertilizer production and supply, plantation silviculture, harvesting and transport, wood processing for products including lumber, pulp and paper, and wood-based panels as well as bioenergy production and various forest by-products and non-wood forest products. In 2013, the combined output value of these eucalypt industries in China was around 300 billion RMB (US$49 billion).

Chinese research and development has been instrumental in supporting growth and development through the whole depth of the country's eucalypt industrial chain. In this report, recent progress in such eucalypt R&D is reviewed under six key topics: 1. Advanced propagation techniques; 2. Germplasm resources and breeding; 3. Targeted silviculture; 4. Maintenance of plantation health; 5. Enhancing eucalypt plantation ecology and sustainability; 6. Eucalypt wood processing and by-product technologies.

Research and development has greatly facilitated expansion and proliferation at all points of China's eucalypt industrial chain. As a result of this, this industry is now of major importance to China's economy with the complete chain involving tens of thousands of companies that provide livelihoods for hundreds of thousands of people.

Management of Forest Plantations under Abiotic and Biotic Stresses in a Perspective of Climate Change

José Leonardo de Moraes Gonçalves

USP, University of São Paulo, ESALQ, Forest Science Departament, Piracicaba, SP, Brazil, jlmgonca@usp.br

In any sustainably managed forest plantations, production and protection functions should be possible. The design and implementation of management techniques should therefore be adapted to the specific production and protection objectives, which depend on the regional and local edaphoclimatic circumstances, water resources management, and protection against soil erosion, diseases, pests and alien species. Climate abnormalities in recent years are putting stress on many forest plantations, owing to higher mean annual temperatures, altered rainfall patterns and more frequent and extreme weather events. Among the forest management measures that could take to facilitate climate change adaptation are the breeding of new genetic materials, implementing forest management practices that reduce vulnerability to both incremental climate change and extreme events such as storms and fires, undertaking *in-situ* and *ex-situ* conservation measures to protect water yield and biodiversity. The growing concern over water use by crops and the search for greater water efficiency has been compounded by the expansion of plantations in Brazil to areas with lower water availability. The afforestation of such areas leads to a decrease in catchment streamflow that is lower in absolute terms, as compared to more humid areas, but more severe to local water users. Simulations made by some researchers showed that in the short-rotation eucalypt plantation plus native forest scenario, the presence of native vegetation reduced the yield variation during plantation growth and the maximum rainy season flow was also reduced by approximately 20%. Clonal plantations with single species and interspecific hybrids have been fundamental for eucalypt adaptation. In general, mechanisms and processes that enable a plant to cope with periodic, severe, water deficit in the soil involve a tradeoff to the plant in terms of reduced growth potential. Species or hybrids exhibiting low drought tolerance produce a large number of medium and fine lateral roots in the surface soil horizons, but not a deep and strong tap root, and the root systems show a small response or do not respond at all to dry soils. This presentation is addressed to the basic requirements of forest plantation management under abiotic and biotic stresses in a perspective of climate change. Will be shown examples of principles and strategies that can be used in different tropical and subtropical regions of the world in order to minimize the water constraint in forest plantations and surrounding water and native vegetation resources.

Oral Presentation

Eucalypts, Carbon Mitigation and Water

Richard Harper[1], John Ruprecht[1], Keith Smettem[2], Daping Xu[3]

1 School of Veterinary and Life Sciences, Murdoch University, Murdoch, WA, Australia 6150
2 University of Western Australia, Nedlands, WA, Australia 6907
3 Research Institute of Tropical Forestry, Chinese Academy of Forestry, Guangzhou, China

There is considerable international interest in the role that forests can play in mitigating carbon emissions and thus contribute to global action to tackle climate change. Mitigation can occur through several pathways such as reducing rates of deforestation, increasing carbon stocks through afforestation or reforestation, managing carbon stocks in existing forests (forest management) or by substituting fossil fuel use through either the use of bioenergy or substituting high energy building products with timber.

A range of international, national and sub-national approaches have been or are being developed, with resultant payments for carbon mitigation in forests. Consequently, carbon mitigation may represent either a significant source of income, or a liability, for forest owners. Additionally, carbon mitigation might also be associated with co-benefits or tradeoffs, related to water, food and biodiversity resources. Some of these may be able to participate in other emerging environmental markets.

This paper will examine the contribution of eucalypts to the carbon mitigation agenda, using examples from both Australia and the countries where they have been planted on a commercial scale. In particular, it will consider the contribution to mitigation through avoided deforestation, afforestation/reforestation, forest management and bioenergy production and in particular approaches used to maximise co-benefits and avoid disbenefits particularly related to water supplies.

Oral Presentation

Effects of Forest Policy on Plantation Development

Hanmin Dong, Ph.D.

Founder of "China Forest Growers Association", China

China needs wood, a lot of it. The gap between wood demand and supply widens each year with the country's economic development. According to China's State Forestry Administration, total imports from all sources now amount to about 260 million cubic meters/year. To alleviate such huge demand pressure, domestic plantations play an increasingly important role and forest policy needs timely reform to encourage all sectors of investment to grow more forest trees in China.

Forest policy plays a decisive role in the direction of China's plantation development. Major barriers for plantation development in China currently include: a) subjects of forest investment are not clearly defined by the country's current "Forestry Law"; b) the silvicultural fund and associated arbitrary fees levied by various levels of government discourage further plantation expansion through non-government investment; c) with the exception of all but a few forestry companies/growers, sustainable forest management practices are not implemented; d) complicated tenure rights make the forest land even more fragmented and hard to manage sustainably; and, e) various sectors with unrealistic expectations are competing for the same forestlands.

It is imperative that the country's forest policy be reformed to encourage greater investment in the plantation development from all sectors. The country's forest growers are appealing to be treated more like farmers, who are excluded from all taxes and fees and with additional government subsidization. Silvicultural fund and related arbitrary fees should be immediately abolished to realize the government promise that those who grow trees should benefit from their endeavours.

Nutrient Management of Eucalypt Plantations in Southern China

Daping Xu[1], Bernard Dell[2]

1 Research Institute of Tropical Forestry, Chinese Academy of Forestry, Longdong, Guangzhou 510520, P.R.China (gzfsrd@163.com)
2 Murdoch University, WA6150, Australia (b.dell@murdoch.edu.au)

About 4 million ha of eucalypt plantations have been established in southern China in the past 30 years, and the average productivity of commercial eucalypt plantations has been increased from 7 m^3/ha/yr to 20 m^3/ha/yr due to tree breeding, nutrient management and weed control. Early land degradation of eucalypt plantations was caused by soil and nutrient erosion, residue and slash harvest and non balance fertilization. Fertilization experiments proved that P application increased tree growth obviously cross southern China, but the increment in the east part was much greater than it in the western part due to soil pH change. The application of N and K also increased tree growth, but not so largely as P application. B deficiency of eucalypts was found in some sandy soils and low rainfall areas with long dry season. Adequate nutrient management of eucalypt plantations in southern China is very important for improve productivity and wood quality.

Oral Presentation

Quality Planning for Silviculture Operations Involving *Eucalyptus* Culture in Brazil

Diana Carolina Vásquez Castro, Marcos *Milan*

Forest Resources Program Posgraduation Escola Superior de Agricultura Luiz de Queiroz ESALQ – University of São Paulo. Av. Pádua Dias, 11, 13418-900, Piracicaba, São Paulo, Brasil. Email: carito1986@hotmai.com, macmilan@usp.br

The forestry sector is an important part of the Brazilian economy and reforestation with exotic species such as pine and eucalyptus has contributed to a reduction in the destruction of remaining native forests. Currently, various species of the genera *Eucalyptus* spp and *Pinus* spp exhibit a very high level of genetic improvement, productivity and quality of timber. With the need to expand the sector to meet future demand, silvicultural operations are often implemented with little consideration for quality planning in regard to forest plantation management, as all phases of forest investments are of fundamental importance to the success of forestry enterprises. Considering that the potential for productivity is related to the quality of operational processes, given that improper practices may lead to unsatisfactory results in the field, this study's objective is to identify and evaluate the priority features of silviculture operations in order to implement and monitor eucalyptus production in Brazil, and, in doing so, contribute to the management of forest stands with precision silviculture. The methodology used was the mapping of each of the silviculture operation's operational processes, identifying elements in regard to quality and technical features with the use of quality function deployment - QFD. Data collection has been carried out at locations of the Suzano Papel e Celulose do Brasil Company (Itapetiniga, Limera – SP, Brazil). The results to date have been the identification of 48 quality elements and 90 priority features pertaining to eucalyptus silviculture operations with the data obtained from the Suzano Papel e Celulose do Brasil Company. In accordance with the methodology, subsequently, the correlations of each element with every quality technical requirement will be established, the competitor analysis based on standard areas and a QFD house of quality analysis will be conducted to determine the features' negative or positive effects, having identified the priority features with the use of control charts. These features will be evaluated in the field and probable causes of operational deviations will analyzed.

Key words: priority features, forest quality, Quality Function Deployment- QFD

Oral Presentation

Eucahydro: Predicting *Eucalyptus* Genotypes Performance under Contrasting Water Availability Conditions Using Ecophysiological and Genomic Tools

Rafael Rubilar[*1,2], *Marco Yanez*[1,2], *Hector Valenzuela*[3], *Alex Medina*[6], *Oscar Mardones*[6], *Juan Carlos Valencia*[6], *Cristian Montes*[5], *Veronica Emhart*[6], *Sofia Valenzuela*[1,4], *Marta Fernandez*[1,4], *Juan Espinoza*[1,2], *Jose Luis Ulloa*[1,6]

1 Universidad de Concepción, Departamento de Silvicultura. 2 Forest Productivity Cooperative 3 Forestal Celco S.A.4 Genómica S.A.5 Bioforest S.A. 6 Forestal Mininco S.A.

Early selection of *Eucalyptus* genotypes that may use less water, or survive under future limited water availability scenarios of climate change, may provide a strong basis for development of an integrated genetic x environment x silviculture approach for management of fast growing species. In order to evaluate the potential to estimate early prediction of genotype performance, 16 selected contrasting *Eucalyptus globulus*, *E. nitens* x *globulus*, *E. globulus* x *camaldulensis* clones and *E. nitens* seedling were established under contrasting water availability conditions (summer irrigated vs control) at two contrasting sites in atmospheric demand. Correlation of field growth performance with early physiological and gene expression under drought nursery experiments of the same genotypes under semi-controlled environment conditions evaluated at 0, -1.5 and -3.0 MPa soil water potentials. Physiological assessments included photosynthesis, stomatal conductance, water use efficiency, predawn water potential and individual plant growth. Our results suggest that pre-dawn water potential, gas exchange measurements and gene expression may allow for early prediction of one-year old genotype performance. Use of combined ecophysiological and genomic tools may arise as a solution for early selection of genotypes on areas with higher risk to drought improving survival, or areas where large conflicts for water use may require genotypes with higher water use efficiency and reduced impact on water resources.

Oral Presentation

Transpiration, Canopy Characteristics and Wood Growth Influenced by Spacing in Three Highly Productive *Eucalyptus* Clones

Rodrigo Hakamada[1], Silvio Ferraz[2], Robert Hubbard[3], José Luiz Stape[4], Cristiane Lemos[5]

[1]Forest Resources Graduate Program, University of São Paulo, 13400-970 Piracicaba, SP, Brazil
2Department of Forest Science, University of São Paulo, 13400-970 Piracicaba, SP, Brazil
[3] USDA FS RMRS, Fort Collins, CO 80526, United States
[4] Department of Forestry and Environmental Resources, North Carolina State University, PO Box 8008, Raleigh, NC 27695, United States
[5] International Paper do Brasil, Rodovia SP 340 – Km 171, Mogi Guaçu, SP 13.840-970, Brazil

The definition of planting spacing is a strategic decision in establishment of any forest culture once it directly involves its productivity and competition for resources among individuals. Many studies in *Eucalyptus* planted forests have been done to define the spacing with the main focus on biomass. However, there are few studies, especially in high productivity sites, on the impact of plant density on water relations. The overall goal of the study is to determine the effect of spacing on leaf area index, canopy conductance and transpiration in three *Eucalyptus* clones (*E. grandis* x *E. urophylla* (Urograndis), *E. grandis* x *E. camaldulensis* (Grancam) and *E. urophylla*). Our assay is a systematic planting density trial planted at Southeast of Brazil (22º20´58´´S, 46º58'16´´W) which is part of a larger study belonged to TECHS network (*Eucalyptus* Tolerance of Thermal and Hydric Stresses). Four spacings were used (3.4, 7.0, 9.7 and 16.9 m² tree^{-1}, equivalent to 2949, 1424, 1028 and 591 stems ha^{-1}). Leaf area index was estimated each three months by ceptometer and canopy conductance was estimated based on transpiration per unit of leaf area divided by vapor pressure deficit. Evaluation of 24 months of sap flux was assessed through the constant heat method of Granier with homemade probes with 2 cm installed when trees were 1.5 years. Measurements were done in eight trees per treatment, resulting in 96 trees evaluated (3 clones × 4 spacings × 8 trees). As we expected, leaf area index (LAI) decreased from tighter to wider spacing, resulting in higher light capture by tighter spacing trees. GranCam presented significant lower LAI in all spacings compared with UroGrandis and Urophylla. Thus, the increase in LAI resulted in an increase in transpiration. During the two years, tighter spacing trees transpired 40% more than the wider spacing trees. Urograndis, Grancam and Urophylla, respectively, had the highest transpiration values. Considering all spacings, GranCam had almost 50%higher canopy conductance than UroGrandis and Urophylla, which partially explain why even with a much lower LAI it has a higher transpiration than Urophylla. The higher water use provided a higher cell expansion and division, resulting in more Carbon assimilation and stem growth. Tighter spacing accumulated in average 55% more wood biomass than wider spacing. This result reveals a powerful strategy of management to alleviate water use in conflict areas and reduce water stress, mainly considering climatic changes and the dry regions where new plantation has been established worldwide.

Oral Presentation

Challenges to Site Management During Large-scale Transition from *Acacia mangium* to *Eucalyptus pellita* in Short Rotation Forestry on Mineral Soils in Sumatra, Indonesia

Eko B. Hardiyanto[1], E.K..Sadanandan Nambiar[2] and Maydra A.Inail[3]

[1]Faculty of Forestry Gadjah Mada University, Yogyakarta, Indonesia

[2]Forest System Group, CSIRO Land Water, Canberra, Australia

[3]PT. Musi Hutan Persada, Muara Enim, South Sumatra, Indonesia

Oral Presentation

Acacia mangium plantations have been a major source of wood for pulp mills in Sumatra. The species was broadly planted since 1989 and by 2004-2005 it occupied 700,000 ha in Sumatra and about 1.0 million ha nationally. This expansion was encouraged by the species' growth rates (in 6-7 year rotations) ranging from 22 to 35 m^3/ha/yr) and the quality of wood for pulp and paper making. In general second rotation stands grew as well or faster than the first rotation, if genetically improved stocks and inter-rotation practices promoting conservation of site organic matter and weed control were deployed.

During the first and second rotations there were incidences of *Ganoderma* root rot disease but it's spread increased with time. This was followed by the arrival and rapid spread of *Ceratocystis* wilt disease, aggravated by the damages caused by monkeys and elephants. Gradually, tree mortality became so high that *A. mangium* was no longer viable. Based on earlier studies, *Eucalyptus pellita* emerged as the next best candidate species. The change of species from *A. mangium* to *E. pellita* began in 2006 by some companies.

The current growth rates of *E. pellita* are lower than or at best comparable to *A. mangium.* This poses challenges to wood supply to existing mills. Slash retention has been the common practice during the last decade resulting in accumulation of organic matter and nutrients especially N. Question is, would the rates of supply of N, P and cations from these sources and soil be sufficient to support the necessary fast growth rates of eucalypts? In a study now in the fourth rotation, the growth rates of young first rotation *E. pellita* decreased by 50% if acacia slash and litter were removed compared to slash and litter retention, and growth rates doubled when P was added to plots where slash and litter have been retained over successive rotations. Other early results show wide spread response to P at sites were acacia slash and litter were retained over two rotations and previous trees were fertilized with P. So far we have not found response to N, Ca and K.

Typically, *A. mangium* stands close canopy by age one year or soon after and this suppresses weed growth. In contrast, *E. pellita* stands seldom close canopy throughout the rotation and this has implications to vegetation management.

These and other issues being faced during the change of species in response to threats to sustainability will be discussed.

Key words: change of species, productivity, site management, sustainability

Operational Issues in Growing *Eucalyptus* in South East Asia: Lessons in Cooperation

David Boden[1], Yani Japarudin[2], Manuel Espey[3], Edmund Gan[4] and Basil Ngui M.L[5]

1 Boden & Associates Pty Ltd, PO Box 162, Cooroy, Qld 4563 Australia
2 Sabah Softwoods Berhad, P. O. Box 60966, 91019, Tawau, Sabah, Malaysia
3 Asian Forestry Company (Sabah) Sdn. Bhd, 89108, Kota Marudu, Sabah, Malaysia
4 Sabah Forest Industries Sdn. Bhd, 89859, Sipitang, Sabah, Malaysia
5 Jaya Tiasa Forest Plantations Sdn Bhd, 96000, Sibu, Sarawak, Malaysia
Corresponding author; boden.associates@gmail.com

South east Asia is a region blessed with abundant rainfall and reasonable soils for commercial forest plantation development. Yet there are far too many failures amongst organizations propagating trees and this is especially true in the case of eucalypts. Failures are regarded as plantations with a Mean Annual Increment of < 20 $m^3 ha^{-1}$ against sites that should be producing > 30 $m^3 ha^{-1}$. Critical establishment operations are discussed against this background and the five key issues of harvesting practices, weed free silviculture, suitable nursery stock, planting operations and site-species selection are highlighted. While these operations are essentially simple to perform many organizations struggle to carry them out consistently with due attention to detail. The importance of getting the operations right during the first 12 months cannot be over emphasised – mistakes during this period cannot be cost effectively rectified later on in the rotation. Growing *Eucalyptus* spp. for solid timber adds an additional degree of complexity to operations, timing and budgets.

It is considered that in this region where *Eucalyptus* spp. have been grown only on lowland sites for less than 10 to 15 years, cooperation and communication is key to achieving optimum results in the shortest time possible. This cooperation starts within the company where harvesting and growing units must abide by the principle “plant for harvesting and harvest for planting”. It extends to the fostering of communication between operational and research staff, as there are few companies in the region that manage to successfully realise the operational gains shown in research trials. And finally the cooperation should include collaborative research between companies and R&D organisations. In particular pest and disease research – an area that history has shown will define the long term future of eucalypts in the wet tropics and requires a combined approach to overcome the complexities of these issues. Tree Improvement Programs are optimised by testing species, families and clones over a range of sites and sharing germplasm for the betterment of all. The five year results from the Borneo Forestry Cooperative, an organisation established in east Malaysia, provide an example of how financial advantages and professional development resulting from a cooperative approach can best be achieved.

Oral Presentation

Nutrition Studies on *Eucalyptus pellita* in the Wet Tropics

Agustan Alwi[1], Yani Japarudin[1], Manuel Espey[4], David Boden[2] and Tim Smith[3].

1 Sabah Softwoods Berhad, P. O. Box 60966, 91019 Tawau, Sabah, Malaysia
2 Boden & Associates Pty Ltd, PO Box 162, Cooroy, Qld 4563 Australia
3 FOSHEE, University of the Sunshine Coast, Sippy Downs, Qld 4556 Australia
4 Asian Forestry Company (Sabah) Sdn. Bhd, Kota Kinabalu, Sabah Malaysia
Corresponding author: agus_alwi@outlook.com

Nutrient losses from successive rotations and site variability are a potential problem for timber plantation sustainability. Since *E. pellita* is a new species in the wet tropics, experiments to study the responses of *E. pellita* to nitrogen (N) and phosphorus (P) were established in Sabah, Malaysia (on gradational soils) and north Queensland, Australia (on a duplex soil). On some of these sites the studies commenced with short term NP-factorial trials using nine treatments with P varying from 0 to 111 kg TSP 46% ha^{-1}, and N from 0 to 48.9 kg Urea 46% ha^{-1}. Highly significant responses were obtained to both N and P over the life (18 months) of these trials. However, the interaction between levels of N and P were inconsistent due to high site variability. Therefore, we initiated a second series of trials using selective treatments to further evaluate long term responses. The results showed that there were again highly significant growth responses to fertilizer treatments. Best results in Sabah indicated five-fold increase (significant at P=0.05) in tree volume to the best N-P treatment at 11 months compared to the control. The results also concur with a P rate trial with *E. pellita* in north Queensland in which diameter at breast height increased by 13.3% and stem volume by 33.7% in the 60 kg P ha^{-1} treatment at 15 months, compared to zero P controls. These responses are compared with the contrasting chemical and physical status of the soil types, the different climatic regions and previous land uses. Results across all trials indicated that P fertilization at planting was essential to optimise *E. pellita* establishment and growth, with varied responses to complementary applications of N.

Oral Presentation

Sustainable Agroforestry Model for Eucalypts Grown as Pulp Wood Tree on Farm Lands in India–An ITC Initiative

Jagdish Tamak

ITC Limited. India

The Paper and Pulp Industry in India is growing rapidly, and it consumes about 10 million tons of pulpwood annually to produce about 3 million tons of pulp. Approximately 80% of the pulpwood is sourced from farm forestry and 20% from Government sources. Eucalypts are a major pulpwood tree species grown over 1.0 million ha in India, and ITC PSPD has promoted over 0.2 million ha area with pulpwood plantations at farm lands in last two decades. In India, Eucalypt are grown as block plantation at a spacing of 3.0m X 1.5m accommodating 2222 trees per ha and harvesting cycle is four years, since land is owned by small and marginal farmers. About 70% of the population in India lives in villages and their livelihood is based on agriculture. To improve farm income and generate sufficient pulpwood for expanding business of paper industry, recently an innovative agro forestry model is developed with focus on wood and food security. This novel concept in agro forestry is based on paired row design. In this design, two rows of Eucalypts are planted at 1.5m apart with tree to tree spacing being at 1.0m within the row. Paired rows are placed 8.5m apart, to create sufficient space for agriculture crop cultivation independently. In this model 75% of the land area is allocated to agriculture and 25% to forestry. Major agriculture crops grown, along with clonal Eucalypts in this model, are cotton, maize, wheat, pulses, chilli, tobacco etc. By adopting this paired row design, a farmer can grow 2000 trees per ha in 1/4th portion of the land and leaving 3/4th area, for growing agriculture crops. Also, Eucalypts are better adapted to harsh conditions in rain-fed areas, hence, it mitigates the risk of crop failure, if any. On the other hand mono-cropped area is put to plant production throughout, leading to efficient utilization of natural resources. The income from agriculture crop fulfils the regular needs of the small and marginal family, whereas, income from harvest of pulpwood after four years, serves as fixed income, which, can be better utilized in capital investments. Therefore, this innovative agro-forestry model has potential to improve and sustain farm productivity and profitability, for small and marginal farmers, and also to meet growing wood requirement of pulp and paper industry in India.

Oral Presentation

Adaptability and Performance of Industrial Eucalypt Provenances at Different Ecological Zones of Iran

Hossein Sardabi[1] ,Mohammad Hasan Assareh[2]*

1- Corresponding Author, Associate Prof., Research Institute of Forests and Rangelands, P.O. Box 13185-116, Tehran, I.R. Iran. Email: sardabi@rifr-ac.ir, hosseinsardabi@gmail.com.*
2- Prof., Seed and Plant Certification Research Institute, P.O. Box 31535-1516, Karaj, I.R. Iran. Email: asareh@gmail.com.

The aim of the study was to introduce the adaptable, fast-growing and industrial species and provenances of *Eucalyptus*, using species trials at different provinces of Islamic Republic of Iran. The tested eucalypt species consisted generally of: *E. camaldulensis*, *E. grandis*, *E. globulus*, *E. rubida*, *E. saligna* and *E. viminalis*. The trials usually conducted under statistical design of Randomized Complete Blocks with three replicates and few eucalypt species and provenances. The first stage of the trial started in 2005, but the second stage started in 2010 and ended in 2014. The data were analyzed, using ANOVA and DUNCAN statistical tests and SAS and SPSS computer programs. The most successful species were selected, using two criteria: 1– their adaptability to environmental factors (average survival percentage at different locations), and 2– their potential for industrial wood production (average of quantitative and qualitative growth characteristics at different locations). According to the overall results of various locations and provinces, the most successful species and provenances are as follows in respect to their priority: *E. camaldulensis* (Ilam origin), *E. camaldulensis* var. *camaldulen*sis (seedlot 15030), *E. camaldulensis* var. *obtusa* (seedlot 13701), *E. denticulata* (seedlot 16341) and *E. camaldulensis* var. *subcinerea* (seedlots 15195 and 15272). Furthermore, although *E. microtheca* and *E. sargentii* had good adaptation to arid and semi-arid climates and saline soils, but due to their shrub and coppice forms, their non industrial wood production and their high coppicing high, were introduced for soil and water conservation purposes. Although the average survival of *E. rubida* at different locations and provinces, particularly at arid and semi-arid conditions was low, but its adaptation and performance at Mazandaran province (near Caspian Sea) was outstanding due to its high resistance to severe frosting and snowing and due to good soil physical condition.

Key words: Forest plantation, survival, soil, diameter, height, quality, crown cover diameter

Oral Presentation

Nutrient Management of *Eucalyptus pellita* Plantations after Two Rotations of *Acacia mangium* in South Sumatra

Maydra A. Inail[1], Eko B. Hardiyanto[2], Daniel S. Mendham[3]

[1]PT. MusiHutanPersada, Muara Enim, South Sumatra, Indonesia

[2]Faculty of Forestry Gadjah Mada University, Yogyakarta, Indonesia

[3]CSIRO Land and Water, Hobart, Tasmania, Australia

Large-scale conversion of sites from *Acacia mangium* to *Eucalyptus pellita* has been occurring in Sumatra due to various threats which make *A. mangium* no longer viable in many parts of this region. *E. pellita* has emerged as the most prospective species to replace *A. mangium* at these sites. Nutrient management during the former *A. mangium* phase was reasonably simple, requiring no nitrogen and only a small amount of P for maximum productivity. However, conversion to non-N-fixing *Eucalyptus* has potential to change nutrient dynamics and the management that is required to ensure maximum productivity of these plantations. We conducted nutrient management studies at 2 *E. pellita* sites in South Sumatra to assess the response to application of nitrogen, phosphorus, potassium and calcium fertilizers. *E. pellita* was found to be highly responsive to P fertilizer application, with the addition of P increasing the stem volume by 21.4 to 37.1 m^3/ha at 36 months compared with no addition of P fertilizer. *E. pellita* showed no response to N, possibly due to high residual available N in the soil fixed by the previous *A. mangium* plantations. Even though the soils had low pH (4.38), there was no growth response to addition of 2.5 t/ha of lime. Similarly, there was no response to K. Thus, we conclude that sites which have recently been converted from *A. mangium* will not require additional N fertilizer, nor will the trees be likely to respond to the application of Ca or K at many sites. However, we anticipate that this recommendation requires further monitoring into the future, as the site N status has potential to decline over the course of multiple *Eucalyptus* rotations.

Key words: fertilization, plantation growth, soil nitrogen.

Oral Presentation

Study of Eucalypt-*Sarcandra glabra* Intercropping and Analysis of Its Economic Benefits

Chengqun LÜ [1], Baoling HUANG [1], Yanping YE [2], Shaoyue NONG [3], Shifan LÜ [4]

1. College of Forestry, Guangxi University, Nanning 530004, Guangxi, China; 2.Agricultural College, Guangxi University, Nanning 530004, Guangxi, China; 3.Bureau of Forestry and Park, Guangxi Nanning 530022, Guangxi, China; 4. Xingjian College of Science and Liberal Arts, Guangxi University, Nanning 530004, Guangxi, China

For increasing the global utility of eucalypt plantations and improving the environment, this study was initiated to examine the potential for intercropping of *Sarcandra glabra* within *Eucalyptus* plantations. Two eucalypt-*S. glabra* intercropping patterns and three planting patterns were studied in randomized complete block experiments on a lower hillside site and an upper hillside site in central Guangxi; data collected was used to analyze economic benefits of such intercropping systems. Intercropping systems of eucalypt-*S. glabra* increased the economic returned by up to 456,624 RMB/hm^{-2}, compared to pure *Eucalyptus* plantations, providing a 423% higher return. For an intercropping patterns of 1-line eucalypt + 1-row *S. glabra*, 1-line eucalypt + 2-rows *S. glabra,* 1-line eucalypt + 3-rows *S. glabra* compared to pure eucalypt plantation the output value increase by -1,042 RMB/hm^{-2}, 18,934 RMB/hm^{-2} and 20,212 RMB/ hm^{-2}, providing increases of -3.9%, 71.9% and 76.7% respectively. This showed that the cultivation mode involving 1-line eucalypt + 3-rows *S. glabra* provided the highest economic benefit. The averaged returns from the three cultivation modes increased with time, and at 5 months, 16 months, 25 months average output values increase by 2,264 RMB/hm^{-2}, 15,824 RMB/hm^{-2}, 42,334 RMB/hm^{-2} respectively compared to pure eucalypt plantation, providing increases of 8.7%, 49.6%, and 115.5% respectively. This showed that the highest economic benefit was by continuing the intercropping for 25 months.

Key words：*Eucalyptus*, *Sarcandra glabra*, intercropping pattern, economic benefits

Oral Presentation

Plant Growth Promoting Traits of Actinomycetes from *Eucalyptus* Roots and Rhizospheric Soil

W. Himaman[1, 4], A. Thamchaipenet[2, 4], K. Pongpanich[3],K. Duangmal[1, 4]

[1] Dept. of Microbiology, Faculty of Science, Kasetsart University, Bangkok, Thailand
[2] Dept. of Genetics, Faculty of Science, Kasetsart University, Bangkok, Thailand
[3]Forest and Plant Conservation Research Office, Department of National Parks, Wildlife and Plant Conservation, Bangkok, Thailand
[4]The Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission, Thailand
Email: winandah@gmail.com, fscikkd@ku.ac.th

In Thailand, the eucalyptus plantations rapidly expand across the country. However, the use of microorganisms as biocontrol agent and plant growth promoters is still limited even though it is an alternative method to reduce the use of chemical pesticides and fertilizers. More than four hundred isolates of endophytic and rhizospheric actinomycete which were screened for their antagonistic activity against *Cryptosporiopsis eucalypti*, *Cylindrocladium* spp. and *Teratosphaeria destructans* from previous study were screened for more details of plant growth promoting traits. All these isolates were tested for their abilities to produce siderophores, indole-3-acetic acid (IAA) and phosphate solubility. The result showed that 465 isolates (97.3%), 237 isolate (49.6%) and 344 isolate (72%) produced siderophores, indole-3-acetic acid and solubilize phosphate, respectively. Among these, 184 isolates (38.5%) produced all three plant growth promoting traits. Three antagonistic isolates with high plant growth promoting activities (EUTKR1S17, EUSNT1H43 and EUSKR2S82) were selected to study for *in vitro* plant root colonization using test tubes containing0.4% agar-water. The isolateEUSKR2S82 could colonize internal root tissues and thrive as a root endophyte. The identification of this strain using the 16S rRNA genes sequence revealed 99.4% similarity to *Streptomyces ramulosus* NRRL B 27-14^{T}.

Key words: plant growth promoting traits, actinomycetes, *Eucalyptus*, siderophores, indole-3-acetic acid, phosphate solubility

Oral Presentation

Conventional Breeding and Genetic Transformation for *Eucalyptus* Improvement

Rodrigo Neves Graca[1]; Eduardo José de Mello[1]; Guozuo Lin[2]; Xudong Zhou[2]; Ziv Shani[3].

FuturaGene: [1]Brazil; [2]China; [3]Israel. Email: rodrigo@futuragene.com

Humans have inadvertently manipulated allele frequency of plant populations since the early stages of plant domestication, approximately 16,000 years ago, by selecting and propagating genotypes with desirable phenotypes. Thousands of years later, during the Green Revolution (1960's), the gains provided by hybridized seeds of semi-dwarf/disease-resistant wheat varieties once again changed the way we domesticate and improve plant species. This re-utilization of Mendel's theories provided a solid basis for plant breeding. Today, we can combine gains provided by conventional breeding with benefits accessible through genetic transformation. The possibility of inserting genes from unrelated species/ organisms into a breeding program is a game-changing tool that allows breeders to exploit new boundaries, using genes/traits from sexually incompatible or unrelated species that are impossible to access through conventional breeding. Genetic transformation may also help to shorten the time for obtaining desirable traits, which in *Eucalyptus*, may be as long as 18 years. . The best example for the use of genes from unrelated organisms, is the *cp4* gene from *Agrobacterium tumefaciens* that confers tolerance to glyphosate and is being used commercially in several field crops on millions of hectares around the world. An example of this approach has been FuturaGene's use of the *cel1* gene from *Arabidopsis thaliana* to promote biomass increase in *Eucalyptus*. However, the deployment of genetic modified trees should be combined with conventional breeding in order to maintain sufficient genetic diversity in commercial plantations. This approach maximizes the number of different clones deployed, in order to minimize the impact of disease and pest outbreaks and to provide flexibility for planting in different geographies and environments (GxE interaction). FuturaGene believes that using conventional breeding combined with genetic transformation should optimize the long term yields for forest plantations.

Oral Presentation

Forest Tree Improvement for *Eucalyptus pellita* in Indonesia: Application of Breeding Strategy with Seedling Seed Orchard

Budi Leksono [1], Yuji Ide [2], Susumu Kurinobu [3]

1) *Center for Forest Biotechnology and Tree Improvement, YOGYAKARTA, INDONESIA*

(Email: boedyleksono@yahoo.com).

2) *Department of Ecosystem Studies, Graduate School of Agricultural and Life Sciences, the University of Tokyo, TOKYO, JAPAN.*

3) *Department of Applied Bioscience, Tokyo University of Agriculture, TOKYO, JAPAN.*

Oral Presentation

Most of the tree improvement programs rely on recurrent selection where superior individuals are selected from breeding population and crossed in a particular mating pattern to regenerate a new and hopefully improved breeding population for the next generation. For this reason, the progeny test is gradually converted into a seedling seed orchard (SSO), is a common orchard type used in eucalypt breeding programs. Some issues in the activities on SSO will be the scope of this study to synthesized the results of four separate studies aiming at investigating: 1) to clarify the trend of within plot selection, 2) to investigate optimum age for selection based on genetic gains predicted with an extrapolated trend of genetic parameters, 3) to examine magnitude of the genotype environment interaction by predicting expected gains between single site selection and multi-site selection, 4) to obtain the optimum design of SSO in order to maximize genetic gain, and 5) to compare the plus tree progenies and unselected families in the second-generation SSO. The investigations involved analyzing data collected in first (F-1) and second (F-2) generation SSO of *E. pellita* at four locations in Indonesia. The F-1 orchards were established in 1994-1996 and the F-2 orchards in 2003. The results show that 1) the mean realized gains in the F-2 SSO were around 15% and 18% for height and diameter, respectively; 2) the overall process of selection in the F-1 SSO has favored the improvement of growth rather than stem form; 3) one generation of breeding cycle of *E. pellita* should be achieved in a five-year period with eight-year rotations; 4) the design of SSO should also use ca. 40 to 50 families with six to eight trees per plot, and 5) the GEI in SSO of *E. pellita* will have significant adverse effect if the seed from F-1 orchard are supplied to other island. The results also indicate that a breeding strategy plays a key role in ensuring the success of tree improvement programs.

Key words: *Eucalyptus pellita*, genetic gains, genotype-environment interaction, seedling seed orchard, tree improvement

Genetic Improvement of *Eucalyptus* Hybrid (Mysore gum) through Selection and Cloning: Field Performance of Cuttings vs. Seedlings

Meena Bakshi

Plant Physiology Discipline, Forest Research Institute
Dehradun, India-248 006, e-mail: bakshim@icfre.org, bakshim123@gmail.com

Oral Presentation

The wide adaptability of Eucalypts in India under varied climatic zones is a prime reason for its choice as a source of renewable wood based material. To fulfill the demand for plant material many plantations are being established through seeds. The plantations raised through seedlings show considerable inherent variations resulting in unpredictable yields, which is not conductive for successful plantations. Cloning in Eucalypts has been practised since long through coppicing of adult trees (rejuvenation), however, what is not known is the extent to which rejuvenation occurs, the periodic response of trees to coppice shoot production and the quantity of propagules that can be produced seasonally. These are essential for practical implementation of propagule production by Researchers for improving yield.

Selected superior trees of *Eucalpytus* hybrid were coppiced seasonally to assess the coppice shoot production ability for maximum propagule production. Single nodal cuttings were prepared treated with various concentrations of auxins and planted under mist chamber. Significant variations (0.01%) were observed in coppice shoot production ability with respect to season, auxin treatment and root formation. Thus genetic potential of *Eucalyptus* hybrid (Mysore gum) to maximum plantlet production could be enhanced through amalgamation of season of coppice production, rooting period coupled with proper auxin.

The morpho-physiological performance of field planted rooted propagules along with seedlings will contribute a great deal in understanding and assessing the overall feasibility of the technique. Comparative performance of cuttings vs. seedlings in growth attributes, photosynthetic parameters as well as dry matter production showed substantial variations (0.01%) in height, collar diameter, leaf area, root length and number of branches with cuttings performing better. The total dry weight of cutting raised plants was nearly double of seedling raised plants.

Inherent differences in carbon assimilation as monitored through LiCOR Portable Photosynthetic system (LiCOR 6000) were observed between seedling raised and cutting raised plants when measured at 2 peaks viz. 1100 ans 1500 hrs. AC_{350} of cutting raised plants was higher than seedlings revealing high photosynthetic capacity of former. Similarly, a 10% increase in RUBP consumption was also noticed in cuttings compared to seedlings.

Thus improvement strategies through selection and cloning can be used to provide plants for unusual sites, elimination of inbreds, mass production of genotypes and enhanced biomass production in *Eucalyptus* hybrid (Mysore gum).

Key words: *Eucalyptus* hybrid (Mysore gum), selection, season, coppice production, rooting, auxin, growth characteristics, dry matter production, carbon assimilation

Genetic Variation of Log-End Splitting and Growth Traits of *Eucalyptus grandis* in a Second Generation Progeny Trial at Erabedda, Sri Lanka

K. M. A. Bandara

Sri Lanka Forest Institute, Sri Lanka
e-mail: cf.slfi@gmail.com

Eucalyptus grandis is one the main commercial forest plantation species in the highlands of Sri Lanka. An *E. grandis* genetic improvement program was initiated in 1995 with second generation progeny trials being established in 2007. The second generation progeny trial consisted of 132 families from plus trees selected in Sri Lanka (72 families from a first generation trial at Erabedda, 17 families from seed production area at Kinigama, 11 families from a seed production at Erabedda and 32 families from up country plantations); this was planted in a row-column design with six replications. Each plot comprised 5 trees and trees from a first thinning (removal of 2 trees per plot, 12 trees per family) were used for the log-end splitting assessment. Those trees were crosscut at 1.3 m height; the first log was labeled and stored for one week before the end splitting assessment. This used the CSIR log-end splitting evaluation criteria: one point for crack extending to half of the radius of the log, 1.5 points for a crack extending to 3/4 of the radius and 2 points for a crack extending to the bark. Growth data (dbh and tree height) measurements were taken for five trees per plot prior to the thinning. General ANOVA was performed for growth and log-end splitting data. Significant differences were observed among seed sources and families within seed sources for dbh, tree height, whilst differences found for log-end splitting were non-significant. The highest volume growth (48 dm^3/tree) was a seedlot from the Erabedda seed orchard (SSO1) and second best the Kinigama seed production area (SPA) at (42.2 dm^3/tree). These results indicate that the current production plantation seed sources of used by the Sri Lankan Forest Department (the SSO and SPAs) are superior to the plantation collections. Positive and unfavorable phenotypic correlation was observed between log end splitting and growth traits indicating that future selections have to be made with due consideration to both growth and wood quality traits.

Oral Presentation

Interfacing Classical and Molecular Breeding in Red Gums in India: Observed and Expected Gains

*Rajasugunasekar D, Vellaichamy P, Mayavel A, Sivakumar V, Modhumitha D, Bachpai V.K.W, Yasodha R, Nagarajan B**

Institute of Forest Genetics and Tree Breeding, India

Interfacing classical and molecular breeding is an effective strategy to crop improvement. While quantifying a phenotyic trait a genotyping endorsement catalyses in fast eliminating selection errors. The first effort to molecular and classical breeding with Red gums as target taxa was initiated in IFGTB during 2010. Quantitative traits such as improved pulping, greater rooting, lower lignin and higher salt tolerance were targeted. Pedigreed clones of *E. camaldulensis* (*Ec-7, Ec-17 and Ec-111*), *E. tereticornis* (*Et 217and Et 86*) and an *E. grandis (13017 Lorne)* selection were deployed for hybridizing the above said traits. Dihybrid combinations of *E. camaldulensis* × *E. tereticornis, E. tereticornis* × *E. camaldulensis, E. camaldulensis x E. grandis* and *E. tereticornis* were developed under the program. The dihybrid crosses were successful with a PERS values varying 0.10–0.20. Purity analysis using Genetic analyses (Applied Biosystems-Hitachi, T-3500 Inc., USA) confirmed the hybridization of parental genomes. Two breeding populations with four full sib families each (three hundred siblings per family) were developed at an inland arid site (Panampally, 10°47'N; 76°45'E) and at a coastal location (Satyavedu, 13°26'N; 79°56'E). At twelve months all the crosses survived (95-100%). In terms of leaf and bark morphology *E. tereticornis* × *E. grandis* were found to be closer to the pollen parent. During 2011, the inland arid site was strategized as a VMG. Significant genotypic variation was noted in the rooting behaviour. The cross *E. tereticornis* × *E. grandis* exhibited the lowest level of success in rooting in accordance to the hypothesis. However, all the four full sib families were successfully cloned and deployed in seven different field across four different states of peninsular India. Over twenty thousand clonal ramets were produced of which over 19,500 have been successfully deployed. During the period 2012-13 three clonal trials were developed at a riparian semi arid site (Karur, 11°02'N; 78°01'E) a coastal plain site (Muthupet, 10°28'N; 79°30'E) and an inner arid location (Pudukottai, 10°23' N,78°51'E). In 2013-14 five more trials were developed in an inner riparian semi-arid (Chennagiri, 13°59'N; 75°41'E), an inner riparian wet site (Hosakoppa, 14°10'N; 74°58'E) a coastal site (Nellore, 14°23' N; 80°02'E), an inner semi arid (Thuvarankuruchi, 10°22'N; 78°23'E) and an inner arid site (Neyveli 13°50'N; 79°03'E). All the study locations have been intensively managed for 100% survival. In future with better comprehension of economic traits supportive to industrial forestry at phenotype and genotypic levels breeding programs expected to advance to the next levels. It is concluded that currently pedigreed inter-specific hybrid clones are expected to replace the existing open pollinated untested and elite clones.

Key words: Hybrids, inter-specific cross, quantitative traits, red gum

Oral Presentation

Forest Tree Improvement: the Shift from quantitative Genetics to Quantitative Genomics

Yousry El-Kassaby, Jaroslav Klapste, Omina Gamal El-Dien, Blaise Ratcliffe*

Faculty of Forestry, University of British Columbia, Canada

Next Generation Sequencing technologies increased the availability of sequence data for model and non-model forest tree species. This in turn transformed quantitative genetics from the pedigree-based analyses founded on the utilization of Sewell Wright's coefficient of relationship between individuals (Wright S. 1922; Amr Nat 56:330-338) to a genomic-based realized kinship methods for estimating genetic parameters (e.g., individuals' breeding values, traits' heritability, genetic correlations etc.). This substantial shift literally transformed quantitative genetics to quantitative genomics and led to the development of innovative methods such as the pedigree-free and the unified single-step (a combination of pedigree and genomic realized kinship) evaluation approaches where the classical Best Linear Unbiased Predictor (BLUP) is replaced by the Genomic Best Linear Unbiased Predictor (GBLUP). The recent development of quantitative genomics created opportunities for obtaining more precise genetic parameters, better partitioning of the genetic variance, and even breeding without structured pedigree. Examples from unstructured black cottonwood and white spruce open-pollinated populations will be presented to demonstrate the unsurpassed potential of incorporating sequence data in classical quantitative genetics and breeding.

Key words: pedigree, coefficient of relationship, realized kinship, Best Linear Unbiased Predictor (BLUP), Genomic Best Linear Unbiased Predictor (GBLUP), quantitative genetics, next generation sequencing

Oral Presentation

Genotype × Environment interaction of *Eucalyptus globulus* in Australia Has Similar Patterns at the Provenance and Additive levels

Gregory Dutkowski[1], Brad Potts[2], David Pilbeam [3]

1. PlantPlan Genetics; 2. University of Tasmania; 3. Southern Tree Breeding Association, Australia

Genotype by environment interaction (G×E) in *Eucalyptus globulus* at the provenance level has been shown to relate to test site dryness using native forest open-pollinated individual tree seedlots. Advanced generation control-pollinated trials are needed to get estimates of G× E at the additive level, unconfounded by differential partial selfing and inbreeding depression, and at the SCA (Specific Combining Ability) level. For advanced generation trials in a rolling front breeding scheme there is some parental overlap between trials in adjacent years, but little between years beyond that. This disconnection (and differences in measurement age) make GxE estimation difficult. Correlation estimates were derived from pairwise analysis of trials with more than 40 parents in common using within trial design features, and between trial additive and SCA effects. Correlations were more variable (and had higher standard errors) when trial pairs had less than 100 parents in common. SCA correlations were generally more variable, but slightly higher overall. All available trial pairs were used to adequately sample the range of possible environmental attributes in models of inter-site correlations based on long-term trial climatic attributes. Trials were split into groups based on critical values of environmental attributes which minimised model weighted error sum of squares. Age differences were accounted for using a Lambeth age ratio correlation model derived from within-trial multivariate models. SCA correlations between ages were higher than additive correlations. For additive correlations, the best site groupings were based on the minimum temperature of the warmest month of the trial sites, and vapour pressure deficit within low temperature sites. However splitting into three site groups based on minimum monthly evaporation was almost as good a model and gave a sensible trend of decreasing correlation with differences in evaporation, with a correlation of 0.42 between the extreme classes. The average correlation between sites within each group was around 0.66, indicating that the model was grouping trials effectively, but that there was still substantial unexplained G×E. SCA site type groups were dominated by wind speed, and then aridity within low wind speed areas. Using the same evaporation classes as used for additive correlations did not show any trend or lower between class correlations than within class correlations. Thus moisture availability was important for G×E at the provenance and additive levels, but was only of secondary importance at the SCA level. Breeding values can now be estimated using these new site groups, rather than the previous site groups based on geographic or regional boundaries.

Key words: *Eucalyptus globulus*, genotype by environment interaction, breeding value prediction

Oral Presentation

Breeding *E. globulus* for Drought Hardiness in the Bío-Bío Region of Chile

Patricio Rojas Vergara1- María Paz Molina1 - Braulio Gutierrez2 - Roberto Ipinza2*

[1]Metropolitana, INFOR, Chile, [2]Bío-Bío. INFOR, Chile, [3]Bío-Bío. INFOR, Chile, [4]Valdivia, INFOR, Chile.
**Contact person, e-mail: parojas@infor.cl.*

Oral Presentation

Eucalyptus globulus Labill "Tasmanian Blue Gum" is the main species for pulp and paper production in the world due its exceptional fiber properties. There are 563,813 hectares planted in Chile that represents 23% of the total plantations with exotic species (INFOR, 2014). The species was introduced by the end of XIX century for coal mining poles in Colcura (BíoBío Region) and due to successive selection and propagation cycles a "Chilean Land Race" was formed that has been well adapted to dry climatic conditions in the country.

By 1990 many organizations in Chile started breeding programs to improve frost hardiness, growth, yield and fiber quality of the species, but drought hardiness was not included as a trait. Last results of INFOR survey shows that the climatic change will decrease the productivity of plantations due to lower precipitation and extreme temperatures in the central and south region of Chile up to 6-8%.

An INFOR research Project started on 2006 was oriented to select, recombine and propagate drought hardiness *E. globulus* genotypes in the semiarid region of Chile. Three populations were included for this purpose: (A) selected genotypes ranked by volume in a clonal seed orchard that correspond to the INFOR tree breeding program, (B) open pollinated families of 107 plus trees selected on extreme dry conditions (C) control pollinated families generated by intraspecific crosses of population B × A. This material combined the genetic superiority of the clonal orchard genotypes and the drought hardiness of the Chilean land race of *E. globulus*.

This paper shows the results of two open-pollinated trials and one controlled pollination trial from these three populations planted in representative sites of dry land areas of the Bío-Bío Region on 2009-2010. Genetic parameters for drought tolerance *E. globulus* were obtained through the survival and growth of 24 control pollinated families and 61 open pollinated families at 5-6-year-old using as controls commercial seed sources of E. globulus and drought tolerant species like *E. camaldulensis* and *E. cladocalyx*.

Conclusions are related with the applicability of this breeding strategies for improving drought tolerance of E. globulus in dry zones areas of the Bío-Bío Region including selection of best PC and OP progenies for commercial deployment.

Breeding Temperate Versus Sub-tropical Eucalypts – a South African Experience

Tammy Swain

ICFR, Box 100281, Scottsville, Pietermaritzburg, 3201, South Africa

Oral Presentation

A significant percentage of South African eucalypt plantations are established to temperate eucalypts and, as such, make an important contribution to the South African forestry sector. Tree improvement programmes in the country have made significant advances for commercial temperate species, both as pure species and for developing inter-specific hybrids, these in response to a range of unique challenges.

South African plantation forestry is characterised by a wide range of site types and environmental conditions, the latter based on altitude, temperature and rainfall, also with differing severities of frost, snow and drought events. The advent of new pests and pathogens in these areas has added to the task of breeding resilient species for a range of sites and environments, and niche species and inter-specific hybrids for specific sites. Growth patterns and breeding systems can differ markedly for the species and across the sites.

Breeding of sub-tropical eucalypts and their inter-specific hybrids in South Africa is focused on clonal deployment, as in many global tree improvement programmes. The gains to be made by deploying clones are generally magnitudes greater than in seedlings; however, the breeding cycle of temperate eucalypts has some biological constraints when compared to the breeding of sub-tropical eucalypts. Flowering generally occurs years later, and often only in open-grown or thinned stands with the application of flowering enhancing products. Siting of seed orchards is important for flower bud induction, which could then negatively impact on available suitable pollinators and outcrossing rates. Flower size is smaller and flowers are less abundant, resulting in poor seed production, as well as difficult conditions for controlled-pollinations. The grafting of elite material for breeding programmes is challenged by rootstock-scion incompatibility in some species. Similar propagation by rooted cuttings, both for breeding and commercial deployment, is hindered by the inability of many of the species to produce coppice and thus hedge plants, as well as by poor rooting of cuttings.

All of these factors impact on the length of the breeding cycle, and may impact on the level of genetic gain deployed from the breeding programmes into commercial plantations. It has thus been critical to invest in technologies to overcome some of these biological constraints in South Africa. Research is ongoing to improve the breeding cycle of the temperate eucalypts and provides interesting opportunities for tree breeders!

Towards Genomic Dissection of Economic and Adaptive Traits in *Eucalyptus*

Siming Gan[1,2], Fagen Li[2], Changpin Zhou[2], Qijie Weng[2], Mei Li[2]*

[1] State Key Laboratory of Tree Genetics and Breeding, Chinese Academy of Forestry, Xiangshan Road, Beijing 100091, China

[2] Research Institute of Tropical Forestry, Chinese Academy of Forestry, Longdong, Guangzhou 510520, China

** Correspondence. Tel. +86 20 87032402. Fax. +86 20 87031622. Email: siming.gan@ritf.ac.cn*

We used two approaches to detect genomic regions influencing economic and adaptive traits in *Eucalyptus*, namely, linkage and association analyses. For linkage analysis, we developed more than 3,000 expressed sequence tag (EST) derived molecular markers and, in combination with markers reported previously, constructed dense genetic maps of *E. urophylla* and *E. tereticornis*. Quantitative trait loci (QTLs) controlling growth and wood properties were mapped on the dense maps, which showed marked differences between clonal and seedling traits and could be critical for designing strategies for clonal breeding and recurrent selection in *Eucalyptus*. For association analysis, we identified 58 F_{ST} outlier microsatellite markers that were probably involved in divergent selection in *E. grandis* populations, of which five loci (seven alleles) were significantly associated with local climatic variables mean annual temperature, isothermality and/or annual precipitation. Moreover, seven microsatellites were revealed to be associated with resistance in *E. grandis* to gall wasp (*Leptocybe invasa*), and several candidate genes were obtained in RNAseq with resistant and susceptible samples. All these results could be highly valuable towards genomic dissection of economic and adaptive traits in *Eucalyptus*.

Oral Presentation

Changes in the Genetic Control of Eucalypt Physiology Induced by Water Stress

Jeremy Brawner[1] and Paul Warburton[1&2]

1 University of the Sunshine Coast – jbrawner@usc.edu.au; 2 Riau Andalan Pulp & Paper – paulwarb66@gmail.com

The physiological state of a large pedigreed population of eucalypts subjected to water stress was assessed using a-priori calibrated spectroscopic models. Predictions of Relative Water Content (WC), Leaf water potential (WP) and photosynthetic rate (Asat) were made for 1200 seedlings in a *Eucalyptus camaldulensis* progeny trial that was assessed at three points in time; when seedlings were hydrated, water stressed and rehydrated. Genetic parameter estimates were derived to understand the degree of genetic control and the relationships among these physiological traits. Heritability estimates indicate these physiological traits are under a moderate level of genetic control and these estimates are impacted by the level of water stress. Altering physiological state through selection would be most efficient when heritability estimates are greatest, which occurred in a different state of hydration for each physiological trait: WC when hydrated (0.38 ±0.08), WP when water stressed (0.20 ±0.06), and ASAT when rehydrated (0.39 ±0.08). The rankings of families for all physiological traits were very stable across the hydrated, water stressed and rehydrated conditions; indicating little genotype by environment interaction for these three traits. Among the traits, there were moderately strong genetic correlations between WC and WP and little relationship with either of these traits and Asat; indicating selection for increased photosynthetic rate would not alter either of the leaf water status traits. These results indicate selection may be used to develop populations with an altered physiology and that the relative differences in state between selected populations and the population average will be maintained following changes in water availability. While these results are promising, the experimental model that is presented must be validated on other populations, extended to field trials and evaluated over a much greater periods of time before the technology may be applied in breeding programs. Certainly, a greater understanding of how stable changes due to selection will be over time, given the eucalypts ability to alter their physiology in response to environmental change (phenotypic plasticity), will be required before we are able to use direct selection on physiological traits in a way that will impact productivity in planted forests.

Oral Presentation

Modeling Additive and Non-additive Effects in a *Eucalyptus* Hybrid Population Using Genome-wide Genotyping – Implications for Multi-trait Genomic Selection

Jean-Marc Bouvet[*], *Garel Makouanzi, Marie Denis, Alexandre Vaillant, Philippe Vigneron*

Cirad, Centre International de Recherche Agronomique pour le Développement, Research Unit

Hybrids are broadly used in *Eucalyptus* breeding and accurate estimation of variance components is crucial for optimizing genetic gain. Genome-wide markers such as single nucleotide polymorphism may be used to explore models designed to assess the extent of additive and non-additive variance and their prediction accuracy for the genomic selection using single and multi-trait approaches.

In a first step, ten linear mixed models, involving pedigree- and marker-based relationship matrices among parents, were developed to estimate additive (A), dominance (D), and epistatic (AA, AD and DD) effects. Five complementary models, involving the gametic phase to estimate marker-based relationships among hybrid progenies, were developed to assess the same effects. The models were compared using tree height and 3303 SNP markers from 1130 cloned individuals obtained via controlled crosses of 13 *Eucalyptus urophylla* females with 9 *Eucalyptus grandis* males. AIC, variance ratios, asymptotic correlation matrices of estimates, goodness-of-fit, prediction accuracy and mean square error were used for the comparisons. The variance components and variance ratios differed according to the model. Models with a parent marker-based relationship matrix performed better than those that were pedigree-based, i.e. an absence of singularities, lower AIC, higher goodness-of-fit and accuracy and smaller mean square error. However, AD and DD variances were estimated with high standard errors. Using the same criteria, progeny gametic phase-based models performed better in fitting the observations and predicting genetic values. However, DD variance could not be separated from the dominance variance and null estimates were obtained for AA and AD effects. This study highlighted the advantages of progeny gametic phase-based model using genome wide information.

In a second step, using the progeny gametic phase-based model, the performance of multi-trait genomic selection was analysed using experimental data and simulations. With experimental approach, we used juvenile growth (height increment between 8 and 18 months), critical trait to avoid weed competition, and volume at mid-rotation age. Experimental data showed that multitrait- was slightly better than single trait genomic selection. This low difference can be explained by the very close heritabilities (h^2=0.36 for height increment and volume h^2=0.39). With simulation we considered two traits with contrasted heritabilities (h^2=0.10 and h^2=0.70) with additive and environmental correlation varying from 0.1 to 0.9. Compared to single trait genomic selection, the results showed that the prediction accuracy for a low-heritability trait could be significantly increased by multivariate genomic selection when a correlated high-heritability trait was available.

Key words: relationship matrix, linear mixed model, variance components, G-BLUP, experimental data, simulations

Oral Presentation

Genetic Improvement of *Eucalyptus pellita*: Integrating Growth and Wood Quality

Tran Huu Bien[1], Nguyen QuocToan[2], Nguyen Duc Kien[2]

[1] South Eastern Forest Experimental Centre, Forest Science Institute of South Vietnam
[2]Institute of Forest Tree Improvement and Biotechnology

The objective of this research was to understand possibilities of genetic improvement of *Eucalyptus pellita* for sawn timber production in Vietnam. A total of 160 trees from 40 open pollinated families were randomly selected in an 11 year old progeny trial in Pleiku, Gia Lai province. From wood billets collected at 1.3–2.0 m height, wood basic density, directional shrinkage (tangential, radial and longitudinal), modulus of elasticity (MOE) and modulus of rupture (MOR) at 12 MC were studied. Mean basic density was 584 kg m^{-3}; shrinkage was 4.2%, 2.7% and 0.1% in tangential, radial and longitudinal direction, respectively. The tangential/radial ratio was 1.6. MOE and MOR were 24.7 GPa and 208 MPa, respectively. Provenance effects were not significant for any of the wood properties. Individual-tree, narrow sense heritabilities were 0.46 for wood basic density, 0.33 for MOE and 0.52 for MOR; and those for both tangential and radial shrinkage were about 0.38. Coefficients of additive genetic variation for tangential and radial shrinkage, and MOR were high (9-11%) while those for wood basic density and MOE were low (4.5–5.0%). Genetic correlations between diameter at breast height and wood properties were low and not significant. The results suggest that genetic improvement for wood quality in *E. pellita* is achievable and selection for growth would not adversely affect wood quality. Because bending stiffness and strength is adequate, future genetic improvement of *E. pellita* should focus on improved growth and dimensional stability.

Oral Presentation

Future Prospects for *Eucalyptus* Plantations and the Role of Genetic Improvement

Rod Griffin

School of Biological Science, U Tasmania, Hobart, Australia

Likely development of eucalypt plantation forestry and wood utilization over the next 30 years is reviewed with comment on the extent to which breeding might contribute to the associated challenges to management and how breeders and genetic researchers might respond in setting their R&D priorities.

Breeding is an expensive and long term business and only justified in the absence of management or processing solutions. Objectives must focus on traits of generic value such as improved volume yield, adaptation to site and pest and disease resistance.

The pulp and paper industry is by far the largest user of plantation grown eucalypt wood and the major client for intensive breeding technology. However the future for paper is quite unclear and there are moves to consider the tree more broadly as a natural product factory, with all components of wood have potential value, transforming the pulp mill into a biorefinery. Increased cellulose content and reduced cost of pulping will remain of value whatever the end products.

Eucalypt wood is important for solid wood products, biofuel and carbon sequestration, but costs of breeding specifically for these small or low value markets is hard to justify.

Oral Presentation

Genetic Analysis of Adaptive and Growth Characteristics for Short-rotation Eucalypt Clones at Hillsides of West-Central Guangdong, South China

Runpeng Wei

Weirptech Bioresources Limited, F, 28/F Fullview Court, 32 Fortress Hill Road, North Point, Hong Kong

In China, most of the eucalypt plantations are distributed in hilly and low-mountainous forestlands where are embedded with huge varying environmental conditions. Choice of proper sites for genetic testing becomes critical in revealing genetic and environmental variation and their interaction, and selecting best varieties for different planting zones to gain high yield. The present study tested 72 clonal varieties selected from multiple eucalypt species and hybrids at two typical hilly sites in the central western Guangdong. Conventional silviculture operations for most commercial eucalypt plantations were adopted over the testing period, mainly including: 1) tree spacing = 3 × 2 m; 2) planting hole size = 50 × 50 × 40 cm; 3) tissue-cultured cuttings as planting materials; 4) 300 g of basal fertilizer (N:P:K=8:15:7) applied before planting; 5) 500 g of topdressing fertilizer (N:P:K=15:8:7) applied separately for the second and third years, each combined with weeding; 6) planted in June, 2007.

Genetic analysis was carried out to each of two testing sites with 60 and 58 clones respectively, and combined two testing sites with 46 common clones. The result indicated that clonal variation in annual and cumulated survival changed from insignificant to significant in early ages (<=2-yr), and reached significant level from 3 to 6 years old. Tree growth and form traits differed at a high level of statistical significance among clones involved from year 1 to 6 ($P<0.001$). The interaction of clonal and environment influenced greatly on tree growth and form traits ($P<0.001$), but the annual and cumulated survivals ($P>0.05$). The clonal mean repeatability of tree survival trended to increase over ages but was relatively low, indicating the major role of the environmental conditions in this adaptive trait. Also increasing over ages, the clonal mean repeatability of tree growth and form traits ranged from medium to high level, and ranked in order from high to low by individual volume, diameter at breast height, tree height and ratio of tree height to diameter at breast height. All traits studied had strong age to age genetic correlation, particularly those after 18 months old ($P<0.01$). Genetic correlation was also analyzed between different traits, and sites as well.

Key words: eucalypt, clone, site, adaptability, growth, repeatability

Oral Presentation

Applying Marker-assisted Selection in Eucalypts

Bala Thumma, Saravanan Thavamanikumar, Jeremy Brawner and Simon Southerton

Gondwana Genomics Pty Ltd: 1 Wilf Crane Crescent Yarralumla ACT 2600 Australia

The impact on the profitability of eucalypt-based industries that may be realized from selecting seedlings using their DNA profiles has led to significant investments in the development of marker-assisted selection (MAS) technologies. Application of MAS will lead to larger genetic gains by increasing the selection intensity and shortening the breeding cycle through early selection. While much of the tree breeding community has followed livestock research into a genomic selection (GS) approach that uses thousands of randomly spaced markers, we have developed a method (allelic selection-AS) to target genes that regulate traits of interest. AS provides robust predictions of genetic merit in unrelated populations and distinct environments and does not require the development of expensive and time-consuming training populations such as those required by GS.

We tested this method in several species of eucalypts including *E. nitens*, *E. globulus*, *E. dunnii*, *E. camalduensis*, *E. grandis* and *E. pellita*. We observed robust accuracies for predicting different traits in all species. For example, in *E. globulus* we developed a prediction model using small numbers of markers associated with pulp yield and growth. When we applied this model to predict these traits in an unrelated clonal testing population growing in a different environment we observed a predictive ability (correlation between phenotype and marker breeding values – MBVs) of 0.68 for pulp yield and 0.45 for growth. Similarly, in *E. dunnii* we observed a predictive ability of 0.50 for pulp yield in a clonal seed orchard. These predictive abilities equate to accuracies of 0.60 to 0.90 depending on the assumed heritability of the trait. Integration of the technology into existing tree improvement programs will be discussed. Currently we are applying this approach in breeding programs of several commercial partners.

Oral Presentation

The Journey to Successful Commercial Propagation and Deployment of *Eucalyptus dunnii* Cuttings

Damien Naidu[*]*, Nicky Jones*

Sappi Forests

Currently, *Eucalyptus dunnii* is a widely planted temperate species on Sappi land holdings within South Africa. Advantages of the species include fast growth on poor sites, good stem form, abundant early flowering and desirable wood properties for chemical cellulose and paper production. Disadvantages of the species include susceptibility to frost, snow and *Gonipterus scutellatus* snout beetles. The species is typically propagated via seed due to recalcitrant rooting. Numerous initiatives are described in this paper to ameliorate the rooting thus enabling the viable commercial propagation and deployment of *E. dunnii* cuttings which offer superior fibre gain over seedlings.

Within South Africa, initial efforts in the late 1990's to vegetatively propagate *E. dunnii* proved futile with rooting from field coppice recorded at 13%. Efforts to hedge the species in an outdoor clone bank only improved rooting slightly to 15%. In 2008, growing mother stock plants in bags and providing good plant nutrition yielded a rooting of 32%. Comparatively, mini-hedges planted in sand beds rooted significantly better than bags at 37%. Various techniques to improve the vegetative propagation success of the species were adopted and these enhancements increased the rooting percentage to 45%. In 2011, supplemental foliar fertiliser application to mini-hedges resulted in faster and better rooting making commercial propagation via cuttings viable at 53% rooting success. More recently, the effect of cutting position on the mini-hedge has been investigated. For *E. dunnii*, harvesting coppice shoots from particular positions on the mini-hedge has improved rooting to 58%. Variation in rooting exists within the species population indicating feasibility of genetic selection to clonally propagate *E. dunnii* and further enhance rooting to above 60%.

Early indications have suggested superior initial survival and growth of *E. dunnii* mini-cuttings compared to seedlings.

Key words: mini-cuttings, *Eucalyptus dunnii*, propagation, rooting

Oral Presentation

Optimization of Nuclear Isolation Buffers for Plant DNA Flow Cytometry of *Eucalyptus*

C. Han, J. M. Xu**, J. M. Su, Y. T. Su*

Research Institute of Tropical Forestry, Chinese Academy of Forestry, Guangzhou, 510520, P. R. China.
***Corresponding author. E-mail: jianmxu@163.com*
** first author. E-mail: charleshhan@gmail.com*

DNA flow cytometry of *Eucalyptus* requires preparation of suspensions of intact nuclei, which are stained using a DNA-specific Fluor chrome prior to analysis. Various buffer formulas were developed to preserve nuclear integrity, protect DNA from degradation and facilitate its stoichiometric staining. Although nuclear isolation buffers differ considerably in chemical composition. This study was to select the appropriate buffer for *Eucalyptus*. Six buffers (Galbraith's, LB01, Otto's, Tris.MgCl2, GPB and WPB) were used to prepare samples from leaf tissues of *Eucalyptus*. The following parameters were assessed: forward (FS) and side (SS) light scatters, fluorescence of propidium iodide-stained nuclei, coefficient of variation of DNA peaks, presence of debris background and the number of nuclei released from sample tissue. According to the result of this study, LB01 were generally the best buffers which could provide better results in *Eucalyptus* with relatively old leaves. GPB buffer was generally the worst buffers. The tendency of leaf is crucial for the outcome of DNA flow cytometry, the newborn leaves can get best outcome.

According to this analysis result of flow cytometry, tetraploid, mixoplioidy and aneuploid plantlets of clone DH32-29 of *Eucalyptus* were all obtained with the introduction of colchicine. All of these genotypes can grow well. The proportion of intact tetraploid is 5% or so when the seedling height reached 30 centimeters or so. Compared with usual species, the inductivity rate is relatively lower. Compared with diploid plants on morphological characteristics, tetraploid plants have thicker leaves, about 2 times larger leaves, darker leaf colour. This apparent characteristics could offer certain help to recognize tetraploid plants from diploid plants.

Oral Presentation

The Innovation of Developing and Technologies in Chinese *Eucalyptus* Veneer's Industry

Zhilin Chen

Chinese Research Institute of Wood Industry, Chinese Academy of Forestry, Beijing, 10091, China

The eucalyptus wood mainly uses in the papermaking, the fiberboard, and the plywood production in China, but the eucalyptus wood has the high growth stress, easy to have the dry shrinkage and the internal crack, the size stability is bad, easy to twist, the distortion in the processing process, difficulty in bonding. When the wood was used in the veneer industry , the prominent question is the diameter level small, yield of green veneer is low, the stress is big, the veneer crack are many. In China, with the technological innovation, such as spindle-less lathes, the patching in piece veneer, the modified adhesive, hybridizing of eucalyptus veneers and poplar veneers, thermo-compression step by step, decorating in the face veneers, The key technologies has solved the eucalyptus plywood problem of technology processing, and promoted the eucalyptus industry development.

Fast Growing Eucalypt Trees – the Applicable Solution for Sustainable Development of China's Pulping Industry

Guigan Fang, Kuizhong Shen and Yongjun Deng

Institute of Chemical Industry of Forest Products, Chinese Academy of Forestry, 210042 Nanjing, Jaingsu, PRC

The current situation of China's pulping and papermaking industry was analyzed, the component of fibrous raw materials supply illustrated in detail. Comparison and pulping suitability evaluation of commercial woodchips of major Eucalyptus spp. grown in China. Relations of pulping performance vs. Eucalyptus species using chemical pulping process and chemi-mechanical process were regressed and appropriate Eucalyptus spp. were recommended. The scientific issues that should be paid attention to the development of Eucalyptus fiber raw materials are summarized, which provides a theoretical reference for the directional cultivation of eucalypt pulp wood forest.

Key words: Pulping and papermaking, Eucalyptus spp., chemical pulping, chemimechanical pulping, pulping performance

Oral Presentation

Using Established Principles and Simple Models to Quantify Water Use by Plantations of *Eucalyptus* in SE Asia and China

Donald White[1,5], Ren Shiqi[2], Tran Lam Dong[3], Jetsada Wongprom[4], Khamphone Mounlamia[6], Apeng Du [7], Roger Arnold[7], Dongyun Xiang[2], Stephen Midgley[8]

(1.Murdoch University; 2.Guangxi Forest Research Institute; 3.Vietnamese Academy of Forest Sciences; 4.Kasetsart University; 5.University of Tasmania; 6.National Agricultural and Forest Research Institute Laos; 7.Chinese Eucalypt Research Centre; 8.Salwood Pacific PL)

Over the last few decades the global expansion of *Eucalyptus* plantations has been accompanied by legitimate concerns about their effect on local people and natural resources. *Eucalyptus* species have a particular reputation for high rates of water use. This reputation is largely untested in tropical and monsoonal climates and the few complete studies in Brazil and China have reached very different conclusions. Every plantation is established under a unique combination of site and climatic conditions and experiences a unique sequence of weather between planting and harvest. While plantation water use is situation specific there are general principles that can guide understanding and assist in land use and water resource planning. This paper will present results of a recent project to review the science on water use by *Eucalyptus* plantations and develop and apply a tool for assessing the potential impact on water resources of plantation establishment in SE Asia and China.

A steady state model and a monthly water balance model developed were used to estimate the potential water use by *Eucalyptus* plantations in the major plantation growing regions of South Eastern China, Laos, Vietnam, Thailand and Indonesia. Even in low rainfall years predicted runoff was nearly 50% of rainfall throughout Malaysia, Indonesia, Southern Thailand and Northern Vietnam and Guangdong and Southern Guangxi provinces in China. In central and Southern Vietnam, Central and Northern Thailand, Southern Laos and in Central Guangxi plantations are unlikely to reduce annual runoff to less than 30% of rainfall even in dry years but may have some important effects of dry season flow in small upland catchments. Dry season flow is an under researched area of forest hydrology that should be the focus of future efforts in SE Asia.

Oral Presentation

Bird and Plant Diversity of Stora Enso's *Eucalyptus* Plantations of Southern Guangxi, China

Xingfeng Zhao

Project Manager, Fauna & Flora International China Programme

Eucalyptus plantations have undergone rapid development in Guangxi Zhuang Autonomous Region, which is ranked as the third province leading province in China for richness of biodiversity. Some government authorities and members of the public have expressed concerns that intensively managed eucalypt plantations might have unexpected impacts on biodiversity. Therefore, there is a need to monitor the changes of biodiversity within the existing ecosystems with the combination of plantation, public welfare forest and natural forest. Guangxi Stora Enso Forestry Co., Ltd. (hereinafter referred to as "SEGX") was established in 2002 with the purpose to establish 120 000 -130 000 ha of *Eucalyptus* fiber base in total land area in south of Guangxi. Fauna and Flora International (hereinafter referred to as "FFI") is a non-government organization which focuses on biodiversity conservation. In 2010, SEGX and FFI began cooperation for carrying out independent and sound biodiversity monitoring through a participatory approach. The long-term monitoring is expected to enhance stakeholders' understanding of its potential impacts on biodiversity as well as improve effectiveness of management responses for better practices.

Differences and the dynamics of biodiversity in plantations of different ages, land condition and management measures both in *Eucalyptus* plantation and non-eucalyptus woodland/ forest areas will be compared. Totally 10 monitoring sites in Guangxi Stora Enso Forestry's plantations were selected. Birds and plants will be the focus of biodiversity monitoring. Since the cycle from establishment through to harvesting of *Eucalyptus* plantations usually takes 6 to 7 years, the monitoring will be continued for at least 6 years.

Since 2011, totally 4 years of biodiversity monitoring has been conducted. The monitoring results have already presented some interesting findings. The first key result was that non-eucalypt woodlands/forests can keep high biodiversity and can become refuges and critical habitats of some birds. The diversity of birds in *Eucalyptus* plantations was found to increase year by year from 2011 to 2014. The numbers of bird species also increased to 58 in 2014 from 35 in 2011; meanwhile the population density (individuals/ha) increased to 3.27 in 2014 from 0.96 in 2011. The diversity index (Shannon- wiener index) also increased to 3.11 in 2014 from 2.82 in 2011. Meanwhile, numbers of bird species, population density and bird diversity in non-eucalypt woodland/forest monitoring areas were much higher than that of *Eucalyptus* plantations. For plant diversity, the diversity of plant species in 10 monitoring sites of *Eucalyptus* plantations was increased year by year from 2011 to 2014. The plant diversity of non-eucalypt woodlands/forests was higher than that of *Eucalyptus* plantations. The non-eucalypt woodlands/forests can keep diversity of important tree species (such as *Litsea glutinosa*) which can offer nesting sites for some birds' species. Based initial monitoring result, we suggested that SEGX should make best use and management of non-eucalypt woodlands and forests and restore natural vegetation if possible and appropriate. We also suggest SEGX should, as a priority, forbid the use of burning for site preparation before plantation establishment.

Oral Presentation

Preliminary Study of the Runoff and Runoff Processes of Two Kinds of Forest Watersheds

Hongwen Liang [1], Jinchuan Guo [2], Wei Pan [2], Ronghui Li [2], Xiaoqiong Li [1]

1.Guangxi University, Nanning 530004, P.R. China; 2. Guangxi Zhuang Autonomous Region Hydraulic Research Institute, Nanning 530001, P.R. China

The runoff and runoff processes of *Eucalyptus* and *Pinus massoniana* forest watersheds were studied to provide guidance for scientific evaluation of water conservation capacities of forest. The runoff characters of *Eucalyptus* and *P. massoniana* forest watersheds were continuously monitored using the small watershed runoff monitoring method and the automatic data collection devices from August, 2013 to July, 2014, and effects of heavy rainfall and continuous rainfall on the runoff processes were studied. Experimental results show that the annual runoff and the runoff coefficient of *Eucalyptus* forest watershed were 1077.28 m^3/ha and 8.16%, respectively, while that of *P. massoniana* forest watershed were 3193.78 m^3/ha and 24.2%, respectively. When there was no runoff, runoff duration, time lags, maximum runoff of rainfall, and runoff amounts caused by a heavy rainfall process (amounting to147.5 mm) between the two kinds of forest watershed were significant different: those of *Eucalyptus* forest were 13.8 h, 0.2 h and 355.76 m^3/ha, respectively, while those of *P. massoniana* forest watershed were 35.5 h, 0.7 h and 284.65m^3/ha, respectively. *Eucalyptus* forest watershed produced only 4 days runoff amounting to 37.99m^3/ha with a 7 days continuous precipitation process of rainfall with 125.0 mm, while *P. massoniana* forest watershed produced continuously 13 days runoff, and the runoff volume was 100.44 m^3/ha. In conclusion, water conservation capacity of *P. massoniana* forest is obviously better than *Eucalyptus* forest.

Key words: *Pinus massoniana* forest, *Eucalyptus* forest, watershed, runoff volume, runoff processes

Oral Presentation

Eucalyptus Trees for Biological Drainage as a Climate Change Adaptation and Mitigation Strategy

Beckline Mukete

Department of Forest Management, Beijing Forestry University, China

There are no drainage systems in low-lying coastal areas of Cameroon which are constantly flooded during the rainy season. At the onset of the rainy season, water tables rise resulting into aggressive floods. These constant flooding decreases soil fertility while it increases soil salinity and water logging as well as destroying farmlands, homesteads and roads. This study is based on the premise that, planting trees belts across low-lying constantly flooded landscapes increases infiltration of water into the soil thus contributing to flood risk mitigation.

The objective:

The overall objective of this study is to identify key low-lying areas that are prone to floods during the rainy season.

Why *Eucalyptus*?

Due to:

- it is deep rooted
- suitability for wind breaks
- tolerance to increasing soil salinity and water logging
- its capacity to store carbon which makes it useful in climate change mitigation

The Method:

In Bekora Barombi of South West Cameroon, 1000 saplings of ages 1-2 years (young trees) from established nurseries were planted in rows about 5m wide, separated by 5-10m strips at the start of the rainy season. The saplings were weeded and their lower branches pruned to encourage growth.

Expected Results:

The study expects:

- Reclamation of degraded land
- Increased crop production
- Increased Land-user incomes
- Improvement of soil structure, lowering of acidity, waterlogging and salinity
- Biodiversity enhancement and availability of recreational area
- Increase in wood for timber and fuel production
- Improvement in knowledge on soil and water conservation as well as erosion prevention methods

Conclusion:

The study is based on the premise that, effects on local scale surface floods can be large and not supported by local monitoring. Also that, significant effects on flood flows at small scale catchments can be identified when moving from intensively farmed. This indicates that, the potential benefits of low-footprint tree planting can be significant at that scale in terms of reducing flood peaks. At larger scales, impacts on flood flows could not be discerned. However, in order to elucidate the true value of land use management, more work is needed to understand the interactions between floods and local environment at multiple scales. Other priorities for further work include, strengthening the link between sciences and visualization tools and addressing the need for more, longer-term field experiments.

One Step Forward, Two Steps Back: Managing Eucalypt Pests for Sustainable Forestry

Jolanda Roux, Brett Hurley, Jeff Garnas, Bernard Slippers, Michael J. Wingfield

Tree Protection Co-operative Programme (TPCP), Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, South Africa
Jolanda.roux@fabi.up.ac.za

The success of plantation forestry utilizing non-native species, such as eucalypts, has been attributed, at least in part, to the separation of these trees from their natural enemies, i.e. “enemy release”. This “release” of eucalypts, as well as other plantation forestry species from their natural enemies has allowed these trees to grow vigorously in their new environments. However, over time, pests (including pathogens and insects) have moved into these new environments where eucalypts have been established. In these situations, where the trees typically have lower levels of genetic diversity and resilience to pest infestation/infection, significant losses often result. Studies monitoring the appearance of pests in plantations of non-native eucalypts have shown increases in number and regularity in their appearance over time. The pests involved commonly reach these new environments via the movement of asymptomatic, infected plant material. With the globalization of forestry companies, this appears to be a growing trend that is also apparently gaining momentum. This is placing significant strain on plant health specialists and tree breeders seeking to reduce the impact of these pests. Even with the implementation of so-called “new technologies”, forestry industries are likely to continue to face challenges from increasing numbers of eucalypt pests. The investment in pest management strategies including for example, biological control programmes and tree breeding, without stricter management of plant movement is similar to taking one step forward and two steps back. The continued movement of plant material is essentially undermining years of investment in forestry and forestry research. Without more effective quarantine, both at the levels of governments and internally within companies, industries will continue to suffer losses from pests. A concerted effort is clearly needed to increase responsible trade and plantation development. Training in, and the application of responsible forestry practices, an increase in human capacity in tree health management and associated breeding strategies, as well as support for forestry research is required if sustainable eucalypt plantation forestry is to be maintained.

Key words: Quarantine, fungal pathogens, insect pests

Oral Presentation

Abiotic and Biotic Stressors Constraining Productivity of Eucalypt Plantations in the Asia-Pacific Region

Bernard Dell[1], Pham Quang Thu[2], Daping Xu [3], David Boden[4],Richard Harper[1]

[1] School of Veterinary and Life Sciences, Murdoch University, Perth, Australia
[2] Forest Protection Research Centre, Vietnamese Academy of Forest Sciences, Hanoi, Vietnam
[3] Research Institute of Tropical Forestry, Chinese Academy of Forestry, Guangzhou, China
[4] Boden and Associates, Queensland, Australia

Abiotic and biotic constraints to the success and productivity of eucalypt plantations have been documented and managed ever since eucalypts were first grown in industrial plantations. However, new pests and disease outbreaks continue to emerge and well known abiotic causes of tree under-performance continue to surprise plantation managers. This paper will examine recent occurrences and trends in abiotic and biotic stressors in established and new eucalypt plantations in the Asia-Pacific region and reflect on how changes in climate might exacerbate their impact. Information will be drawn from recent events in Australia, Malaysia, Vietnam and China. For Australia, this will also include examples of emerging problems within natural eucalypt forests. Examples of constraints discussed include wilt disease and gall wasp damage, soil infertility and compaction, climate extremes and water availability. Options for minimising constraints are considered and research needs identified.

Oral Presentation

Eucalyptus Plantation Disease Research in China: Past, Present and Future

ShuaiFei Chen[1,2], GuoQing Li[1], FeiFei Liu[1], JieQiong Li[1], QianLi Liu[1], Jolanda Roux[2], Michael J. Wingfield[2]*

[1]China Eucalypt Research Centre (CERC), Chinese Academy of Forestry (CAF), ZhanJiang 524022, GuangDong Province, China

[2]Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0028, South Africa

[*]Corresponding author e-mail: shuaifei.chen@gmail.com

Oral Presentation

Plantation forestry based fast-growing trees, especially species of *Eucalyptus,* has expanded rapidly in China during the past three decades to meet the increasing demand for pulp and paper. Currently, approximately 4.6 million hectares of *Eucalyptus* plantations have been established in South China. Focus in the past has been on the selection of rapidly growing *Eucalyptus* clones. However, during the course of the last decade, several disease and pest problems have emerged in these plantations. Diseases include stem canker/wilt caused by species of Botryosphaeriaceae, *Ceratocystis*, *Chrysoporthe* and *Teratosphaeria*, leaf blight/spot caused by species of Teratosphaeriaceae, Mycosphaerellaceae, *Calonectria* and *Quambalaria*, seedling stem/leaf rot caused by species of *Botrytis* and *Calonectria*, and bacterial wilt associated with *Ralstonia solanacearum*. Contemporary studies have shown that the species and genetic diversity of some of these pathogens is very high, suggesting that they might have evolved in China. We have conducted field trials to test the pathogenicity of these fungi on commercially grown *Eucalyptus* clones and results have shown that there are significant differences in the susceptibility of these clones to the tested fungi. This clearly indicates an opportunity to select resistant material for commercial planting in the future. There is little doubt that the number of disease problems on *Eucalyptus* species in China will continue to grow, similar to the experiences of other countries. In future, more extensive research regarding pathogens that threaten *Eucalyptus* health in China will need to be conducted. These studies should seek to more accurately understand the distribution, genetic diversity and biology of the pathogens and to screen for disease tolerance in *Eucalyptus* clones. Such research results will support integrated strategies for disease management to ensure a sustainable *Eucalyptus* industry in China.

Three Genetic Groups Amongst African Isolates of the *Eucalyptus* Stem Canker Pathogen *Teratosphaeria zuluensis*

L Jimu [ac], SF Chen [b], MJ Wingfield [b], E Mwenje [c], J Roux [b]

[a]Department of Plant Production and Soil Science, Forest Science Postgraduate Programme, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Private Bag X20, Hatfield, Pretoria 0028, South Africa

[b]Department of Microbiology and Plant Pathology, FABI, University of Pretoria, Private Bag X20, Hatfield, Pretoria 0028, South Africa

[c]Bindura University of Science Education (BUSE), P. Bag 1020, Bindura, Zimbabwe

Oral Presentation

Teratosphaeria stem canker of *Eucalyptus* caused by *Teratosphaeria zuluensis* was discovered in South Africa in 1988. Since that time, the pathogen has been reported from several countries in eastern and southern Africa, south-east Asia and central America. Interestingly, *T. zuluensis* is not known in Australia where most *Eucalyptus* species have their origin. In this study, the population structure and genetic diversity of *T. zuluensis* were analysed using microsatellite markers to gain an improved understanding of its movement in Africa. Isolates were collected from several sites in Malawi, Mozambique, Uganda and Zambia. Data obtained were compared with those previously published for a South African population. The data from 334 isolates, amplified across eight microsatellite loci, were used for assignment, differentiation, genetic diversity and recombination tests. Bayesian analysis conducted in STRUCTURE, UPGMA and principal component analysis revealed the existence of three genetic groups, one dominated by isolates from South Africa, another by isolates from the Zambezi basin including Malawi, Mozambique and Zambia as well as an admixed group. High levels of admixture were found within and among populations, dominated by the Mulanje population in Malawi. Moderate to low genetic diversity of the populations supports the view that the pathogen was introduced into Africa. The clonal nature of the Ugandan population suggests a very recent introduction, most likely from southern Africa.

Key words: Admixture, evolutionary history, multi-locus genotype, population structure, genetic diversity

Ecological Effects of Endemic Pests on *Eucalyptus* Plantations in China

Yaojun Wu, Mingshan Chang, Dewei Li, Huayan Huang, Ji Luo

Guangxi Zhuang Autonomous Region Forestry Research Institute, Nanning 530002, China

Eucalyptus plantations in southern China have expanded dramatically in the past 30 years. Success of these intensively managed plantations is largely attributed to the fact that trees have been separated from their natural enemies. Due to increasing rates of invasive and unexpected native pests and pathogens infecting eucalyptus, *Eucalyptus* plantations are facing a growing risk of biohazard. However, the ecological impacts still cause serious concerns. According to the investigation and reports, over 400 species of insect pests feed on eucalyptus in China. Among them, just a few species like *Leptocybe invasa* Fisher & LaSalle, *Blastopsylla barbara* Li, etc., can be identified to be invasive. The course of the host shifts of local insects appears to be initiative and passive, some species like termites, that have a feeding preference for eucalyptus, become the eucalyptus pests at the soonest; the eruptive endemic pest *Buzura suppressaria suppressaria* (Guenee), for its short life history, high fecundity and easy acquisition of host-shift ability, has developed into a widespread eruptive eucalyptus pest; more and more latent crop pests like *Orgyia postica* Walker, *Ectropis grisescens* Warren, *Trabala vishnou* Lefebure, *Anua indiscriminata* Moore, *Darna trima* (Moore), *Anomala corpulenta* Motschulsky, etc., have been evolving into regional harmful or eruptive eucalyptus pests; most seriously, more and more species with no damages recorded, even species rarely encountered in local forest ecosystems, such as *Jankowskia fuscaria* (Leech), *Suaoa dicisa* (More), *Compsogenepanopus* (Cramer), *Endoclyla signifier* Walker etc., have also been evolving into regional harmful or eruptive eucalyptus pests. As a result of destroying the native vegetation and community construction due to the large-scale pure *Eucalyptus* plantations, many local heterophagous insects are forced to feed on eucalyptus trees, and evolve into adaptive populations with high fecundity, on account of the rich food resources and weaker control functions. This is a situation that more and more harmful species and bigger populations of endemic pests are emerging in local ecosystems, there is also growing evidence that outbreaks of these indigenous pests increase damages to crops and wild trees or shrubs. Management countermeasures to this situation should be scientific planning and cultivation methods of the exotic plantations.

Key words: ecological effects, endemic pests, *Eucalyptus* plantations

Oral Presentation

Global Patterns of Spread of Invasive Insects on Eucalypts

Brett P. Hurley[1], Jeff Garnas[1], Michael J. Wingfield[2], Manuela Branco[3], David M. Richardson[4], Bernard Slippers[5]

[1]Department of Zoology and Entomology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002, South Africa
[2]Department of Microbiology and Pathology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002, South Africa
[3]Centro de Estudos Florestais (CEF), Instituto Superior de Agronomia, Technical University of Lisbon, Lisbon, Portugal
[4]Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Matieland 7602, South Africa
[5]Department of Genetics, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002, South Africa

Oral Presentation

Native to Australasia, *Eucalyptus* is one of the most planted genera of trees in the world. However, the sustainability of *Eucalyptus* as plantation species in non-native areas are increasingly threatened by the introduction and spread of *Eucalyptus*-feeding insects from Australia. We examine patterns and potential trends with respect to the global spread of *Eucalyptus*-feeding insects. Likely pathways of introduction and drivers of the rapid distribution of these insects, as well as management options are considered. The rate of introductions is shown to have increased nearly five-fold since the 1980s. As a result, the number of non-native pests of eucalypts outside of Australia has doubled in less than three decades. Furthermore, the rate of secondary spread among continents has also increased. Surprisingly, no association between area planted and the number of pests or new introductions was found. In addition, only a small number of countries have been the points of first introduction outside the native range. Quarantine regulations aimed at reducing the spread of invasive organisms appears to be ineffective at a global scale, with pathways allowing these invasions to occur being poorly understood or unknown. In order to ensure the sustainability of eucalypt forestry worldwide, an expanded suite of management options will be required to provide resilience against the rapid accrual and homogenization of eucalypt pests.

Key words: biological invasions, *Eucalyptus*, bridgehead effect, pathway management, forestry, pest homogenization

Developing a Plantation Eucalypt Saw Log Timber Resource for Southern China

Kevin Harding[1,2], *Dongyun Xiang*[2]

1. University of Sunshine Coast, Qld, Australia; 2. Guangxi Forest Research Institute, Guangxi, China

China's plantation eucalypt resource has expanded rapidly since the 1980's. Initially this expansion was to supply the developing domestic pulp and paper industry. As China's economy grew and massive scale urban high-rise construction, transport and road infrastructure was undertaken over the last two decades a veneer and plywood industry also developed to supply structural form-ply panels. Rotation lengths for wood chip and ply wood products commonly range from 3 to 7 years. These short rotation lengths have created some concerns about long term sustainability and generated interest in longer saw-log rotations of 15 -18 years that would benefit some sites.

Eucalypt plantation genetic resources in China encompass a range of key species and hybrids that were developed for pulp and paper and have been utilised for veneer logs. Some good saw log species were trialled but not persisted with due to their lower suitability for pulp and paper products and new introductions and species trials are needed to provide some additional high quality sawlog options. Nevertheless, much of the genetic base for the current eucalypt resource is well suited for sawn timber products. The large populations of the key species under the co-operative management of the Chinese Eucalypt Breeding Alliance (CEBA) provide a valuable base for hybridisation and pure species selection for saw logs. Most selection traits emphasised in the CEBA breeding plans are those required for sawlogs with perhaps a stronger emphasis on stem straightness and a need to screen for propensity to split and sawing performance. The range of species and hybrid options recommended for sawlog management will be discussed along with the selection traits of importance to produce high yield and sawn product quality.

The saw log resource will encompass clones and selected family progenies depending on the ease of propagation of the various parent species and their hybrids. China has a wealth of existing genetic resources and will complement this with new species introductions. However, currently available sawing and drying technology is generally poor and needs to be improved to produce high quality and high value sawn products. Future marketing opportunities for this sawlog resource are likely in both domestic and international export markets. Technology and product requirements to produce high value returns will be outlined.

Current Research and Utilization of Essential Oil and Polyphenols from *Eucalyptus* Leaves

Yong Cao, Yunjiao Chen, Wei Li, Rongwei Tan

College of Food Science, *South China Agricultural University, Guangzhou, Guangdong* 510642, *China*

Eucalyptus is a large genus of the Myrtaceae family. They are planted widely in our country and a large number of *Eucalyptus* leaves are wasted after the production each year. Studies showed that chemical composition of *Eucalyptus* essential oil is complicated, which may be composed of dozens or even hundreds of different ingredients mainly including aromatic, aliphatic and terpenoids. *Eucalyptus* leaves also has a large number of active polyphenols which include phloroglucinol compounds, flavonoids and tannins. *Eucalyptus* essential oil are widely used in the fields of food, chemical, pharmaceutical, environmental and spices. As a natural antioxidant, *Eucalyptus* polyphenols can be developed into food antioxidants, cosmetic additives, feed antioxidant, feed meat quality improver, and other products. This article summarizes the current situation of research and utilization of *Eucalyptus* essential oil and polyphenols from *Eucalyptus* leaves, and further expand its application prospect.

Assessment of Plantation-Grown *Eucalyptus pellita* in Borneo, Malaysia for Solid Wood Utilisation

Hii Sii Yew[1], Ha Kii Su[1], Ngui Ming Lung[1], Sato Junior Ak Penguang[1], Roger Meder[2]

1. *Jaya Tiasa, Pusat Suria Permata, Sibu, Sarawak 96000, Malaysia*
2. *Meder Consulting, PO Box 3185, Bracken Ridge, QLD 4017, Australia*

Eucalyptus pellita was introduced to the Sarawak and Sabah States of Malaysia on the island of Borneo in the last twenty years with provenances from Queensland and Papua New Guinea. The species is well established in Indonesia, particularly Sumatra, as a pulp species but it is also well suited to solid wood end-use. There is relatively little published data on the solid wood end-use of *E. pellita* apart from some recent work in Queensland, Australia and in Vietnam. This study describes initial data obtained from a sawing and peeling study of 7 yo and 9 yo *E. pellita* grown in Sarawak.

Standing trees were assessed for growth and form and their acoustic velocity measured via Fakopp. From initial measurement a total of 10 trees were selected at each site for felling. Individual logs (2.6 m) were similarly measured using the Fibre-Gen HT200. The butt, third and fourth logs were peeled to produce either face-back or core veneer while the second log was sawn to produce solid timber.

Plywood produced from the veneer using a UF resin passed JAS standards for F1 emission and mechanical properties, with shear, strength and stiffness exceeding JAS requirements. Although 0.6 mm face-back veneer was able to be recovered, only a small fraction was of sufficient appearance quality due to the presence of knots. This is due to progressive pruning not being in place during the earlier silvicultural regime which has been adopted in recent years. Mean height and DBH for the standing trees was 25.0 m and 26.3 cm for the 9 yo stand and 26.6 m and 22.6 cm for the 7 yo stand. Log-level acoustic velocity ranged from 3.34 to 4.20 km/s across the two sites.

Significant degrade of the butt log was observed due to bit termite attack, heart-rot and end-splitting with the incidence of end-splitting lessening at logs taken from increasing height in the tree.

Analysis of the solid wood (drying degrade, dynamic MOE) is currently ongoing but expected to produce data in time for presentation at the conference. Initial results are available for recovery (43.2% for 9 yo and 40.2% for 7 yo sites), with boards currently being air-dried.

Oral Presentation

Eucalyptus camaldulensis — a Priority Species of Private Planters in Bangladesh

Mohammed Kamal Hossain

Institute of Forestry and Environmental Sciences
Chittagong University, Chittagong- 4331, Bangladesh
E-mail: mkhossain2009@gmail.com

Three species of *Eucalyptus*, e.g. *Eucalyptus camaldulensis, E. tereticornis* and *E. brassiana* were recommended for large-scale planting with the aim of fulfilling the huge demand of timber, pole, post and firewood of the country since the late 1980's in Bangladesh. Following a series of field trials, *Eucalyptus camaldulensis* – Petford provenance was found suitable and promising for large scale plantation programs in the country. But, the controversies of environmental degradation due to Eucalypt planting became an issue and the Bangladesh government issues an order not to planting the species furthermore in Forest Department plantation programs. However, the species is getting priority in private plantation programs because of its quick growth, early return, and wider adaptability of the species in a diverse range of lands. A wider scope of planting the species in marginal, homestead, agroforestry and private lands are significantly contributing in fulfilling the huge demand of rural people of the country. The present paper analyzed the prospects and problems of planting *Eucalyptus* in Bangladesh based on the growth performances of the species in the field and people's perception across the country in an aim to resolve the controversy of large scale plantation programs of *Eucalyptus*. Farmers planting the species in homesteads, marginal lands, and agroforestry programs and outstanding growth and productivity of the species make it a top priority species for small holders in most areas of Bangladesh.

Oral Presentation

Expression Analysis and Development of Co-expression Networks of PEG Induced Water stress Responsive Genes in *Eucalyptus grandis*

Modhumita Dasgupta[*], *Veeramuthu Dharanishanthi*

Institute of Forest Genetics And Tree Breeding, India

Water stress is identified as a major abiotic stress limiting growth of plant species worldwide, followed by salinity, acidity and low temperature. Ecophysiological studies in *Eucalyptus* has shown that water is the principal factor limiting stem growth. The present study was conducted to identify the differentially expressed PEG induced water stress responsive genes in *E. grandis* and develop gene co-expression networks to identify major candidates in water stress tolerance.

Forty day old rooted cutting of *E. grandis* was subjected to -0.225 MPa polyethylene glycol (PEG) treatment and total RNA was isolated from leaves of water treated control and PEG treated samples after three hours of treatment. The differential expression of water stress responsive genes were documented by microarray analysis. An array representing 3359 water stress responsive genes from *E. camaldulensis* was designed and printed. Two dye labeling was done and dye-specific bias effects, commonly observed in the two-color microarray platform, was corrected using the Dye-Swap design. Experiments were conducted in three biological replicates. The gene ontology (GO) analysis of differentially expressed genes in the array was conducted using Cytoscape with GeneMania plugin. A correlation matrix of all shortlisted genes was constructed by calculating pair-wise Pearson Correlation Coefficient for genes using normalized expression value using the software Co-Express v1.5 with threshold of >0.90 and the co-expression network was constructed using Cytoscape ver 3.1.0.

The number of differentially expressed genes across control and treated samples were 1014 and the fold expression ranged from -3.09 to 5.10. A total of 447 genes were up-regulated while 567 were down-regulated at fold threshold of >0.8 and <- 0.8. GO analysis revealed that maximum representation of differentially expressed genes in the array were from GO responsive to water stimulus with 35 genes followed by response to water deprivation with 34 genes. A Co-expression network was constructed with 932 nodes and 60,309 edges using Cytoscape. The top co-expressed hub genes included Disease resistance protein (CC-NBS-LRR class) family, Adenine nucleotide alpha hydrolases-like superfamily protein, Uridine diphosphate glycosyltransferase, nine-cis-epoxycarotenoid dioxygenase, photolyase/blue-light receptor, raffinose synthase family protein and osmotin.

The coordinated analysis of gene expression patterns and co-expression network developed in the present study helped in identifying a number of candidate genes that are likely to be involved in PEG induced water stress responses in *E. grandis*. The study can be used to identify functional markers for tagging water stress tolerance in *Eucalyptus* species.

Key words: *Eucalyptus*, co-expression, gene network, water stress

Oral Presentation

Co-operative Improvement of Key Eucalypt Species in China

Roger Arnold[1], Jianzhong Luo[1], Wangong Lu[1], Chubiao Wang[1], Yan Lin[1]

China Eucalypt Research Centre
30 Mid Renmin Avenue, Zhanjiang, Guangdong 524022, P.R. China
E-mail: roger.arnold@y7mail.com

China currently has over 4.0 M hectares of eucalypt plantations. The largest areas of these are in warmer coastal regions of southern China, especially in Guangdong and Guangxi provinces. Hybrid clones of *E. grandis*, *E. urophylla*, *E. camaldulensis* and/or *E. tereticornis* comprise the vast majority of planting stock in these warmer areas. In cooler inland regions of southern China, tropical and subtropical hybrid clones from China's warmer areas have proved ill adapted, due to frequent winter frosts and cold events down to -8°C or lower. Cold tolerant species that have shown the best adaptation and yields in such cooler sites have been *E. dunnii* and *E. benthamii* at lower elevations (<1000 m asl), and *E. globulus*, *E. maidenii* and *E. smithii* at somewhat drier, higher elevation (>1000 m asl) sites.

Substantial resources have been devoted to eucalypt improvement and breeding in southern China over the past 30 years or so. And, up till 2005, and many thousands of eucalypt families, including hundreds of hybrid families, had been produced and included in field trials. However, the number of clones selected from these and then used commercially on a significant scale remained relatively small and very little progress had been made to breed and progress beyond first generation genetic material.

So, in 2006 the China Eucalypt Breeding Alliance (CEBA)[1], led by the China Eucalypt Research Centre, was formed to bring key research institutes to work together with major growers on well planned and coordinated improvement programs that would increase the magnitude and speed of genetic gains in key commercial eucalypt species to benefit commercial growers. The key species for this cooperative breeding program are: *E. grandis, E. urophylla, E. tereticornis, E. camaldulensis* and *E. pellita*.

Work completed by the Alliance since its founding less than 10 years ago is discussed in this report. From the outset the priorities have been to develop large, advanced generation breeding populations to support ongoing recurrent breeding and selection, and to use these new advanced populations to provide new superior parents for development of new superior hybrid and pure species clones.

The interests of most Alliance members do not extend to cooler inland regions; in these regions the China Eucalypt Research Centre works bilaterally, or with small groups of local partners, on population improvement, and seed orchard development, of key cold tolerant eucalypt species.

1 The name of this collaborative alliance has since changed, it is now known as the "China Eucalypt Industrial Technology Innovation Strategic Alliance".

Hybrid *Eucalyptus* Development by Stora Enso for Pulp Production in Guangxi China

Youxu Cheng

Stora Enso Guangxi, Beihai, Guangxi, China

StoraEnso Guangxi is managing about 90,000ha plantation in the south of Guangxi China with 80% of the area for *Eucalyptus* and 20% is planted with non-*Eucalyptus* trees.

The Company started to plant locally developed *Eucalyptus* hybrid clones in 2003 and has been running its own breeding program since 2004 and the target is to develop better clones for chemical pulping. A formal breeding strategy document was prepared in 2008 and updated in 2015. Traditional tree breeding has led to many new clones will take about 10 years. SEGX will begin to research the use of genomic selection to select the potential trees at young age. It is estimated about that four years will be reduced for the clone development

Based on the experience of Sino-Australia cooperation project in 1980s five *Eucalyptus* species were chosen as parents for hybrid combinations. They are *E. urophylla, E. grandis, E. camaldulensis, E. teretecornis and E. pellita*. Pure species breeding programs are managed for all these species, but the main attention is in *E. uropylla* and *E. grandis*. Clones are developed from the best trees among hybrid progeny and tested in a three stage field test program. Tissue Culture was developed by the company in 2012 to assist the tree improvement.

As of January 2015, a total of 2250 pure species families have been tested in field trials for the five pure species. The number of control-pollinated families in progeny trials exceeds 660 and nearly 1,000 new clones have been tested. About 30 clones have been identified with good MAI, wood properties and typhoon resistance for pilot scale planting. One new clone was tried in 2012-13 for small scale commercial planting and two new clones will be planted in 2016.

SEGX has a very challenging environment for tree breeding and clone development. The main difficulties include typhoons, various diseases, and disturbance to field trials by local people, livestock and etc. Due to these difficulties some important trials and a lot of valuable genetic material have been lost, and breeders frequently have shortages of desired pollen or mother trees, or young field trials are lost before any results were obtained. In these conditions, collaboration and with other agencies, institutes, universities in China or abroad is welcomed and necessary.

Key words: Stora Enso Guangxi, hybrid *Eucalyptus*, plantation, tree breeding; challenges, cooperation

Oral Presentation

Carbon Biosequestration Potential of Eucalypts Afforestation in Arid Areas in Western Australia

Hideki SUGANUMA[1,2], Hajime UTSUGI[3], Nobuhide TAKAHASHI[4], Yuji SAKAI[5], Yasuyuki EGASHIRA[6], Richard HARPER[1], Toshinori KOJIMA[2,7], Yukuo ABE[8], Koichi YAMADA[9]

1: School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch 6150 WA, Australia ; 2: Department of Materials and Life Science, Seikei University, 3-3-1, Kichijoji-kitamachi, Musashino, Tokyo, 180-8633, Japan; 3: Forestry and Forest Products Research Institute (FFPRI), 1, Matsunosato, Tsukuba, Ibaraki, 305-8687, Japan; 4: Faculty of Textile Science and Technology, Shinshu University, 3-15-1, Tokida, Ueda, Nagano, 386-8567, Japan; 5: School of Advanced Engineering, Kogakuin University, 2665-1, Nakano-machi, Hachioji, Tokyo, 192-0015, Japan; 6: School of Engineering, Tokyo University of Technology, 1404-1, Katakuramachi, Hachioji, Tokyo, 192-0982, Japan; 7: Adjunct Professor, Edith Cowan University, 2 Bradford Street, Mount Lawley, WA, 6050, Australia; 8: Emeritus Professor, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki, 305-8577, Japan ;9: Deputy Director General, Center for Low Carbon Society Strategy, Japan Science and Technology Agency, 5-3, Yonbancho, Chiyoda, Tokyo, 102-8666, Japan

Oral Presentation

There are two main methods for terrestrial carbon bio-sequestration using Eucalypts, one is active plantings such as monocultures and environmental plantings, and the other is passive reforestation such as assisted natural regeneration and woody thickening. Among alternatives, from the aspect of avoiding land use competition, afforestation in arid areas is considered as promising candidate.

Afforestation experimentation in Sturt Meadows (120˚58'E, 28˚40'S) in Western Australia during 1999 to 2012 revealed that 93% of *Eucalyptus camaldulensis* Dehnh. (n = 76) survived even experienced continuous drought (2007-2009), which was the highest survival ratio among ten native tree species (n = 470), and grew averaging 4.4 Mg ha^{-1} $year^{-1}$ throughout the measurement period in the afforestation plots consisting of water harvesting method combined with hardpan blasting method. On the other hand, from natural woodland (mainly consist of *Acacia aneura* Benth.) surveys during 1997 to 2012, baseline carbon sequestration rate in the absence of afforestation activities was estimated at averaging 0.1-0.4 Mg ha^{-1} $year^{-1}$ (n = 128) depending on present land cover, which were less than 1/10 of growth rates in afforestation plots. In addition, because low grazing pressure (0.06 dry sheep equivalent ha^{-1}) is considered to avoid additional land clearing induced by afforestation activities, leakage should be assumed nearly 0 t ha^{-1} $year^{-1}$.

Incorporating these measured data, estimated data such as initial CO_2 emission of afforestation activities, and land cover and biomass distribution derived from LANDSAT image analyses, about 350 Gg-CO_2e $year^{-1}$ mitigation potential was estimated in Sturt Meadows. Considering similarity of annual rainfall (200-300 mm), underlying Wiluna hardpan distribution, vegetation cover (*Acacia* woodland) and land use (extensive rangeland grazing), this mitigation potential can be expanded to whole Murchison bioregion (281,200 km^2). Total carbon mitigation potential by Eucalypts afforestation in Murchison bioregion was then estimated at 32.1 Tg-CO_2e $year^{-1}$, which is equivalent to 12% of Australia's annual CO_2 emissions derived from fuel combustion. Thus, this biosequestration method using arid areas should have great importance as one of the future carbon mitigation alternatives of Australia.

Introducing *Eucalyptus* as Livelihood Option for Forest Dependent Tribal Communities of Odisha, India

Suchita Bhandari, Amit Datta, Sudhansu Mishra

Bilt Tree Tech Limited, First India Place, Gurgaon, Haryana, India.
suchita.bhandari@bilttreetech.com

Oral Presentation

Bilt Tree Tech Ltd (BTTL), for the last decade is engaged with the tribal farmers in the state of Odishato promote *Eucalyptus* plantations on their degraded, fallow mostly rainfed lands for earning livelihood. Increasing fragmentation of land holdings, shorter cycles in shifting cultivation & highly eroded soils on slopes, all pose a threat to the subsistence farming practiced by these tribal communities in traditional methods. Inaccessible hilly terrains, lack of adequate infrastructure, resources and market linkage offer little opportunities for these forest dependent communities to earn their livelihood in the area.

Eucalypt Plantation initiative of BTTL is a subsidy free, sustainable Model, that while keeping its for-profit nature, contributes to poverty reduction through the inclusion of low income farming communities in its value chain. The eucalypt program engages with small and marginal tribal farmers with small land holding of <one hectare and encourages them to grow eucalypt trees on their farmlands along with other crops. The farmers are encouraged to plant trees in various models, suited to their requirement and availability of land. Agro-forestry allows for both annual income from seasonal crops and additional income at the end of 4/5 years from sale of wood.

This is an inclusive support model which begins with identifying the target farmers; making them realize the benefits of short rotation eucalypt plantations through awareness and exposure; facilitating loan/grant for first plantation; providing them quality saplings for plantation; guiding and supporting them for the entire growth period and finally linking them with the paper mills for sale of wood, reaping maximum benefits. The model also enriches the environment by planting approximately 20 million trees annually on farmland, reduces degradation of natural forests for fuel wood, increases productivity of degraded lands and stops soil erosion. The model is sustainable as the wood harvest from the first cycle of plantation yields income that enables farmers to plant new areas.

Through its involvement with the forest dependent tribal community, BTTL has planted approximately 48 million trees on 20,870 hectares involving close to 30,000 farmers belonging to Base of the Pyramid. Jobs have been created for local community as employees in the nursery with 80% being women and during the plantation activity thereby reducing migration of villagers considerably. As suppliers to pulp and paper mills, the local farmers stand to gain access not just to more employment opportunities but higher income and enhanced technical skills as well.

Determining levels of natural contamination of *Eucalyptus urophylla* in an *E. grandis* population in South Africa using microsatellite DNA markers

Geoff Galloway[1], Melissa Reynolds[2], Alex van Rensburg[2], Sharmane Naidoo[1], Arnulf Kanzler[1], Zander Myburg[2]*

1. Sappi, PO Box 473, Howick, 3290, South Africa
2. Department of Genetics, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Private Bag x20, Pretoria 0028, South Africa

Oral Presentation

During the early 1990's severe mortality was experienced in young *Eucalyptus grandis* plantations, due mainly to Chrysoporthe canker (caused by *Chrysoporthe austroafricana)* and other diseases. The solution to the disease problem was to replace pure *E. grandis* with hybrids – mainly *E. grandis* x *E. urophylla* (GU), or *E. grandis* x *E. camaldulensis* (GC).

Between 1989 and 2010 Sappi continued breeding for disease tolerance over three generations at a low intensity, turning over populations using open pollinations (OP). In each cycle, selections were made at around 4-5 years, OP seed collected and established as seedlings in the next cycle progeny trials. All selections / parents in each generation were archived into a clonal breeding bank. As a result, the level of tolerance to these fungal diseases appears to have improved dramatically in the pure species, but some tolerance could also have derived from natural hybridization with and introgression from *E. urophylla.*

The objective of this study was to detect hybrids and quantify levels of introgression from *E. urophylla* into this *E. grandis* population using a panel of 15 SSR markers (previously shown to be species informative) to assess the purity of this reference population. The markers were able to successfully discriminate among six species of *Eucalyptus* (*E. camaldulensis*, *E. globulus*, *E. nitens*, *E. grandis*, *E. urophylla* and *E. dunnii*).

The following conclusions were reached:-

1. The Sappi Zululand 'disease tolerant' *E. grandis* breeding population has relatively little 'contamination' from *E. urophylla* (fewer than 10% of individuals carry detectable *E. urophylla* allelic diversity). This was despite the fact that populations have been carried forward using OP through three generations with selection for tolerance.

2. A Bayesian clustering analysis implemented in STRUCTURE v2.3.3 identified approximately 6% pollen contamination from commercial GU hybrids planted in adjacent commercial stands. This result was confirmed through a parentage analysis using discrete DNA marker matching to several commercial clones.

3. The Bayesian clustering analysis also revealed F_1 hybrids (~3%) resulting from pollination by surrounding *E. urophylla* stands, and one pure *E, urophylla* individual which was most likely mistakenly incorporated into the *E. grandis* trial.

This study has application in forestry for species identification, differentiation between landraces/populations within species, identification and classification of hybrids and the quantification of introgression levels.

Key words: *Eucalyptus grandis*, *Eucalyptus urophylla*, open pollination, contamination, introgression, species discrimination

PART II
Posters

Carbon Biosequestration Potential of Eucalypts Afforestation in Arid Areas in Western Australia

Hideki SUGANUMA[1,2], Hajime UTSUGI[3], Nobuhide TAKAHASHI[4], Yuji SAKAI[5], Yasuyuki EGASHIRA[6], Richard HARPER[1], Toshinori KOJIMA[2,7], Yukuo ABE[8], Koichi YAMADA[9]

1: School of Veterinary and Life Sciences, Murdoch University, 90 South Street, Murdoch 6150 WA, Australia ; 2: Department of Materials and Life Science, Seikei University, 3-3-1, Kichijoji-kitamachi, Musashino, Tokyo, 180-8633, Japan; 3: Forestry and Forest Products Research Institute (FFPRI), 1, Matsunosato, Tsukuba, Ibaraki, 305-8687, Japan; 4: Faculty of Textile Science and Technology, Shinshu University, 3-15-1, Tokida, Ueda, Nagano, 386-8567, Japan; 5: School of Advanced Engineering, Kogakuin University, 2665-1, Nakano-machi, Hachioji, Tokyo, 192-0015, Japan; 6: School of Engineering, Tokyo University of Technology, 1404-1, Katakuramachi, Hachioji, Tokyo, 192-0982, Japan; 7: Adjunct Professor, Edith Cowan University, 2 Bradford Street, Mount Lawley, WA, 6050, Australia; 8: Emeritus Professor, University of Tsukuba, 1-1-1, Tennodai, Tsukuba, Ibaraki, 305-8577, Japan ;9: Deputy Director General, Center for Low Carbon Society Strategy, Japan Science and Technology Agency, 5-3, Yonbancho, Chiyoda, Tokyo, 102-8666, Japan

There are two main methods for terrestrial carbon bio-sequestration using Eucalypts, one is active plantings such as monocultures and environmental plantings, and the other is passive reforestation such as assisted natural regeneration and woody thickening. Among alternatives, from the aspect of avoiding land use competition, afforestation in arid areas is considered as promising candidate.

Afforestation experimentation in Sturt Meadows (120˚58'E, 28˚40'S) in Western Australia during 1999 to 2012 revealed that 93% of *Eucalyptus camaldulensis* Dehnh. (n = 76) survived even experienced continuous drought (2007-2009), which was the highest survival ratio among ten native tree species (n = 470), and grew averaging 4.4 Mg ha^{-1} $year^{-1}$ throughout the measurement period in the afforestation plots consisting of water harvesting method combined with hardpan blasting method. On the other hands, from natural woodland (mainly consist of *Acacia aneura* Benth.) surveys during 1997 to 2012, baseline carbon sequestration rate in the absence of afforestation activities was estimated at averaging 0.1-0.4 Mg ha^{-1} $year^{-1}$ (n = 128) depending on present land cover, which were less than 1/10 of growth rates in afforestation plots. In addition, because low grazing pressure (0.06 dry sheep equivalent ha^{-1}) is considered to avoid additional land clearing induced by afforestation activities, leakage should be assumed nearly 0 t ha^{-1} $year^{-1}$.

Incorporating these measured data, estimated data such as initial CO_2 emission of afforestation activities, and land cover and biomass distribution derived from LANDSAT image analyses, about 350 Gg-CO_2e $year^{-1}$ mitigation potential was estimated in Sturt Meadows. Considering similarity of annual rainfall (200-300 mm), underlying Wiluna hardpan distribution, vegetation cover (*Acacia* woodland) and land use (extensive rangeland grazing), this mitigation potential can be expanded to whole Murchison bioregion (281,200 km^2). Total carbon mitigation potential by Eucalypts afforestation in Murchison bioregion was then estimated at 32.1 Tg-CO_2e $year^{-1}$, which is equivalent to 12% of Australia's annual CO_2 emissions derived from fuel combustion. Thus, this biosequestration method using arid areas should have great importance as one of the future carbon mitigation alternatives of Australia.

The Impacts of Three Volatile Chemicals from *Eucalyptus grandis* on *Eisenia fetida*

*Zhiqun Tang, Jian Zhang, Wanqin Yang, Chunzi Wang, Danju Zhang**

Institute of Ecological Forestry, Sichuan Provincial Key Laboratory of Ecological Forestry Engineering, Sichuan Agricultural University, Wenjiang 611130, China.

Previous studies of allelopathic effects of *Eucalyptus* mainly focused on water-soluble allelochemicals with weeds and crops as receptors. However, little information was available for the volatile allelochemicals from *Eucalyptus* on soil fauna. In the present study, three volatile chemicals of octane, undecane and 2,4-Di-tert-butyl-phenol from *Eucalyptus grandis* were selected and their impacts on the *Eisenia fetida* were evaluated. The results showed that 1) the three volatile chemicals have significant effects on the survival and growth of *Eisenia fetida* and represent time and dose effects. 2) The inhibitory effects of the chemicals on the earthworm's weight increased along with the exposing time of 7, 14, 21, 28days. With the increase of the volatile chemicals concentrations, the inhibitory effects of Undecane increased at C1-C2 concentrations, and then weakened. The inhibitory effects of Octane decreased at C1-C3 dose and then were strengthened. 2,4-Di-tert-butyl-phenol has significant inhibitory effects on the weight of earthworm but did not changed significantly with concentrations. 3) Under Octane treatment, the mortality of *E. fetida* at the C1 concentration increased significantly during the exposing time of 1-14 days and then had no significant changes over time. At C2-C4 concentration, the mortality increased significantly along with the exposing time. Under Undecane treatment, there were no mortality during 1-14 days of exposing time at C1 concentration, and then increased significantly over time. At C2-C4 octane, the mortality increased significantly during the exposing time of 1-7 days, and then did not changed over time at other concentrations. Under 2,4-Di-ter-butyl-phenol treatment, the mortality increased significantly with exposing time (1-7 days), and then had no significant differences over time. 4) There were significant inhibitory effects at C1-C2 concentrations and stimulative effects at C3-C4 concentrations of the three chemicals on the SOD activity of the earthworm. With the increase of three chemicals concentrations, the stimulative effects of the three chemicals on the GST activity decreased. However, the effects of 2,4-Di-tert-butyl-phenol on the GST of earthworm at C4 dose were inhibitory. There were significant stimulative effects of the three chemicals on TChE activity and decreased with the increase of concentrations. It represented the inhibitory effects of Undecane on the TChE activity of earthworm at C3-C4 concentrations.

Key words: Volatile chemicals, *E. grandis*, ecological toxicology, *Eisenia fetida*

A Decade of Acacia Polyploid Breeding in Vietnam

Nghiem Quynh Chi[1]; Rod Griffin[4]; Jane Harbard[4]; Ha Huy Thinh[1]; Chris Harwood[3]; Le Dinh Kha[2]; Aina Price[4]; and Tran Duc Vuong[1]

[1] *Vietnamese Academy of Forest Sciences, Vietnam*
[2] *Inst. for Improvement of Forest Genetic Resources and Product Development, Vietnam*
[3] *CSIRO Land and Water, Private Bag 12, Hobart 7001, Australia*
[4] *School of Biological Sciences, University of Tasmania, Private Bag 55, Hobart 7001, Australia*

We review a decade of progress with breeding polyploid varieties of *Acacia mangium* (AM) and other tropical acacias in Vietnam. Polyploidy offers novel ways of expressing genetic diversity inbreeding populations, changing wood fibre properties and other traits, and reducing reproductive output of these potentially weedy taxa.

Polyploid breeding program began with the introduction of tetraploid (4*x*) lines of AM established in 3 polyploid hybridizing orchards in Vietnam together with clones of diploid (2*x*) AM and *A. auriculiformis* (AA). Tetraploid clones were found to be slower growing than 2*x*, but with stronger apical dominance and thicker bark. No phenological, morphological or pre-zygotic pollen-pistil barriers to crossing were found, but open-pollination yielded very few inter-cytotype (triploid, 3*x*) progeny. AM-4*x* yielded 4x seed, which was predominantly selfed in contrast to outcrossing observed in 2*x*. Tetraploid progeny grew slower than 2*x* controls. Kraft pulp yields from 8-year-old 4*x*treeswere similar to 2*x* but the 4*x* wood consumed less chemical to reach kappa 20. Wood fibres of 4*x* were 20% longer than those of 2*x*.

Triploid (3*x*) seed yields following controlled pollination were extremely low. Triploid seeds were small and did not germinate under standard conditions, but some could be successfully germinated and multiplied *in vitro*, with triploid status and cross identity confirmed. Flow cytometry of hundreds of open-pollinated progeny from 2*x* and 4*x* mothers found low rates of spontaneous production of 3*x* seedlings through production of unreduced gametes. Eleven 3*x* clones are now under field evaluation, two display rapid early growth. Some are now reproductively mature and although flowers were produced, polyads were mostly sterile and the majority of spikes abscissed. Seeds were harvested from one 3*x* AM clone but no seedlings survived germination, suggesting effective sterility had been achieved. Tetraploid breeding populations have been expanded via the production of new 4*x* lines of AM, AA, the interspecific hybrid AM x AA, and *A. crassicarpa*, with multiple lines of each now under test.

Key words: *Acacia mangium, A. auriculiformis*, polyploid breeding, tetraploid, triploid, wood fibre, sterility.

Adaptability and Performance of Different Industrial Eucalypt Species and Provenances at Fars Province of Iran

H. Sardabi[1], M. Hamzepour[2], S.K. Bordbar[2], M. Nejabat[2]

1- Associate Prof., Research Institute of Forests and Rangelands, P.O. Box 13185-116, Tehran, I.R. Iran. Email: sardabi@rifr-ac.ir, hosseinsardabi@gmail.com.
2- Scientific Board Member, Fars Agricultural and Natural Resources Research Center, Shiraz, Fars, I.R. Iran.

The aim of the study was to introduce the adaptable, fast-growing and industrial eucalypt species and provenances for marginal lands and city plantations of Noorabade Mamasany area of Fars province of Islamic Republic of Iran. In addition, data related to phenology of eucalypt species was collected and recorded. The trial was conducted under statistical design of Randomized Complete Blocks with three replicates and 3 x 3 m. spacing. For two years (2007 and 2008), 15 eucalypt species and provenances were planted in GHaemieh Olive Experimental Station as follows: *E. camaldulensis* ig. *camaltereti* 20709, *E. camaldulensis* var. *camaldulensis* 11340, *E. camaldulensis* var. *camaldulensis* 15023, *E. camaldulensis* var. *subcinerea* 15195, *E. camaldulensis* var. *subcinerea* 15272, *E. camaldulensis* 41-ch, *E. camaldulensis* 41-zh, *E. globulus* ssp. *bicostata* 16731, *E. globulus* ssp. *bicostata* 19493, *E. globulus* ssp. *maidenii* 20230, *E. globulus* ssp. *maidenii* 300-sh, *E. nobilis* 19805, *E. rubida* 166-sh, *E. saligna* 18241, *E. saligna* 20581.The annual measurements consisted of survival (two times, after cold and warm seasons), total height, diameter at breast height (dbh) (after growth season) and phenology. Soil chemical and physical analysis, climate data analysis, ground floor vegetation collection and identification and geographical characteristics records were implied prior to the eucalypt species trial. The data were analyzed, using Variance Analysis and Duncan test methods by SAS and SPSS computer Programs. Number of seedlings per plot was variable (8-49). Results showed that effects of the treatments and years on the eucalypt parameters were significant ($\rho<0.05$ and $\rho<0.01$, respectively). Four species, including: *E. camaldulensis* var. *camaldulensis* 11340, *E. globulus* ssp. *bicostata* 19493, *E. nobilis* 19805 and *E. saligna* 18241 died completely prior to end of the trial data analysis, so they were deleted from the analysis process and recorded as failed species. The greatest survival values belonged to: *E. camaldulensis* var. *subcinerea* 15195 and *E. camaldulensis* var. *subcinerea* 15272 (99.1 and 98.0 percent, respectively), whereas the lowest values belonged to *E. camaldulensis* 41-ch (2%). The eight remained species and provenances had different ranks and significant differences to each other. The highest values of dbh belonged to: *E. camaldulensis* 41-ch, *E. globulus* ssp. *maidenii* 300-sh and *E. globulus* ssp. *maidenii* 20230 (9.3, 9.4 and 9.4 cm, respectively), whereas the lowest values belonged to *E. camaldulensis* ig. *camaltereti* 20709 (3.4 cm). The seven remaining species and provenances had different ranks and significant differences to each other. The tallest and the shortest species were: *E. globulus* ssp. *maidenii* 20230 and *E. camaldulensis* ig. *camaltereti* 20709 (713.3 and 30.5 cm., respectively). The nine remained species and provenances had different ranks and differed significantly to each other. Except average survival in 2011 (25.5%) which was significantly greater than in 2012 and 2013 (20.4 and 20.1 %, respectively), average dbh and total height in 2012 and 2013 was significantly more than in 2011.

Key words: Phenology, survival, diameter, height, soil, quality, canopy

Adaptability and Performance of Industrial Eucalypt Species and Provenances at Tehran Province

H. Sardabi[1], M. Jafari[1], E. Farahani[2]

1- Associate Prof., Research Institute of Forests and Rangelands, P.O. Box 13185-116. Tehran, I.R. Iran. Email: sardabi@rifr-ac.ir, hosseinsardabi@gmail.com.
2- Scientific Board Member, Tehran Agricultural and Natural Resources Research Center, Varamin, Tehran, I.R. Iran

The aim of the study was to introduce the adaptable, fast-growing and industrial eucalypt species and provenances at southern parts of Tehran province, particularly Varamin area. The trial was conducted under statistical design of Randomized Complete Blocks with five replicates, five treatments and 3 x 2 m. spacing. The treatments were as follows: *E. camaldulensis*, *E. denticulata*, *E. globulus*, *E. saligna*, and *E. viminalis*. The annual measurements consisted of survival (two times, after cold and warm seasons), total height, diameter at breast height (dbh) (after growth season) and phenology. Furthermore, canopy diameter, resistance to coldness and tree quality were measured at end of the trial. Soil chemical and physical analysis, climate data analysis, ground floor vegetation collection and identification and geographical characteristics records were examined prior to the trial establishment. The data were analyzed, using Variance Analysis and Duncan test methods by SAS and SPSS computer Programs. The results showed that there are significant differences between the treatments in respect to survival, dbh, quality and resistance to coldness characteristics. Furthermore, there were not significant differences between the replicates in respect to different eucalypt characteristics. The species *E. camaldulensis* and *E. denticulata* achieved the greatest survival percentage (100 and 95, respectively) and the other species achieved the lowest survival rate without significant differences between them. The greatest and the lowest amount of total height belonged to *E. camaldulensis* (11.2 m) and *E. globulus* (8.2 m), respectively and the other species achieved the second rank without significant differences between them. The greatest and the lowest amount of dbh belonged to *E. camaldulensis* (13.4 cm) and *E. globulus* (7.7 cm), respectively, whereas *E. denticulata* achieved the second rank (11.6 cm) and the other species achieved the third rank without significant difference between them. The greatest amount of quality belonged to *E. camaldulensis* and *E. viminalis* (12 and 11.1, respectively) and the lowest amount of quality belonged to *E. globulus* (7.6) whereas the other species achieved the second rank without significant difference between them. Although there was no significant difference between the eucalypt species in respect to crown diameter, but according to Duncan test, the greatest amount belonged to *E. camaldulensis* and *E. denticulata* species (3.5 and 3.4, respectively) and the lowest amount belonged to *E. globulus* species (2.3) whereas the other species achieved the second rank without significant difference between them. The most resistance species to coldness were *E. camaldulensis* and *E. viminalis*, whereas the resistance of *E. denticulata*, *E. saligna* and *E. globulus* to coldness was moderate, low and very low, respectively. Based on cluster analysis, *E. camaldulensis* and *E. denticulata* achieved the best performance and they are suggested for eucalypt plantation at Varamin city and south of Tehran.

Keywords: *Eucalyptus*, adaptation, phenology, survival, dbh, total height, quality, crown diameter, cold resistance

Demonstrating and Experimental Trials of Short-rotation Eucalypts in Aeoral, Cambodia: Some Early Results

Runpeng Wei

Weirptech Bioresources Limited, F, 28/F. Fullview Court, 32 Fortress Hill Road, North Point, Hong Kong

To obtain reliable supporting data for planning commercial planting of eucalypts in Cambodia, we arranged a series of field trials in Aeoral, the central-south part of the country. We summarized the 22-month old genetic trials, 30-month old silvilculture experiment and 30-month demonstration planting in the present study.

With large genetic variation, both clonal and family/provenance varieties significantly varied in tree survival, growth, form, and crown width. High genetic variation was also observed within family/provenance varieties. Macro site condition markedly affected the early performance of varieties while replicate or micro site condition had much less effect. Interactions of variety with macro or micro site condition alone were not significant.

Varieties highly differed in the performance of both clonal and family/provenance materials. Four best clones were much better than other clones included in the clonal trial. Family/ provenance varieties grew relatively slow with slightly low survival in comparison with clonal varieties. Most of the fastest growing individuals were from the best families, superior over the best ramets from the best clones.

In silvicultural trial, replicate combining variety role was extremely significant in formulating most of the adaptation, growth and form traits. In general, silvicultural treatments played much less role. The main influencing factors included tree spacing and carbofuran application. Base fertilizer had a low level of effect on tree form. Over ages, tree spacing trended to be more influential while other effective factors impacts would disappear or be weakened.

Seven clonal varieties performed well in growth and survival until 30-month old in the demo plantings (70.43 ha). The best clones included SB23001 and SB15006, respectively, with average height and DBH of 13.5 m and 10.1 cm, and 12.0 m and 11.7 cm. Both consistently expressed their superiority over ages, as well as in genetic and silvicultural trials. We predict that by planting these best clones in well-managed plantations, the mean annual increment may exceed 35 m^3/ha over 6 years.

Most of the best varieties originated from the hybrids or seedlots of *E. urophylla* x *E. camaldulensis*, *E. urophylla* x *E. grandis*, *E. urophylla* x *E. tereticornis*, and *E. urophylla*. *E. grandis* and *E. camaldulensis* clones or seedlots performed rather poor in contrast to their hybrids with other species. One of the reasons was probably that *E. grandis* and *E. camaldulensis* were sensitive to the attack of *Leptocyle invasa*.

Development and Deployment of Interspecific *Corymbia* Hybrids: A Novel Resource with Improved Pulp Yield and Resilience to Leaf Gall Disease in India

B. Nagarajan[*1] *Mohan Varghese*[2], *M.Palanisamy*[1], *K.S.Venkataramanan*[1] *R. Kamalakannan*[2], *P.Selvaraj*[1]

[1] *Institute of Forest Genetics and Tree Breeding, Coimbatore, India.*
[2] *ITC R&D Bangalore, India.Email:nagarajan@icfre.org*

The period 2004-2008 in the history of *Eucalyptus* plantations in India was plagued with leaf gall disease caused by the wasp *Leptocybe invasa* La Salle. Nurseries, juvenile plantations and young coppice crops were equally devastated. The species deployed at the said time in commercial planting were *E. camaldulensis, E. tereticornis, E. grandis, E. pellita* and *E. urophylla.* This led to the forceful exit of a few large scale cultivated commercial clones. The need for Eucalypt domestication focused on disease resistance was felt by growers and industries alike. In this scenario during 2012, a *Corymbia* hybridization program was initiated by the Institute of Forest Genetics and Tree Breeding (IFGTB) in collaboration with ITC R&D, a Eucalypt major industry in India. The focus was disease resistance breeding with an emphasis to pulp improvement. Taxonomically the species *E. citriodora* and *E. torreliana* was assigned to a new genus *Corymbia* during 1995. The seed parent *Corymbia torelliana* Hill & Johnson, (Walayar 10°85'N; 76°85'E) and pollen parent *C.citriodora* Hill & Johnson (Panampally 10°50'N; 76°50'E) were deployed for the cross. Studies on pollen revealed 1% infertility. After quantifying the phenology in both taxa, control pollination methods were standardized. In inter-specific crossing seed set per capsule varied from 5±1 - 20±3. Inviability of progeny was also noted among the inter-specific full sib families. *Pre Emergent Reproductive Success* (PERS) ranged from 0.001-0.251. The cross *C. torelliana x C. citriodora* was successfully established in field. At seedling stages (90-120 days) a phenotype with linear leaves/longer internodes and the other with large ovate leaves/shorter internodes were recognisable. This characteristic implicated the straightness of the saplings after 12 months. The progeny were traceable to their pollen parent in characteristics such as leaf shape, stem straightness, stomatal distribution and lignotuber development. During 2012, a pilot trial with seven full-sib families in an inland arid site (Karamadai;11°14'N; 76°57'E). An inland wet (Walayar, 10°85'N; 76°85'E) and a coastal site (Nellore, Andhra Pradesh; 14°26'N; 79°9'E) were also developed. While infestation of leaf gall was noted in the Eucalypt control, till date no infection has been noted in the parents or the interspecific dihybird *C. torelliana x C. citriordora*. Analysis on pulp with a putative progeny indicates over 50% pulp recovery. After eighteen months in field the dihybrid *C. torellina x C. citriodora* could be cloned successfully (about 80% rooting). At present anatomical, chemo and DNA based markers for the said cross is being attempted. In future it is expected that sub-lining of full-sib genetic resources towards deployment in pulp, timber and veneer industries could be achieved.

Effects of Inbreeding on Growth and Wood Properties of *Eucalyptus* Tree Improvement at OJI Lao Plantation Forest Co., Ltd.

Shinichi Sukeno[1,2], Apichat Chanlakhon[1,2], Vongchanh Mouapavue[2], Allie Muneri[1,2]*

1. OJI Green Resources Co., Ltd.
2. OJI Lao Plantation Forest Co., Ltd.

OJI Lao Plantation Forest Co., Ltd. was established in 2005 by taking over the operation of BGA Plantation Forestry Co., Ltd. The plantation area is located in the middle part of Lao along Mekong River.

The climate in the region is tropical monsoon receiving 2500 -3000mm of rainfall per year. Main constraints of *Eucalyptus* plantations in Lao include bacterial wilt and leaf diseases in the rain season and drought in the 6-7 month dry season.

At the beginning of the project various *Eucalyptus* materials were introduced including hybrid clones from China, Thailand and Vietnam, hybrid progenies of urograndis (*E. urophylla* x *E. grandis*) from Brazil and South Africa and progenies of *E. pellita* from Australia and Vietnam. However, none of those materials exceeds the growth of *Acacia auriculifomis* × *mangium* hybrid, which is currently the preferred operational species.

Throughout the introduction and testing of *Eucalyptus*, we have realized that *E. pellita* and *E. deglupta* show better tolerance to various leaf disease although their initial growth rate is much less than other fast growing species such as *E. camaldulensis* and *E. urograndis*.

Based on this background, we started plus tree selections and grafting on those species since 2008 to make hybrids with better growth performance as well as good disease tolerance.

Initial flowering from the grafted materials was observed at the beginning of rain season in 2012. We then started cross-pollination to make various hybrid materials for testing. To shorten the program, we applied tissue culture to propagate test clones from the hybrid seeds.

From this process we set up the first clone trial in 2013 using 129 new clones. Since then, we have repeated this process and test planted 130-150 clones in 2014 and 2015.

The current results at age of two year-old shows that some hybrids of *E. pellita* with *camaldulensis* or *urograndis* are growing much better than the parent species, previously tested *Eucalyptus* clones and *A. auriculifomis* × *mangium* hybrid. The program is still early stage, however, we are hoping to select commercially acceptable clones in the next few years.

Due to the demand for utilization of those clones for higher value market such as solid wood and veneer, we now include wood quality traits for our selection criteria. We have recently started wood quality analysis of our crossing materials to increase the chance to get suitable materials for our purpose.

Key words: *Eucalyptus*, breeding, *E. pellita*, hybrid, Lao PDR, clone

Genome Wide *Eucalyptus* Gene Co-expression Network for Secondary Cell Wall Biosynthesis in *Eucalyptus tereticornis*

*Dharanishanthi Veeramuthu, Modhumita Ghosh Dasgupta**

Institute of Forest Genetics and Tree Breeding, India, e-mail: vdharanishanthi@gmail.com

Eucalyptus is one of the most widely planted hardwood tree genera in the world because of its fast growth, short rotation, adaptability and superior wood properties. Extensive research has been conducted towards understanding the genetic, biochemical and molecular basis of wood properties. However, the exact mechanism of secondary cell wall biosynthesis still remains elusive. To achieve this goal, it is important to understand the role of functional genes, regulatory genes and master switches during cell wall biosynthesis.

In the present study a total of 25,908 xylogenesis- related genes were selected from literature which included genes involved in cell division, cell expansion, cell wall thickening, cell wall proteins, cell wall related polysaccharides, lignin biosynthesis and programmed cell death. A microarray chip with 53,988 probes was designed and a custom array (8x60K) was developed. The size of the probe was sixty base pairs and maximum three probes were designed per gene. Gene expression analysis was performed in the cDNA pool derived from developing xylem tissues of four extreme phenotypes of *E. tereticornis*. The expression profiles were validated for selected genes using quantitative reverse transcription polymerase chain reaction. The normalized fold expression across all four phenotypes was used to generate the genome wide *Eucalyptus* Gene Co-expression Network (EGCN). A correlation matrix was constructed by calculating pair-wise Pearson correlation using normalized expression values across all samples. The number of significantly co-expressed genes (threshold >0.9) was 330. The EGCN was constructed with 330 nodes (genes) and 4512 edges (interactions) using Cytoscape 3.1.0. The network documented 75 (22%) transcription factors with high degree. Subsequently, clustering was done using MCODE (Molecular complex detection) and 15 clusters were identified. Cluster 1 was a complex group with 37 nodes and 502 edges. Gene ontology enrichment confirmed that the cluster was significantly enriched with cell wall biosynthesis related biological processes, molecular functions and cellular components. Secondary wall associated NAC domain protein 2 (*SND2*) was involved in the regulation of forty eight functional genes including Cellulose synthase, 4-coumarate:CoA ligase, FASCICLIN-like arabinogalactan, beta-galactosidase, pectin methyl esterase, ubiquitin, ascorbate peroxidise and eukaryotic aspartyl protease. Additionally, it had interactions with ten transcription factors like Homeodomain containing transcription factors, *WRKY* and Zinc finger and C3HC4 type (RING finger). This co-expression network confirmed that transcription factors regulate the major pathways involved in secondary development.

The EGCN developed in the present study will help in identification of uncharacterized genes with probable role in wood formation in *Eucalyptus*.

Key words: Co-expression network, secondary xylem, *Eucalyptus*, cell wall, transcription factor, microarray, gene expression.

Hybrid Breeding for Screening Ideotypes in Red Gums: Implication on Improved Industrial Forestry Characteristics and Salinity Tolerance

B. Nagarajan[1], P. Selvaraj[1], M. Palanisamy[1], P. Chezhian[2], R. Seenivasan [2]G. Venkatesan[2]*

*1 – Institute of Forest Genetics and Tree Breeding, Coimbatore, 2 – Tamil Nadu Newsprint and Papers Limited * - Corresponding Author.*

Until the early 1990s, commercial planting of red gums was pivoted to seeds of complex local landraces and a few clones of untested origin. To ameliorate the situation and the crop, Institute of Forest Genetics and Tree Breeding (IFGTB) initiated a program on red gums *Eucalyptus tereticornis* Smith. and *E. camaldulensis* Dehn. in India during 1998 with the technical inputs of Australian Tree Seed Centre (ATSC). This program aimed to address farmland Eucalypt cultivators with appropriate selections. About one thousand half-sib families were deployed across multi-locations that led to selection of about three hundred clones. These were multi-location tested and thirty elites were short listed. The top three *E. camaldulensis* selections C19 (Katherine River-NT), C53 (Kennedy River-QLD) and C111 (Kennedy River-QLD) were combined through control crossing and with *E. pellita, E. grandis* and *E. urophylla x grandis* as pollen parents for generating intra and inter-specific di and tri hybrid full sib families. The combinations *E. tereticornis* × *E. alba, E. tereticornis* × *E. grandis E. camaldulensis* × *E. grandis, E. camaldulensis* × *E. pellita* were field tested across an inland riparian (Velayuthampalayam, 11°02′56″N,_77°59′52″E), an inland arid (Sivagangai, 09°43'0"N, 78°49'E) and a coastal site (Muthupettai, 10°04'N, 79°5'E). In terms of biomass production an intra-specific *E. camaldulensis C-53 x C-111*, a dihybrid *C-19 x E. pellita* and a trihybrid cross *C-19 x E. urograndis* weighed over 75 kg (@ 24 months compared to 30–40 kg realized from pedigreed half-sib families. A selection from C-53 x C-111 weighed over 170 kg at forty months. Likewise *E. camaldulensis* dihybrids *E. 111* × *E. grandis* 19 yielded over 50% pulp (against 42-44% in control). The cross *E. tereticornis* (South of Helenvale) *x E. grandis* (Lorne, 13017) exhibited a clear straight bole of over 12 meters with 42 cm at DBH and yielded 60% of veneer (local untested yields only 45%). The cross *E. tereticornis* × *E. alba* seems to be highly adapted for in saline affected coastal conditions and as potential crop for the energy sector. Developing pedigreed full sib families seem to be highly advantageous in selecting phenotypes with higher pulp, greater veneering and adaptability to saline affected sites. In due course, these phenotypes with elimination of selection errors could be deployed as market Ideotypes in the veneer, pulp and energy industries.

Key words: Di-hybrids, *Eucalyptus*, full-sib, ideotype, pulp, tri-hybrid, veneer.

Natural Hybrids between *Eucalyptus urophylla* and *E. alba*: Early Selection and Clonal Testing in Vietnam

Le Dinh Kha[1], Dinh Thi Phong[2], Nguyen Thi Thanh Huong[3], Nguyen Van Du[4], Mai Trung Kien[5]

[1]Prof. Dr., Institute for Improvement of Forest Genetic Resources and Products Development (IIFPD), [2]Assistant Prof. Dr., Natural Museum of Vietnam, [3]M Sc., IIFPD, [4] IEng.IIFPD, [5.] Dr. Forest Tree Improvement and Biotechnology (IFTIB)

Research was conducted on natural hybrids between *Eucalyptus urophylla* and *E. alba detected* in two *E. urophylla* seedling seed orchards (SSO) at Ba Vì, and Van Xuan in northern Vietnam. Putative hybrid individuals were identified from their morphological and anatomical characteristics, which were intermediate between the two parent species. DNA analysis using microsatellite markers of 7 representative putative hybrid trees showed that 6 of these trees had alleles from both parental species, while the other tree had allele characteristics of *E. alba* but originated from an *E. urophylla* mother tree, so should be considered a hybrid.

Open-pollinated seeds from the hybrid trees were sown and seedlings raised for early selection on morphology and initial growth at the nursery stage, followed by field testing of the selected seedlings. After 2 years in the field, 30 best-performing individuals were propagated for clonal testing at 4 trial locations across Vietnam. Growth to age 4 years was fastest on a level site with deep soil in the south of Vietnam and slowest on a sloping site previously dominated by bamboo in the North. There were differences in clone rankings across the four sites, resulting in low to moderate (0.32 to 0.66) site-site genotypic correlations for clonal stem volume. However, one clone, H44, grew fastest at all four sites. The best-performing new hybrid clones grew significantly faster, and had superior wind resistance than control treatments (commercial eucalypt clones and seedlings from an *E. urophylla* seed orchard). At one site in the South at age 4 years (after strong winds at age 3 years) clone H44 had 75% survival and mean stem conical volume of 163.1 dm^3 per tree, while the control treatments, commercial clones PN14 and U6 and *E. urophylla* seedlings of SSO, had corresponding survivals of 36.1, 36.1 and 22.2%, and volumes of 136.5, 76.9 and 58.0 dm^3 respectively. Age-age genotypic correlation coefficients for stem volume at 2 and 4 years were low (0.38) for two trials where typhoon damage resulted in changes in clonal rankings over time, and much higher for the two other trials where wind damage was low.

Optimising the Performance of *Eucalyptus pellita* in the Wet Tropics of Borneo

Yani Japarudin[1], MahadirLapammu[1]Agustan Alwi[1] Jeremy Brawner[2], David Boden[3] ,Michael J Wingfield[4]

[1]Sabah Softwood Berhad, Km. 8, Jalan Sin San, 91019 Tawau, Sabah, Malaysia .[2,3] University of the Sunshine Coast, Maroochydore, Qld 4558, Australia, [3]Boden & Associates Pty Ltd, PO Box 162, Cooroy, Qld 4563 Australia. [4]Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, South Africa

Eucalyptus pellita was first planted in trials in Borneo in 1994 and provided some promise for this genus in a region where other eucalypt species had typically failed due to foliar pathogens. However in north Borneo it was only after the recent demise of *Acacia mangium* due to *Ceratocystis* canker and wilt that *E. pellita* has come to prominence as a commercial species. This paper outlines a number of comprehensive research programs and early results that have been initiated in Sabah and Sarawak under the Borneo Forestry Cooperative.

The tree improvement program is based on progeny trials with 4 to 5 such trials testing up to 150 families being established annually over a range of sites. These trials will be converted into seedling seed orchards at 3.5 years and will be complemented by seed production areas developed from seed source trials. The first seed will become available in 2016 and allow for second generation progeny trials to commence in 2017. A hybrid program with species such as *E. grandis* and *E. urophylla* has commenced and will run parallel to the development of improved pure species. We have found pests and diseases including the gall wasp Leptocybe inavasa and the leaf blight pathogen *Teratosphaeria destructans* in the area on other Eucalyptus spp. and these recognized as a major threat. Consequently screening trials have commenced and these include stem canker pathogens such as *Crysoportha spp*. already found on *E. pellita* hybrids. In the tissue culture laboratory protocols are being developed to optimise multiplication rates, hardening-off and re-invigoration of ex-plants. Nutritional aspects have been investigated via a series of macro element trials and optimum rates of phosphorus and nitrogen at planting determined. Trials with boron are currently underway to further refine these results. Stand management regimes are being investigated using a series of trials assessing thinning, pruning and initial stocking to develop optimum regimes for both solid wood and pulp wood. Solid wood quality for veneer- and sawn-timber are being investigated under a program assessing various non-destructive means including NIR and acoustic tomography. It is hoped in future to include individuals of best solid wood quality into the breeding program. These programs have been implemented collaboratively by five member organisations in north Borneo and supported by overseas specialists. This approach offers a wide range of sites for trials, and by sharing germplasm and results offers a cost-effective approach to making substantial gains over a relatively short period of time.

SIMEGE: An Integrated Database and Genetic Analysis System Support to CMPC Breeding Program in Chile and Brazil

Edgardo Velilla[1], Oscar Guerra[2], Berta Rothen[1], Verónica Emhart[1], Marcela Labra[1], Felipe Vargas[3], Nuno Borralho[4], Alex Medina[1]

1. Forestal Mininco S.A; 2. Developers Chile Ltda; 3. Consultant in Management Projects and Information Analysis; 4. Consultant in Tree Breeding and Genetics

Every aspect of tree improvement in the modern age relies heavily on information management and exploiting data. In this sense, data management system is one of the most critical components of all tree improvement programs and help breeders to manage several steps in the breeding process. CMPC tree breeding group has developed a state of the art data management system called SIMEGE. It is a web-based information system and diagnostic tool, and is used to assist in several key decisions concerning with tree breeding activities and populations for deployment.

SIMEGE provides a solid web interface so that users can interactively run the software from any computer using only a web browser interface. SIMEGE basic architecture is built in ASP.NET and database engine is MS SQL Server, but also relies on specific interfaces with open source software applications such as R for the various statistical analyses and GRASS for geo-statistical visualization of data.

SIMEGE database management tools offer integrated design, development, testing, monitoring and administration of database system. SIMEGE main information modulus include: 1) the *Germplasm* module, which contains information about all genetic resources in the breeding and deployment programs. This includes details of the pedigree of each family, the status of seed and pollen stocks, and the breeding status of parents involved in the various ongoing crossing programs (location, flowering or pollen status) 2) *Trial description* module, which contains information regarding layout and history of all trials or breeding facilities (orchards, hybridization yards). This tool also includes a description of treatments involved, the experimental design, detailed maps and location based on Google Maps application, and a detailed history of interventions.

SIMEGE then generates simple statistical summaries (histogram, box-plots, scatter plots for DBH and total height, etc.) based on the measurements for each trial and carries out other more sophisticated single or multi-site REML/BLUP analysis. This produces key statistics for specific sites, including basic data culling (dispersion, outliers) and corresponding treatment means and variance components. Also, geo-spatial visualization of growth is available for each measurement in each trial. This provides a 3D picture of the growth observed on all trials. It is a valuable tool to help to identify possible within block heterogeneity issues, and in implementing specific post-blocking or other spatial analysis strategies in that trial.

SIMEGE supports all genetics research activities of CMPC's eucalyptus and pine breeding programs underway in Chile and Brazil and the plan is to use SIMEGE to manage the data and information from these tree improvement programs.

Key words: tree improvement program, data management system, REML/BLUP analysis, geo-spatial visualization

Trend of Heritabilities and Realized Genetic Gains in the Second Generation Seedling Seed Orchards of *Eucalyptus pellita* in Indonesia

Budi Leksono

Center for Forest Biotechnology and Tree Improvement, Yogyakarta
Jl. Palagan Tentara Pelajar Km 15, Purwobinangun, Pakem, Sleman, Yogyakarta.
Email: boedyleksono@yahoo.com

Trend of heritabilities and realized gains of *Eucalyptus pellita* in four second-generation seedling seed orchards of *E. pellita* established at two locations in Indonesia (Kalimantan and Sumatra islands) were examined by analyzing data on the height and diameter of the trees when they were one to five years old. The seed orchards consisted of 48 open-pollinated families from first-generation plus trees (improved population) and 12 families from natural forest (unimproved population). The individual heritability (h_i^2) of both traits was calculated as the ratio of additive genetic variance to the phenotypic variance for each measured age were moderate genetic control, various between 1.0 to 2.9. The heritabilities were relatively constant for trait and age in each location. The realized gains for height and diameter were ca. 15% and 18%, respectively. The realized gains were calculated as percentage gains based on five years' measurements of growth traits of the first generation plus tree progeny to the controls used in the first generation orchards. These gains were highly significant and consistent, irrespective of age and location. The results confirmed that the first–generation tree improvement program for *E. pellita* has been effective in Indonesia, and that it should provide improved seeds for operational plantation, thus raising their productivity.

Key words: *Eucalyptus pellita*, heritabilities, realized genetic gains, second generation, seedling seed orchard

Use of DNA Fingerprinting Technology to Understand the Outcrossing Rates in Eucalyptus dunnii Seed Orchards

Wayne Jones[*], *Luke Solomon*

Sappi Forests

Eucalyptus dunnii is an important commercial species for the pulp and paper industry in South Africa. Currently this species occupies 10 to 15% of the hardwood landholdings and is a key species in terms of favorable growth, density and fibre properties on temperate sites. The main method of propagation is through improved seed collected in managed seed orchards. These orchards typically consist of breeding seedling seed orchards, seedling seed orchards and clonal seed orchards of varying levels of improvement. Critical to successful plant production is the need for high quality seed both in terms of quantity and genetic superiority achieved through outcrossing between mother trees selected for the traits of interest. Factors affecting outcrossing success include the number of flowering parents at peak flowering, pollinator behavior and successful seed set. Failure at any stage during this process could influence field success, variation in growth and negatively impact on genetic gain. A study was undertaken to genotype the progeny of selected mother trees from various orchard sources to determine the levels of outcrossing and selfing. The study clearly illustrates the ratio of full and half sib progeny and its potential impact on field success. Production of large quantities of open pollinated seed remains important and orchard design and canopy management can influence seed outcomes. This project highlights how DNA technology can add further insights and improve quality of seed products from these systems.

Key words: *Eucalyptus dunnii*, seed, DNA fingerprinting, seed orchards

Variation among Provenances and Families on Provenance-progeny Test of *Eucalyptus urophylla* in South Kalimantan, Indonesia

Budi Leksono and Surip

Center for Forest Biotechnology and Tree Improvement, Yogyakarta, Indonesia
Jl. Palagan Tentara Pelajar Km 15, Purwobinangun, Pakem, Sleman, Yogyakarta, Indonesia.
E-mail: boedyleksono@yahoo.com

Eucalyptus urophylla naturally occurs on volcanically derived soils on seven islands in eastern Indonesia (Timor, Flores, Wetar, Lembata, Alor, Adonara and Pantar) at altitudes that range from 180 m to 3000 m. It is one of the most commercially important forest species as an exotic in the world. In many countries, this species has successfully used for hybridization program with other eucalypts. This suitable species produces raw material for pulp and paper industries and also has good potential for sawn timber. To obtain the variation among provenances and between families within provenance, the combination of provenance and progeny test of *E. urophylla* was established at Plaihari, South Kalimantan (Indonesia) consist of 116 families from 16 provenances. The families were tested in randomized complete block design with 8 replications of five-tree-row plot with 4 x 1.5 meter spacing. Height and diameter of breast height (dbh) were measured as indicators of growth on one to five years old. The data analyzed in two ways: analysis of variance and covariance to assess the variation among provenances and families within provenance, family heritability and genetic correlation among traits. The results demonstrated that variation among provenances and between families within provenance on growth traits were statistically significant and the best provenances from Wetar and Alor. Provenances from low altitude (<600m asl.) seems to be better than above. Family heritability seems to be sufficiently high and almost constant, and the genetic correlations among traits were positive and high.

Key words: *Eucalyptus urophylla,* family heritability, genetic correlation, progeny test, provenance variations.

Studies on Adaptability of Ten Eucalypt Clones under Different Sites in Southern China

Xiaojin LIU[1], Zengjiang YANG[1], Daping XU[1], Hu JIANG[2], Shuxiang SU[2], Ping CAO[2]*

1 Research Institute of Tropical Forestry, Chinese Academy of Forestry, Guangzhou 510520, China; 2 Guangxi Stora Enso Forest Co. Ltd, Beihai, Guangxi, 536000, China

Ten *Eucalyptus* clones were selected to evaluate the adaptability under six sites in Guangdong and Guangxi provinces, southern China through a field experiment. The results showed that hybrid eucalyptus clones still kept excellent characteristics of strong adaptability, and most survival rate could achieve over 95% with an exception of LH9224 (93.7%); There were significant differences of antiviral ability between clone and site condition, LH9224 has the highest incidence (averaged over 6.7%), however, LH1-9211 has the highest resistance to disease (the average incidence was 3.36% under heavy clay soil, and 0 under light sandy soil). Statistically differences of wind resistance were found between each clone (wind damage rate was 5%~65% under the average nine-grade wind), DH32-27 and DH32-26 had the poorest wind resistance (trees blowing down and breaking ratio by winds was over 60% in the young forest of 1.5 years), while LH1-9211, LH9224, Sh1 had the highest wind resistance (under 10%), M1 and DH201-2 had the poorest resistance of breaking by winds in the adult forest of 6 years (trees breaking ratio by winds was over 11% under the eleven-grade wind). There were significant differences of growth speed between each clone, DH32-13 had the best performance (average MAI was 17.19~35.32$m^3 \cdot ha^{-1} \cdot a^{-1}$), and the site conditions had significant effect on yield. The average MAI between ten eucalyptus clones under six site conditions were 14.24~26.97$m^3 \cdot ha^{-1} \cdot a^{-1}$.

Key words: *Eucalyptus* clone, adaptability, resistance, fast growing

Locally developed seed sources of *Eucalyptus camaldulensis* outperform best natural provenances and commercial clones in dry southern Indian environments.

M. Varghese[1], C. Harwood[2], D. Bush[3], B. Baltunis, R. Kamalakannan[1] and P. Ramadevi[1]*

1 ITC Life Sciences and Technology Centre (LSTC), Bangalore – 560 058, India; 2 CSIRO Land and Water, Private Bag 12, Hobart 7001, Australia.; 3 CSIRO Agriculture, Black Mountain, ACT 2601, Australia

** Corresponding author e-mail: Chris.Harwood@csiro.au*

A total of 48 progenies from five local seed sources of *E. camaldulensis*, developed primarily by phenotypic selection for growth from an initial broad base of superior natural provenances were tested against 183 progenies from 6 known best natural provenances and 10 locally developed commercial clones of the species. In trials at three dryland sites in southern India, the local seed sources grew significantly faster to 3 years than the natural provenances and the commercial clones. Survival of clones was poorer (50% at 3 years, across the three sites) than natural provenances (72%) and local seed sources (67%). Local seed sources, natural provenances and clones did not differ significantly in their wood density, pulp yield or lignin content, but there were major differences in wood properties among the sites. Basic density was higher (0.58 g cm^{-3}), and NIR-predicted pulp yield lower 43.7%) at the driest site where growth was slowest, than at the wettest site where growth was fastest (density 0.52 g cm^{-3} and pulp yield 46.5%). Second-generation seed sources, developed with care from an appropriate genetic base, provide a rapid, simple, low-cost option to mass-produce more productive planting material. Clonal forestry does not appear appropriate for these dryland environments, unless improvements in silviculture can increase survival and productivity above current levels.

Variation in Growth and Morphological Characteristics of *Eucalyptus pellita* Progeny Trial in Thailand

Narin Tedsorn, Vitoon Luangviriyaseng

Royal Forest Department, Bangkok, Thailand

Eucalyptus pellita has become an important plantation hardwood species in southern and south-eastern of Asia. It is regarded as a potential choice for both small-scale growers for use in mixed species woodlots targeting low-volume high-value sawn timber, and also by industrial plantation companies whose grow eucalypts for integrated pulp and sawn timber regimes.

The progeny trial of *E. pellita* of 66 families, which included individual mother tree, open-pollinated family seedlots from China Eucalypt Research Centre (CERC), was planted using latinised row-column design with six replicates in western of Thailand at a site with mean annual rainfall of 1,000 mm and low nutrient soil. The families represented 11 original provenances from Queensland Australia (8 seedlots), Papua New Guinea (2 seedlots) and Indonesia (1 seedlot). The trial was planted with 3-tree-row plots and spaced at 2 x 3 m at the beginning, and later selectively thinned to a single tree per plot at age 4 years.

Age 5 year results showed high variation in growth traits (height and DBH) stem form (straightness) and branch characteristic (thickness and angle). The estimate of heritability for all traits ranged from moderate (0.2) to high (0.6). Selection index of multiple traits (DBH, stem straightness, branch thickness and branch angle) was done for further selection for next generation and individual tree selection for clonal testing.

Key words: *Eucalyptus pellita*, genetic variation, progeny trial

Application of PGPB Fertilizer in Green Development to Enhance the Sustainability of Eucalypt Plantations

Baoling Huang, Chengqun Lü, Jiangming Yao, Han Ren

College of Forestry, Guangxi University, Nanning, Guangxi 530004, China.

For promoting trees growth, decreasing chemical fertilizer application, protecting environment, maintaining soil fertility, PGPB (Plant growth promoting bacteria) were isolated from tree rhizosphere. Some selected strains which distinctly promote trees growth were screen out, and prepared a PGPB preparation, PGPB organic fertilizer, PGPB organic and inorganic complex fertilizer. (1) The PGPB preparation was used to inoculate *Eucalyptus* seedlings. 1300 ten thousand tree seedlings were inoculated from 2012.10 to 2014.3, the trees high of 18 month plantation average 11.16 m, DBH is 7.38cm. (2) The fertilizer application tests results show that PGPB organic fertilizer which no inorganic azote take effect slower than that of chemical fertilizer (CK). But after 6 month till 36 month, all the trees high and the DBH exceed CK, the number of soil microbe especially azotobacter was evidence more than that of CK, the soil enzyme activity and azote contention were advanced. It is show that PGPB appear mostly effect. (3) PGPB organic and inorganic complex fertilizer only contain 15% inorganic nutrient, but the trees high and DBH exceed CK which contain 30% inorganic nutrient, 1.5a trees average high is 12.19 m, DBH is 9.01cm. The research result show that PGPB fertilizer provided specific action on promoting trees growth, decreasing chemical fertilizer application, protecting environment, maintaining soil fertility, and in green development to enhance the sustainability of eucalypt plantations.

Key words: PGPB fertilizer, eucalypt plantations, green development

Decline in Soil Net Nitrogen Mineralization under *Eucalyptus pellita* after *Acacia mangium* in South Sumatra, Indonesia

M. G. Wibisono[1], D. S. Mendham[2], E. B. Hardiyanto[1], L. O. Rustam[3]

[1]Faculty of Forestry, Gadjah Mada University, Yogyakarta, Indonesia
[2]CSIRO Land and Water, Hobart, Tasmania, Australia
[3]Faculty of Agriculture, Haluoleo University, Kendari, Indonesia
**Corresponding author: mgwibisono@ugm.ac.id*

Soil net nitrogen mineralization was assessed at three sites in South Sumatra, to explore the impacts of change in land use from *Acacia mangium* (an N-fixer) to *Eucalyptus pellita* (a non-N-fixer) on soil N availability. Each of the three sites consisted of adjacent *A. mangium* and *E. pellita* plantations, on Ultisol soils, and with a common history of 1-2 prior *A. mangium* rotations. Surface soils were sampled from the upper 10 cm of the profile using 50 mm PVC cores. Three plots were assessed for each combination of species and site. An aerobic soil incubation was carried out at room temperature over a period of 28 days. Net N mineralization rates under *E. pellita* were found to be approximately double under *A. mangium* (6.4-10.4 mg N kg^{-1} $28d^{-1}$) compared to *E. pellita* (3.0-6.4 mg N kg^{-1} $28d^{-1}$), which was significant across the three sites ($P<0.05$). The *A. mangium* stands also had higher organic matter, organic C, total N and lower C/N ratios, suggesting that the two species have substantially different impacts on soil fertility parameters. Our results have significant implications for management of N in *E. pellita* plantations, where there is little response to N fertilizer early in the rotation, but this may change over time, if the trend of declining N availability under *E. pellita* continues. Further monitoring of N status over time is recommended to ensure that N supply is able to keep up with demand from future rotations.

Key words: aerobic incubation, availability of nitrogen, decomposition rate

Feasibility Study on Planting *Eucalyptus* Trees with the Proper Strips in the Cassava Cultivation

Woraphun Himmapan, Tosporn Vacharangkura*

[1] *Forestry Research and Development Bureau, Royal Forest Department, 61 Phaholyothin Rd., Chatuchak, Bangkok, 10900, Thailand*

**Corresponding author: e-mail: woraphun_h@hotmail.com*

Agroforestry system tries to make use of this advantage by combining crops with a tree component and can be regarded as a special type of intercropping system. Thus intercropping tree crops with cassava may reduce the adverse effects on environment conditions. An experiment on intercropping *Eucalyptus* trees in cassava growing area was conducted using split plot design with four replications in Sa Kaeo Province. Main plot consists of two *Eucalyptus* clones. Subplot consists of spacing between hedgerows of the *Eucalyptus* trees or spacing between strips (alley width), i.e.: 12 m, 16 m and 20 m spacing and monoculture of cassava (control). Yield of cassava grown on various treatments was measured yearly and analyzed in order to compare yield among treatments. Growth of *Eucalyptus* stands was collected in every six months and three years after planting to determine the effect of intercropping system.

The results showed that diameter and total height of clone K7 and clone K51 were not significantly different, but significantly different among planting patterns. The intercropping plots with spacing showed better growth performance than control plot (*Eucalyptus* monoculture) significantly. Survival rate of *Eucalyptus* stands were not significantly different between two clones and among planting patterns. Total aboveground biomass per tree, stand biomass and fresh weight of clone K7 were significantly greater than those of clone K51. The said values of both intercropping plots were significantly different from control plot, but not significantly different among both intercropping plots. Cassava yields of intercropping plots decreased in the second and third crops. The yields of intercropping plots were significantly different from control plots (cassava monoculture) and among the intercropping plots. The yield in narrow spacing (12 m) was significantly lower than others. For 3-year rotation age the stand yield per hectare of 12 m spacing plot in term of *Eucalyptus* fresh weight was greater than those of 16 m and 20 m spacing plots, but provided less fresh tuber yield than those of other spacing plots.

Key words : *Eucalyptus*, feasibility study, proper strips, Cassava

Growth of Three Forest Species under Soil Water and Compaction Stresses

H. Sardabi[1], E.P. Bachelard[2] and A.Gibson[3]

[1]- Associate Prof., Research Institute of Forests and Rangelands, P.O. Box 13185-116, Tehran, I.R. Iran. Email: sardabi@rifr-ac.ir, hosseinsardabi@gmail.com

[2-] Prof., Department of Forestry, The Australian National University, Canberra, ACT 0200, Australia.

3- Associate Prof., Department of Forestry, The Australian National University, Canberra, ACT 0200, Australia.

The trial examined the effect of control and moderate levels of soil compaction, two irrigation regimes and two soil types (sandy and clay) on shoot growth and root development under glasshouse condition of three tree species. The treatments were two soil types (clay and sandy clay loam), two soil water potentials (-0.1 and -10.0 bars to -15.0 bars) and three tree species (*Acacia mearnsii*, *Eucalyptus viminalis* and *Pinus radiata*). In each pot, the bottom half of the soil column was compacted to moderate and the top half to control level. The soil and plant parameters consisted of penetration resistance, shear strength, shoot height and dry weight, stem diameter, root total length and dry weight, stem dry weight, leaves dry weight and surface area and root/shoot ratio. This experiment highlighted the differences between the two soil types in their physical properties under irrigation when compacted and showed that the tree species differed in their ability to grow in the soils under these conditions. The ability of *E. viminalis* to develop roots in soils with high soil strength (penetration resistance) and poor aeration was greater than the other species. On the one hand, the higher external/internal root ratio of *E. viminalis* in dry soils is a good indication of its preference to utilise soils with lower soil strength, but on the other hand, the results showed that it penetrated the higher strength soils (particularly dry sandy) further than the other two species. The greater ability of *E. viminalis* to penetrate and develop roots in soils with higher strength may be due to its potential for thickening its roots in such soils which enables it to challenge *P. radiata* which innately has thicker roots which can more easily press the compacted soil aside.

Key words: *A. mearnsii, E. viminalis, P. radiata*, penetration resistance, soil shear strength

Planting Domains for *E. pellita* and *E. urograndis*

Trevor Booth[1], Tom Jovanovic[2],Roger Arnold[3]

[1]CSIRO Land and Water, Canberra, Australia –Trevor.Booth@csiro.au; 2Australian National University, Canberra, Australia – sonicentitytj@gmail.com, 3China Eucalypt Research Centre, Zhanjiang, China - contactroger@yahoo.com.au

Climatic conditions suitable for *Eucalyptus pellita* and *Eucalyptus urophylla* x *grandis (E. urograndis)* were identified for current conditions as well as projected climatic changes for 2030, 2050 and 2080. To look at the domains under future projected climatic conditions, a generic method for the preliminary assessment of climate change impacts on planting domains was applied to these two taxa. Maps of climatically suitable areas in SE Asia and China were generated at a 10 min (about 18 km) resolution using CliMond climate change data in ArcGIS. These maps highlighted that if temperature rise is limited to a further 1.10 °C above the 0.85 °C rise already experienced (i.e. if the Intergovernmental Panel on Climate Change are successful in keeping global temperature rise below 2 °C above pre-industrial levels) then few areas currently supporting commercial plantations become climatically unsuitable. However, if the additional temperature rise is 1.96 or 3.83 °C then increasingly larger areas that are currently climatically suitable become unsuitable for plantations of these species.

In addition to these long-term risks the climatic analyses highlighted two risks associated with current climatic conditions. First, that some tropical locations where *E. urograndis* hybrids are being grown, in regions such as Sumatra, are climatically somewhat similar to areas in Brazil considered climatically unsuitable for the *E. urograndis* hybrid because of leaf disease risks. Second, that *E. urograndis* hybrids are being established in increasingly colder inland locations in southern China. These areas are subject to relatively sudden 'cold wave' conditions, known to be damaging to eucalypts, such as those experienced in 1991 and 2008.

Overall, long term climate change risks to the two taxa appear to be relatively small if the global temperature rise can be kept below or close to 2 °C. However, present climate-related risks linked to possible leaf diseases in tropical regions and frost risks in southern China are probably worth more detailed study.

Key words: Climate change, planting domains, hybrids, *E. pellita*

Quality Planning for Silviculture Operations Involving *Eucalyptus* Culture in Brazil

Diana Carolina Vásquez Castro, Marcos *Milan*

Forest Resources Program Posgraduation Escola Superior de Agricultura Luiz de Queiroz ESALQ – University of São Paulo. Av. Pádua Dias, 11, 13418-900, Piracicaba, São Paulo, Brasil. Email: carito1986@hotmai.com, macmilan@usp.br

The forestry sector is an important part of the Brazilian economy and reforestation with exotic species such as pine and eucalyptus has contributed to a reduction in the destruction of remaining native forests. Currently, various species of the genera *Eucalyptus* spp and *Pinus* spp exhibit a very high level of genetic improvement, productivity and quality of timber. With the need to expand the sector to meet future demand, silvicultural operations are often implemented with little consideration for quality planning in regard to forest plantation management, as all phases of forest investments are of fundamental importance to the success of forestry enterprises. Considering that the potential for productivity is related to the quality of operational processes, given that improper practices may lead to unsatisfactory results in the field, this study's objective is to identify and evaluate the priority features of silviculture operations in order to implement and monitor eucalyptus production in Brazil, and, in doing so, contribute to the management of forest stands with precision silviculture. The methodology used was the mapping of each of the silviculture operation's operational processes, identifying elements in regard to quality and technical features with the use of quality function deployment - QFD. Data collection has been carried out at locations of the Suzano Papel e Celulose do Brasil Company (Itapetiniga, Limera – SP, Brazil). The results to date have been the identification of 48 quality elements and 90 priority features pertaining to eucalyptus silviculture operations with the data obtained from the Suzano Papel e Celulose do Brasil Company. In accordance with the methodology, subsequently, the correlations of each element with every quality technical requirement will be established, the competitor analysis based on standard areas and a QFD house of quality analysis will be conducted to determine the features' negative or positive effects, having identified the priority features with the use of control charts. These features will be evaluated in the field and probable causes of operational deviations will analyzed.

Key words: priority features, forest quality, Quality Function Deployment- QFD

Test for Fast-growing Tree Species Selection and Planting Techniques Development in Cambodia

Shinsaku Tobita

Daio Paper Corporation

For the purpose of fast-growing tree species selection and plantation technology development in Southeast Asia, field planting tests were carried out under a tropical monsoon climate in Kampong Speu Province, Kingdom of Cambodia. The field tests were planted from August to September of 2012 and 2013, and the tree age reached 31 and 19 months, respectively, at the time of measurement (March 2015).

In the tests of tree species, planting density and fertilization, the following species or hybrids were included: eucalypt hybrids (*Eucalyptus urophylla* × *E. grandis*, *E. grandis* × *E. urophylla*, *E. camaldulensis* x *E. wetarensis*), *Acacia mangium* and acacia hybrid (*A. mangium* × *A. auriculiformis*). Slow-release fertilizers coated by resin and organic fertilizer were used for 1st fertilization (at planting). A general-purpose chemical fertilizer were used for 2nd fertilization (6months after planting) and 3rd fertilization (18months after planting).

In the tree species test planted with the density of 1,667 trees/ha in 2012, *E. camaldulensis* × *E. wetarensis* performed best in the average high growth of 13.1 m. In the species test planted in 2013, *E. camaldulensis* × *E. wetarensis* also grew fastest with the average high growth of 6.6 m.

For the hybrid of *E. camaldulensis* × *E. wetarensis* in the planting density test planted in 2012, the density of 1,333 trees / ha had the highest growth of 13.5 m. In the 1st fertilization test in 2013, the organic fertilizer (180 g per tree) yielded nearly the same growth as and thus more cost-effective than the two slow-release fertilizers (25 g per tree with 12 months duration and 20 g per tree of with 9 months duration). In the 2nd fertilization test in 2013, the tree growth increased by 40% when the dose of fertilizer increased from 0 to 250 g per tree, and a further growth of 6% was achieved when the fertilizer increased from 250 to 400 g per tree. The belt soil ripping increased about 30% of growth in comparison with the control treatment (without ripping).

These early results and findings based on 19- to 31-month growth and adaptation after the planting could provide useful and relatively reliable information for decision making and further research planning. However, final tree species and varieties selection by combining wood quality such as pulping properties need to be made after three to four years.

The Compound Colony of *Eucalyptus* and *Sarcandra Glabra*'s Influence on Soil and Plants in the Colony

Yanping Ye [1], Yongguang Pan [2], ShangBo Jiang [1], Baoling Huang [3], Yiping Cui [4], Xiao ZhenXiao [5]

1 College of Agriculture, Guangxi University, Nanning, China
2 Nanning Institute of Forestry, Nanning, China
3 College of Forestry, Guangxi University, Nanning, China
4 State Key Laboratory for conservation and utilization of subtropical Agro-bioresources
5 Nanning Yuzhen biotec company

Which plant ,who lives together with *Eucalyptus*,is more favorable to improve the ecological environment in which *Eucalyptus* lives, more conducive to the national housing and economic development? In this paper,we compared the compound Colony of *Eucalyptus* and *Sarcandra glabra* with *Eucalyptus* Colony, to explore the influence of these two biocoenosis on some physical and chemical properties of soil, the growth of Eucalyptus and Sarcandra glabra and the quality of *Sarcandra glabra* .The results showed that,compared with pure Eucalyptus forest , the average increased percentage in height and base diameter of Eucalyptus from the compound biocoenosis were respectively 8% and 13%. After implanted in the compound biocoenosis two months, *Sarcandra glabra*'s survival rate was 98% .And, after implated seven months ,the average increments in height and branches number were respectivly 14.6 cm and 2.5sprouting. In the meanwhile , with the increment of the compound Colony's formation time ,the soil acidity and soil bulk density in the compound Colony decreased, while, the soil organic matter content and available phosphorus content increased significantly. These above results indicated that the compound Colony is conducive to improve soil physical and chemical properties, accelerate the soil ripening degree, and is favorable to the growth of *Eucalyptus* and *Sarcandra glabra*. In addition, the contents of soil arsenic and cadium in the compound biocoenosis in different places are not the same, the contents on the slopes below the edge of village. Even grown in soil with high arsenic and cadmium , *Sarcandra glabra*'s stems still contain low mercury, copper, lead, cadmium, arsenic content, which is much lower than herbal heavy metal content limits prescribed by the State. Once transplanting *Sarcandra glabra*, it doesn't require replant each year, which decreased the intensity of soil preparation and improved the stability and environmental protection function of the compound Colony. Thus it promots a virtuous cycle of *Eucalyptus* plantation ecosystem.

Key words: *Eucalyptus*, *Sarcandra glabra*, colony, soil

Silviculture and Management

Poster

Response of *Eucalyptus* Hybrid to Nitrogen Application on ex-*Acacia mangium* Sites in the Humid Tropical Riau Indonesia

Sabar Siregar, Fui Khiong Wong, Agus Subechi*

APRIL Forestry R&D PT. Riau Andalan Pulp and Paper, Sumatra, Indonesia

Eucalyptus planting size in Riau central Sumatra Indonesia is increasing in the view of increasing mortality of *Acacia mangium* due to root rot and vascular wilt diseases. However, data on response of eucalypts as non nitrogen fixing plants to fertilizer especially nitrogen on sites previously planted to *A. mangium* for 2 rotations or more has been very limited to support judicious nitrogen application. An experiment has been conducted on 2 plantation sites in Riau to study the effect of nitrogen fertilizer rate on growth and yield of *Eucalyptus* hybrid (*E. grandis* x *pellita*) clone. The soil on both sites were Ultisols where on the first site it was fine loamy and on the second site it was fine clayey textured. The experiment on each site was arranged in a Randomized Completely Block Design with 6 replicates. There were 5 treatments tested, namely zero fertilizer (T_0), zero nitrogen (T_1), 70 (T_2), 184 (T_3) and 302 (T_4) kg N ha^{-1}. All fertilized plots received 27 kg P and 33 kg K ha^{-1} respectively. Nitrogen was applied by split application (T_2= at 0 and 4 months, T_3= at 0, 4, 8 and 12 months; T_4= at 0, 4, 8, 12, 18 and 24 months). Results showed that overall growth of *E.* hybrid was better on fine loamy soil than clayey soil, however insignificant. The effect of fertilization was significant on stem diameter and stand volume until age 3 years. At age 3 years, treatments T_1-T_4 increased the stand volume up to 50% on fine loamy soil and up to 240% on clayey soil compared to T_0. Treatment T_1 increased growth and volume significantly compared to T_0 indicating a positive response of *E.* hybrid to P and K. There were insignificant differences in growth and volume between T_1 compared to T_2-T_4 treatments. Nitrogen rate higher than 70 kg ha^{-1} and splitting the nitrogen application longer, did not significantly improve growth and yield of the *E.* hybrid on both sites. This indicated that nitrogen has not been a limiting factor to *E.* hybrid productivity in third rotation so far. Higher response to fertilization in clayey soil was due to poorer growth of non-fertilized plants compared to on loamy soil.

Improving Micropropagation and Transplant Survival of *Eucalyptus urophylla* X *E. Grandis* (*Uxg*) Hybrid Via Tissue Culture

S.Supu[1], Y.Japarudin[1], C.Hargraves[2] and M.Lapamu[1]
1 Sabah Softwoods Berhad, P. O. Box 60966, 91019, Tawau, Sabah, Malaysia
2 Scion, Private Bag 3020, Rotorua, New Zealand

In vitro propagation of *Eucalyptus urophylla x E. grandis (uxg) hybrid* has been developed based on the public domain protocol. Major refinement of both technique and culture media has been carried out to improve productivity both in the laboratory and the acclimatization stage in the nursery. Prior to the process improvements noted here, cultures were prone to overt callus formation at both the base of the shoot clumps and on the foliage. Elongation of shoots was limited and survival of plants after transfer to the nursery ranged from 0 to 50%. These improvements included; reinvigorating cultures by reestablishment from basal coppice of field growing clones. changing of culturing technique during the multiplication stage by spreading the culture clumps with average diameter of 1.5-1.8cm on MS media containing 0.50mg/L 6-benzylaminopurine (BA) and 0.1mg/L 1-Naphthaleneacetic acid (NAA) and 30,00mg/L sucrose in a 250ml conical flask at the multiplication stage. This facilitated the multiplication rate to increase from one vessel to 2 vessels at subculture 4 and onwards. The incubation period takes c.4 weeks for the plant culture to produce about 15-30 elongated shoots. The elongated shoots can be transferred directly to the rooting stage without going through a separate elongation process. In rooting stage, the elongated shoot inoculated on MS media contained 0.25mg/L indole-3-butiric acid, (IBA) and 20,000mg/L sucrose (reduced from 30, 000 mg). The incubation period for rooting stage also take c.4 weeks prior to nursery acclimatization. A careful improvement of the misting chambers has been beneficial so that the in-vitro plants can be gradually acclimatized from high humidity (in excess of 90% in-vitro) to ambient levels. The modification of both culture protocols and culture media has shortened the incubation period required which has resulted in survival of 90-95% of plantlets during acclimatization.

Key words: In vitro propagation, subculture, incubation period, multiplication stage, rooting stage and elongation stage

Carbon nutrition in rooting process of nodal cuttings of *Eucalyptus* hybrid as affected by Auxin

*Meena Bakshi and Manpreet Kaur**
Forest Research Institute Deemed University, Dehradun

Complex interplay of external and internal factors affects the process of root induction and development. Auxins play important role not only in the initiation of root meristem but enhance the root number also. Auxin helps in rooting process by making carbohydrate available in the base of the cuttings. The present study was undertaken to study the difference in carbohydrate pattern in rooting zone of nodal cuttings of *Eucalyptus* hybrid treated with different concentrations of IBA. The results revealed that the sugar accumulated in the basal segments during 15 days period was significantly greater in the IBA treated cutting than that of the control. Maximum sugar content was observed in IBA 4000 treatment. There was further increase in the content s of reducing sugars at 30 days, the level in IBA 4000 being almost twice that of control. The IBA 4000 and control showed an increase in sugar content , whereas IBA 2000 cuttings depicted decline in reducing sugar 45 days after planting which could probably be due to its utilization in the rooting process.

A New Genus of Cryphonectriaceae Causes Stem Disease on Native *Rhodomyrtus tomentosa* (Myrtaceae) in South China and Possibly Threatens *Eucalyptus* Propagation

ShuaiFei Chen[1,2], GuoQing Li[1], FeiFei Liu[1,2], Michael J. Wingfield[2]*

[1] China Eucalypt Research Centre (CERC), Chinese Academy of Forestry (CAF), ZhanJiang 524022, GuangDong Province, China

[2] Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0028, South Africa

[*]Corresponding author e-mail: shuaifei.chen@gmail.com

Poster Forest Health

The Cryphonectriaceae includes many important tree pathogens, especially of the Myrtales. During disease survey on Myrtales in South China, a stem canker disease was observed on native *Rhodomyrtus tomentosa* (Myrtaceae) trees growing in the proximity of *Eucalyptus* plantations in Guangxi Province and in a natural forest area in the Hong Kong Region. Fruiting structures with typical characteristics of the Cryphonectriaceae were observed on the surfaces of cankers. The fungus was identified based on DNA sequence comparisons and morphological features, and its pathogenicity was tested on *R. tomentosa* under field conditions. DNA sequence comparisons for the partial LSU and ITS nuclear ribosomal DNA, and two regions of the *β-tubulin* gene showed that the fungus represents a previously undescribed genus and species in the Cryphonectriaceae. Morphological studies showed that this fungus is most similar to species in the genus *Chrysoporthe*, but can be distinguished from this and the other genera of Cryphonectriaceae. Field inoculations showed that this new genus of fungus is pathogenic to *R. tomentosa* trees, with the ability to kill the inoculated branches within four weeks. Future studies will include assessments to determine whether this newly discovered pathogen is able to infect *Eucalyptus* trees. This would be consistent with the fact that many other species of Cryphonectriaceae have undergone host jumps from native Myrtales to infect *Eucalyptus*. This fungus and its relatives must be monitored carefully in future to understand their potential threat to *Euclalyptus* propagation.

A Note on Some Pests of *Eucalyptus* in Sabah, Malaysia

Chung, A.Y.C., Pang, K.N.K., Kimjus, K., Ajik,M., Ong, R.C. & Johnlee, E.B.

Forest Research Centre, Sabah Forestry Department, P.O. Box 1407, 90715 Sandakan, Sabah, Malaysia
Fax :089531068. Email: arthur.chung@sabah.gov.my

The establishment of *Eucalyptus* plantations is gaining momentum in Sabah to meet the ever increasing demand for industrial wood, and to reduce the pressure on the shrinking supply from natural forest. Lately, the move to plant *Eucalyptus* is primarily due the emergence of the fungal disease, *Ceratocystis*, which has severely affected the *Acacia mangium* plantations in this region. Hence, it is important to diversify the plantation tree species. At the same time, it is also vital to understand the potential pest species and the damage that they would cause as this would prevent or minimize potential pest infestation. This study highlights some of the pests, as well as potential pest species that have been documented causing damage on various *Eucalyptus* species (*E. pellita*, *E. grandis* and *E.* hybrid) in Sabah, especially in the trial plots under Sabah Forestry Department. They included barking of tree stem by tree shrews, defoliation by insects and damage caused by termites.

Comparative Transcriptomics of *Buzura suppressaria* Assembled *de novo* Yields Insights into Response after Infection of *Buzura suppressaria* Nuclear Polyhedrosis Virus

*Ji Luo[1 2 *], Yating Zhong[1], Jiyu Zhu[1], Guoying Zhou[2], Huayan Huang[1], Yaojun Wu[1]*

1, Guangxi Zhuang Autonomous Region Forestry Research Institute, Nanning, China
2, College of Forestry, Central South University of Forestry and Technology, Changsha, China
**Corresponding Author at: Guangxi Zhuang Autonomous Region Forestry Research Institute, 23# Yongwu Road, Nanning, 530002, China.*
Tel. & fax: +86 771 2319844
e-mail:luoji00531ji@hotmail.com (Ji Luo)

Poster Forest Health

Buzura suppressaria (Bs) is a defoliator that causes serious harm to eucalyptus trees in the south of China. *Buzura suppressaria* nuclear polyhedrosis virus (BsNPV) is a baculovirus which infects Bs with high specificity and efficiency. To probe the changes of key genes of Bs after viral infection, transcriptomes of Bs were sequenced before and after BsNPV infection based on the second generation sequencing technology. Approximately 57.4 million high-quality clean reads were generated on average and assembled *de novo* into 69,761 unigenes. 4 public databases; NCBI nonredundant protein (NR), Swiss-Prot, Kyoto Encyclopedia of Genes and Genomes (KEGG), and the Cluster of Orthologous Groups (COG), were used to annotate unigenes through NCBI BLAST procedure, and 33,575 unigenes (48.1%) were mapped to at least 1 database. It could be found by expression difference analysis that 25,212 unigenes were up regulated and 22,880 unigenes were down regulated in at least 1 pairwise comparison. A salient feature found was: Control vs. 24 h and control vs. 48 h had much more identical terms than control vs. 72 h in all database. Genes with differential expression at the initial stage of virus infection were mainly aggregated by various enzymes and metabolic pathways, thus the development related processes increased significantly in late stage, and terms of defense function soared in very late phase. Conclusively, terms associated with infection process of the virus whether in quantity or in content.

Key words: Transcriptome; *de novo*, *Buzura suppressaria*, viral infection, NPV

Diseases of *Eucalyptus* Species in Zimbabwe

L Jimu[a], MJ Wingfield[b], E Mwenje[c], J Roux[b]

[a]Department of Plant Production and Soil Science, Forest Science Postgraduate Programme, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Private Bag X20, Hatfield, Pretoria 0028, South Africa

[b]Department of Microbiology and Plant Pathology, FABI, University of Pretoria, Private Bag X20, Hatfield, Pretoria 0028, South Africa

[c]Bindura University of Science Education (BUSE), P. Bag 1020, Bindura, Zimbabwe

Zimbabwe embarked on planting *Eucalyptus* species in the early 1900's. Based on a robust breeding programme, it has become a major source of seed for other countries in Africa as well as beyond the borders of the continent. Tree health surveys conducted on *Eucalyptus* species in some east and southern African countries over the past two decades have revealed several important fungal diseases that were previously not known in the region, but little is known regarding these problems in Zimbabwe. The aim of this study was to identify important *Eucalyptus* diseases across Zimbabwe's agro-climatic regions. Morphological characteristics and DNA sequence data were used to identify collected pathogens to species level. Widespread stem canker diseases, caused by species belonging to the Botryosphaeriaceae, *Neofusicoccum eucalyptorum* and *N. parvum*, as well as those belonging to the Teratosphaeriaceae, *Teratosphaeria gauchensis*, were identified. Furthermore, symptoms of leaf spot diseases caused by fungi in the Capnodiales,*Mycosphaerella marksii* and *Teratosphaeria ohnowa*, were observed. Armillaria root and stem rot was restricted to a single site in the Eastern Highlands. Fungi that could cause cankers or blue stain of timber were isolated from recently harvested stumps and included species of *Ceratocystis* and *Ophiostoma*. This study is the first to identify *Eucalyptus* pathogens to species level in Zimbabwe and we report for the first time the presence of the stem canker pathogen *T. gauchensis* in southern Africa. The results provide a foundation for the formulation of future disease management strategies in the country.

Key words: Armillaria, Botryosphaeriaceae, Capnodiales, leaf spot, root rot, stem cankers, Teratosphaeriaceae

Field Establishment of *Selitrichodes neseri* (Eulophidae), a Biological Control Agent of *Leptocybe invasa* (Eulophidae)

Kwabena Baffoe[1], Jeff Garnas[1], Bernard Slippers[2], Michael Wingfield[3], Brett Hurley[1]*

1. Department of Zoology and Entomology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002, South Africa

2. Department of Genetics, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002, South Africa

3. Department of Microbiology and Pathology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002, South Africa

The gall wasp *Leptocybe invasa* (Hymenoptera: Eulophidae) is native to Australia, but has spread to many parts of the world where *Eucalyptus* spp. are grown. The insect causes galls on *Eucalyptus* trees and severe infestations result in stunted growth and sometimes tree death. Biological control has been one of the main strategies used to manage this pest since it was first detected outside its native range in Israel in 2000. We monitored the establishment and spread of the biological control agent *Selitrichodes neseri* (Hymenoptera: Eulophidae), which was released for the first time in 2012 in South Africa. Data were collected over a two-year period from ten permanent sampling sites across the country. In addition sticky traps were used to determine the presence / absence of *S. neseri* at a number of release and non-release sites. Results showed that *S. neseri* has established and spread within most release sites. Furthermore, the parasitoid was detected at the majority of non-release sites monitored, including sites over 60 km from the nearest release point. The establishment of *S. neseri* across South Africa is encouraging and studies are ongoing to assess its impact on populations of *L. invasa.*

Poster Forest Health

Genetic Diversity and Pathogenicity of *Botrytis cinerea* from Diseased *Eucalyptus* Seedlings in South China

QianLi Liu[1], GuoQing Li[1], Michael J. Wingfield[2], ShuaiFei Chen[1,2]*

[1] China Eucalypt Research Centre (CERC), Chinese Academy of Forestry (CAF), ZhanJiang 524022, GuangDong Province, China

[2] Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0028, South Africa

[*]Corresponding author e-mail: shuaifei.chen@gmail.com

Eucalyptus has become a preferred species for the production of industrial products but also to protect natural forests in South China. Many diseases affect these trees in both plantations and nurseries. Amongst these, grey mold caused by *Botrytis cinerea* is one of diseases found in *Eucalyptus* nurseries. Recently, symptoms of gray mold were observed on stems and leaves of *E. urophylla* × *E. grandis* seedlings in nurseries in Zhanjiang region of Guangdong Province in South China. Diseased plant parts were covered with mycelium, conidiophores and conidia of the causal pathogen. The species of *Botrytis* infecting the *Eucalyptus* seedlings was identified based on multiple-gene phylogenetic analyses, and the pathogenicity of the fungus was tested on different *Eucalyptus* clones. Thirty-six isolates were identified using DNA sequences data of the internal transcribed spacer regions of the ribosomal DNA (ITS), glyceraldehyde-3-phosphate dehydrogenase (G3PDH), heat-shock protein 60 (HSP60) and DNA-dependent RNA polymerase subunit II (RPB2) gene regions. Analyses of the sequences confirmed that isolates collected from *Eucalyptus* nurseries were all those of *B. cinerea*. DNA sequence comparisons of multiple gene regions showed that these *Botrytis* isolates most likely represent a single clone. The results of the *in vitro* leaf inoculation tests showed that the *B. cinerea* isolated from *E. urophylla* × *E. grandis* clone was virulent on all four tested clones. Future research will focus on developing integrated disease management strategies for grey mold on *Eucalyptus* seedlings in nurseries.

Host Preference of the Invasive *Glycaspis brimblecombei* Moore (Hemiptera: Psyllidae) in South Africa

Samantha Bush[1], Bernard Slippers[2], Brett Hurley[1]*

1. Department of Zoology and Entomology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002

2. Department of Genetics, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0002

Glycaspis brimblecombei Moore (Hemiptera: Psyllidae) is a eucalypt pest native to Australia. The first record of this insect outside its native range was from California in 1998. Since then, *G. brimblecombei* has spread to South America, Europe and Africa. *Glycaspis brimbelcombei* was reported in Pretoria, South Africa in June 2012. The nymphs of *G. brimblecombei* construct lerps when they feed. The sooty mould that develops when the lerps become moist, combined with the impact of the direct feeding may cause leaf wilt, die-back and death of weak or severely infested plants. Previous studies have provided a broad indication of which *Eucalyptus* species and genotypes are most at risk. However many of the genotypes of interest to the South African forestry industry were not included in those studies. In this study we evaluated host preference of *G. brimblecombei* on twenty-eight *Eucalyptus* genotypes. This evaluation included choice and no-choice host selection tests, spectrophotometer tests, and olfaction tests using y-tubes. Preliminary results show widely varying levels of susceptibility of the tested *Eucalyptus* genotypes.

Poster Forest Health

Identification and Distribution of Botryosphaeriaceae from *Eucalyptus* Plantations in China

*GuoQing Li, ShuaiFei Chen**

China Eucalypt Research Centre (CERC), Chinese Academy of Forestry (CAF), ZhanJiang 524022, GuangDong Province, China

Corresponding author e-mail: shuaifei.chen@gmail.com

Presently, *Eucalyptus* plantations in China have reached the remarkable point of covering of 4.6 million ha, the major planted areas are GuangXi, GuangDong, HaiNan, YunNan, as well as FuJian Provinces in South China. The family Botryosphaeriaceae is a species-rich family that includes pathogens of wide variety of trees, including species of *Eucalyptus*. Recently, diseases of *Eucalyptus* plantations caused by species of Botryosphaeriaceae were observed in the main *Eucalyptus* planted areas in South China. Diseased symptoms mainly include stem and shoot canker, shoot and twig blight. In this study, 105 isolates of Botryosphaeriaceae were collected from *Eucalyptus* in GuangXi, GuangDong and FuJian Provinces. These isolates were identified based on comparisons of DNA sequence data of the internal transcribed spacer, translation elongation factor 1-α, and β-tubulin gene regions, and combined with their morphological characteristics. Research results showed that isolates represent nine species of Botryosphaeriaceae, these species includes *Botryosphaeria fabicerciana*, *Neofusicoccum parvum*, *Lasiodiplodia brasiliense*, *L. pseudotheobromae*, *L. theobromae*, and each of two undescribed species of *Botryosphaeria* and *Neofusicoccum*. Of these species, *B. fabicerciana*, *L. theobromae* and *L. pseudotheobromae* were dominant, which were distributed in all three surveyed provinces. Future work is needed to elucidate their impact on *Eucalyptus* species and to develop management strategies.

Identification of *Calonectria* Species Causing Disease of *Eucalyptus* Clones in Ghana

Esna du Plessis, Alistair McTaggart, Jolanda Roux.*

Department of Microbiology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria 0028, South Africa.
**Corresponding author e-mail: jolanda.roux@fabi.up.ac.za*

Calonectria species result in major annual losses to the plantation forestry industry. Disease especially occurs in nurseries, in the form of damping-off and cutting rot. In tropical and sub-tropical regions *Calonectria* species also cause leaf spot and blight, in some cases resulting in total defoliation of susceptible tree species. In Ghana, *Calonectria* cutting rot and leaf blight was observed affecting plants in nurseries and plantations. *Calonectria* was isolated from dying cuttings and leaf blight symptoms. Species were identified based on sequence data from multiple gene regions, including the ITS, TEF-1α, β-tubulin and histone 3, and morphological comparisons. The formation of sexual structures was induced to determine the mating strategies of the isolates and to provide morphological features for species characterization. Koch's postulates were tested to test if the isolated species were the cause of the observed disease symptoms. DNA sequence data showed that more than one species of *Calonectria* was present at the time of isolation. Identification of the pathogens will allow for the development of targeted management strategies to reduce the impact of the disease, both in the nursery and plantation.

Key words: Cutting rot, leaf blight, *Cylindrocladium*

Poster Forest Health

Identification of Two *Ralstonia* Species Associated with Bacterial Wilt of *Eucalyptus*

Gabrielle Carstensen[1], Stephanus Venter[1], ShuaiFei Chen[1,2], Mike Wingfield[1], Teresa Coutinho[1]*

1. Department of Microbiology and Plant Pathology, Forestry and Agricultural Biotechnology Institute (FABI), South Africa

2. China Eucalypt Research Centre (CERC), Chinese Academy of Forestry (CAF), China

Eucalyptus spp. are propagated commercially in plantations in many countries worldwide. Diseases and pests of this tree are numerous and result in significant losses to forestry industries. One such disease is bacterial wilt caused by *Ralstonia solanacearum sensu lato*. Bacterial wilt of *Eucalyptus* has been reported from various countries including China, Indonesia, South Africa, Brazil and Colombia where it typically occurs in tropical and sub-tropical regions. In 2014, the causal agent of bacterial wilt was reclassified to include three species, namely, *Ralstonia solanacearum*, *R. pseudosolanacearum* and *R. syzygii*. These species descriptions were found to be linked to a phylotyping scheme that had been developed for the sub-classification of *R. solanacearum sensu lato* isolates. Phylotype I and III isolates are now known as *R. pseudosolanacearum* and Phylotype II isolates as *R. solanacearum*. In this study, *Ralstonia* isolates were obtained from China, Indonesia, South Africa, Uganda, The Democratic Republic of the Congo (DRC), Colombia and Brazil. All of the isolates had been cultured from *Eucalyptus* trees showing typical symptoms of bacterial wilt and were identified as *R. solanacearum sensu lato* by 16S rRNA gene sequencing. The isolates from China, Indonesia and Africa were identified as *R. pseudosolanacearum* (Phylotype I) and the isolates from Brazil and Colombia as *R. solanacearum* (Phylotype II). In addition to phylotyping of the isolates, the endoglucanase (*egl*), transcriptional regulator (*hrpB*) and DNA mismatch repair (*mutS*) gene regions were sequenced so as to characterise the genetic diversity of these isolates. With the *egl* gene region it was possible to identify the 'sequevar' or 'sequence variant' to which each isolate belonged. Using phylogenetic analyses, the isolates from China and Colombia were found to belong to two previously undescribed sequevars. The phylogenetic trees obtained from each of the gene regions sequenced in this study confirmed the phylotyping results. The results of this study show that bacterial wilt of *Eucalyptus* is associated with two *Ralstonia* spp., namely, *R. solanacearum* and *R. pseudosolanacearum*.

Poster Forest Health

Pheromone Release Rates and Ratio's from an Artificial Pheromoned Ispenser for the *Eucalyptus*-infesting Cossid Moth, *Coryphodema tristis*

Marc Bouwer[1,2], Bernard Slippers[1,3], Michael Wingfield[1,4], Egmont Rohwer[2,4]*

1. University of Pretoria; 2.Department of Chemistry; 3. Department of Genetics; 4.University of Pretoria;

Coryphodema tristis is a lepidopteron pest that infests *Eucalyptus nitens* trees planted in the high altitude summer rainfall areas of South Africa. Female *C. tristis* moths attract males at night with a sex pheromone. In an earlier part of the study, we identified the sex pheromone as a combination of Z9-tetradecenyl acetate (Z9-14OAc), Z9-tetradecenol (Z9-14OH) and tetradecenyl acetate (14OAc). Traps baited with a custom made pheromone permeation device that contained pure pheromone compounds in different combinations was shown to lure male moths in the field, but only when the pheromone compounds were dispensed in certain volumetric ratios. The actual release rates and ratios of pheromone compounds from this artificial pheromone dispenser were investigated. In this study we determine the release rates through a gravimetric method and ratios through a solid phase micro extraction (SPME) sampling method followed by chromatographic quantification. Results show that pheromone release rates are influenced by temperature and that the emitted ratios mirror the volumetrically dispensed ratios. This result confirms that our permeation dispensers release pheromone compounds in a ratio that mirrors that which was dispensed. Variations in the numbers of moths that are caught may be influenced by variations in pheromone release rates as temperature changes in the field. These results open the opportunity to use this pheromone, dispenser and trap combination for large scale field experiments to influence the moth populations through mass trapping at high value sites.

Population Genetic Analysis Reveals a Complex Global Invasion History for the Eucalyptus Gall Wasp, *Leptocybe invasa* (Hymenoptera: Eulophidae)

Gudrun Dittrich-Schröder[1], Brett P. Hurley[1], Michael J. Wingfield[1,2], Simon Lawson[3], Helen Nahrung[3], Bernard Slippers[2]

[1] Department of Zoology and Entomology, Forestry and Agricultural Biotechnology Institute, University of Pretoria, Pretoria, 0002, South Africa

[2] Department of Genetics, Forestry and Agricultural Biotechnology Institute, University of Pretoria, Pretoria, 0002, South Africa

[3]Forest Industries **Research** *Centre, The University of the Sunshine Coast, Queensland, Australia*

Poster Forest Health

Subsequent to being discovered outside its native range and its later description in 2004, the Eucalyptus gall wasp *Leptocybe invasa* has spread to all continents where *Eucalyptus* spp. are planted. In order to trace the routes and extent of *L. invasa* introductions globally, we characterised the genetic diversity within and between populations of the wasp from its origin and invaded regions. From the 460 *L. invasa* specimens, 19 cytochrome oxidase I (COI) haplotypes were identified, of which three were found in the invaded range. Two distinct lineages, which could represent cryptic species, appear to have been independently introduced into different parts of the world. One type (Lineage A) occurs throughout the invaded range, and is the exclusive type found in Europe, the Middle East, South America and most of Africa. The second type (Lineage B) co-occurs with the A-type in Thailand. Preliminary analyses of 13 newly developed simple sequence repeat (SSR) markers in sub-populations of *L. invasa* supported the distinction of the two lineages. These findings underline the weakness of current quarantine measures to halt the movement of plantation pests. Furthermore, it is important that management efforts using highly specific natural enemies and resistant planting stock should consider the likely scenario of eventually having to deal with two different lineages of the pest. Ongoing research using the SSR markers developed in this study should confirm the possible existence of a cryptic species in the *L. invasa* populations, hybridization or admixture between the two lineages, and the reproductive mode in the invasive range. They will also provide additional knowledge regarding the invasion history of *L. invasa*.

Species of *Calonectria* Infecting *Eucalyptus* in China: High Genetic Diversity and Increasing Importance

JieQiong Li[1], GuoQing Li[1], Michael J. Wingfield[2], ShuaiFei Chen[1,2]*

[1] China Eucalypt Research Centre (CERC), Chinese Academy of Forestry (CAF), ZhanJiang 524022, GuangDong Province, China

[2] Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria, 0028, South Africa

[*]Corresponding author e-mail: shuaifei.chen@gmail.com

The genus *Calonectria* includes numerous important pathogens that cause significant damage to a large number of herbaceous and woody plants worldwide. *Eucalyptus* trees are widely planted in South China and pathogenic species of *Calonectria* can cause significant losses for the *Eucalyptus* industry, where these fungi infect trees in plantations and seedlings in nurseries. The disease symptoms caused by species of *Calonectria* on *Eucalyptus* in China include leaf blight on trees in plantations as well as rotting of stems and leaves in nurseries. DNA sequence comparisons of the β-tubulin, calmodulin, histone H3 and translation elongation factor-1α gene regions have recently identified twenty-seven species of *Calonectria* from *Eucalyptus* plantations and nurseries in South China. This is a surprisingly high level of diversity in a relatively small area. It also suggests that many more species of *Calonectria* remain to be discovered in South China and elsewhere in the country. Leaf inoculations with twelve species of *Calonectria* on ten *Eucalyptus* clones showed that all the tested *Calonectria* species produced lesions although the levels of infection different depending on the species of *Calonectria* and the clones tested. These preliminary results suggest that there are good prospects to select disease-tolerant clones for plantation establishment in the future. This will, however, require a more comprehensive understanding of the species diversity of *Calonectria* in the region as well as intensive screening of *Eucalyptus* clones for resistance to these pathogens.

Wood Productivity and Light Use Efficiency Affected by Rust (*Puccinia psidii*) in *Eucalyptus urophylla* Clone

Rodrigo Hakamada[1], Simone Takahashi[2], José da Silva Teixeira[3], Gabriela Moreira[3], Cristiane Lemos[3], Paulo Vomero[3], Carla Garcia[3]

1Forest Resources Graduate Program, University of São Paulo, 13400-970 Piracicaba, SP, Brazil
2The United Nations Development Programme, C.P. 179, P.O. Box 1011Bissau Codex, Guinea-Bissau
3 International Paper do Brasil, SP 340 Road – Km 171, Mogi Guaçu, SP 13.840-970, Brazil

Global warming and expansion of landscape occupation are increasing occurrence of diseases in forest plantation. Puccinia psidii is the main pathogen in Eucalyptus forests and has caused severe damage in forest productivity. However, few studies have been done to evaluate its impact on tree growth by the end of rotation, as well as to characterize the ecophysiological aspects that control wood production. The objective of this study was to quantify the effect of rust in a Eucalyptus urophylla clone on wood productivity and light use efficiency. We used two treatments besides control plots that are commonly applied by managers: one curative pulverization of a fungicide (Triadimenol 250 g l-1) seven months after planting; five pulverization of the same fungicide preventively, i.e., from 1st to 7th month age of saplings. Wood growth and leaf area index were evaluated five years after planting. Leaf area index was 8 and 22% higher in curative and preventive control (4.5 and 4 m² m-2 leaf/soil) than the non-treated plots (3.7 m² m-2 leaf/soil), respectively. In addition, light use efficiency was also higher when fungicides were applied, being 8 and 26% higher in curative and preventive control (1.06 and 1.24 g MJ-1) compared with the absence of control (0.98 g MJ-1). These results clearly evidencing the negative effect of the disease in canopy development, as well as in leaf sanity. Consequently, control treatment obtained a mean annual increment at age five of 39 m³ ha-1 yr-1, against 43 and 53 m³ ha-1 yr-1 of corrective and preventive treatments (12 and 37% higher, respectively). To our knowledge, this is the first report of the effect of rust on Eucalyptus wood growth and its ecophysiology behavior, mainly considering high productive sites. These results shed light on the importance of maintaining the sanity of Eucalyptus plantation or by selecting a tolerant disease genotype or by controlling the disease chemically. More studies are needed to characterize long-term morphological and physiological behavior of Eucalyptus trees under rust infection.

Key words: leaf area index, eucalypt disease, stocking, forest plantation

Poster Forest Health

Effect and Mechanism of Supplementation with EPE on Growth Performance, Meat Quality and Antioxidant Ability in Finishing Pigs

R.W. Tan[a], L.P. He[a,b], W.J. Dai[a], J. Du[a],, Y. Cao[a], J.J. Zuo[c]

[a] *College of Food Science, South China Agricultural University, Guangzhou, Guangdong 510642, China*
[b] *Instrumental Analysis & Research Center, South China Agricultural University, Guangzhou, Guangdong 510642, China*
[c] College of Animal Science, South China Agricultural University, Guangzhou, Guangdong 510642, China

Effect and mechanism of dietary supplementation with EPE on meat quality, antioxidant ability and growth performance in finishing pigs. A total of 180 finishing pigs [(Duroc×Yorkshire)×Landrace] with average initial BW of 70.8 ± 3.1 g/kg were randomly allotted to one of 5 treatments (6 pens/treatment and 6 pigs/pen). 5 treatment groups received diets differently containing basic diet (Con), basic diet+0.3 g/kg EPE, basic diet+0.6g/kg EPE, basic diet+0.9 g/kg EPE, basic diet+1.2 g/kg EPE. The duration of the trial was 30 days. The supplementation of diet and water were limitless for all pigs. The intake of pigs was recorded in every week. And the results showed: 0.3 g/kg group showed a talently increase in ADG than Con group ($P<0.05$). FCR of 0.3 g/kg, 0.6 g/kg, 0.9 g/kg groups were significantly lower than that in Con group ($P<0.05$); The contents of GMP and IMP in 0.6 g/kg, 0.9 g/kg and 1.2 g/kg group were also significantly higher compared to Con group ($P<0.05$); on the period of 30d, GSH-Px and SOD activity of serum samples in 0.9 g/kg and 1.2 g/kg groups were significantly higher than 8that in Con group ($P<0.05$) and No significant differences between other Groups; The mechanism of EPE improving IMP levels of LM by analyzing the expression of genes and proteins depended on cDNA microarrays and Proteomics techniques. This study suggested that dietary supplementation of EPE increased expression of CK, AD and related genes. This phenomenon resulted in the conversion of ATP, AMP and IMP.

Key words: *Eucalyptus*,finishing pigs,growth performance,meat quality, antioxidant ability,mechanism study

Poster Utilization

Book of Abstracts (Revision)
IUFRO Eucalypt Conference 2015

4 Nov 2015

The conference secretariat