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Eucalyptus 2018

Managing *Eucalyptus* plantations under global changes

Abstracts Book

Foreword

Eucalyptus trees cover about 20 million hectares in more than 90 countries around the world with major centers in Brazil (5.7 m ha), India (3.9 m ha) and China (4.5 m ha). Eucalypts are widely grown in commercial plantations to produce raw material for the industry (pulp and paper, charcoal, sawn timber, wood panels) but also in small woodlots for the production of firewood and charcoal for domestic uses.

The considerable expansion of these plantations in recent decades reflects major competitive advantages of eucalypts relative to other tree species in terms of productivity, tolerance to biotic and abiotic stresses, wood quality for a wide variety of uses and ability to be managed in coppice. However, the requirements in water and nutrients of eucalypt trees are high to reach high biomass productions and the environmental impact of the silviculture is still a matter of debate. In a context of global changes with more frequent drought events, temperature rise and rapid expansion of pests and diseases, the sustainability of eucalypt plantations is of concern in many regions. Interdisciplinary research is urgently needed to improve the adaptation of eucalypt plantations to global changes.

Cirad and I-Site MUSE organize an international conference under the auspices of IUFRO (Division 2.08.03 *Improvement and culture of eucalypts* and Division 1.02.01 *Ecology and silviculture of plantation forests in the tropics*) to present recent advances likely to improve the management of eucalypt plantations in tropical, sub-tropical and Mediterranean regions.

The objectives of the conference are:

1. to strengthen a community of researchers and forest managers concerned by the sustainability of forest plantations.
2. to present recent technical and scientific innovations making it possible to improve the management and the ecosystem services of eucalypt plantations.
3. to explore new strategies in tree breeding and silviculture for better adaptation of eucalypt plantations to the major abiotic and biotic stresses that are expected to increase with global changes.
4. to discuss research priorities to improve the sustainability of eucalypt plantations, fueling a growing demand for wood while maintaining environmental and social services in rural areas

The conference is organized in plenary sessions to promote interdisciplinary discussions between forest managers and researchers specialized in tree breeding, silviculture, forest pathology, wood science as well as environmental and social sciences. This book includes the abstracts of 13 keynotes, 55 oral presentations, 18 lighting talks and 132 posters presented during the conference.

Jean-Paul Laclau
Cirad, UMR Eco&Sols
Chair *Eucalyptus* 2018

Key Notes

Resilience of primary metabolism of eucalypts to variable water and nutrients

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The genus *Eucalyptus* and closely related genera, have evolved in a wide range of environments, but especially under well illuminated, dry and warm-hot conditions, on poor soils. Over many years, we have explored responses of the primary metabolism of eucalypts to changing light, nitrogen, water and temperature regimes. Ecological growth strategies are reflected in traits such as the photosynthetic and respiratory capacity of leaves, which determine much of plant carbon balance. As an example, contrasting light environments and nitrogen supply have different effects on Flooded Gum (*Eucalyptus grandis*) and Mountain Ash (*E. regnans*), growing under warm-temperate conditions. *E. grandis* produced three-fold more biomass than *E. regnans*, and benefitted more from enhanced supplies of nitrogen, in particular under semi-shade conditions. Acclimation of leaf mass per area to growth irradiance was more plastic in *E. grandis*, and scaled positively with area-based photosynthesis. In *E. regnans*, growth under high irradiance and nitrogen availability caused significant accumulation of foliar N, which was not matched by mostly small increases in photosynthetic capacity. Foliar nitrogen was used more effectively for the production of new foliage in *E. grandis,* owing to better coordination with foliar capacity and flux mode of mitochondrial oxygen reduction. Just a few physiological/anatomical variables are needed to explain these results, including: foliar density of mitochondria, average nitrogen concentration per mitochondrion, and relative demand for energy versus anabolic intermediates. Demand for anabolic intermediates is one of the major differences among *Eucalyptus* spp and new approaches to physiological modeling are needed to capture 'sink-driven' rates of carbon fixation, and better predict growth.

Keywords: Eucalypt

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Abiotic stresses: where ecophysiology meets management

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The production of Eucalyptus forests is usually limited by abiotic factors in the environment. Nutrient supply is one of the most severe potential limitations on production, but intensive fertilization often minimizes this limitation. Ecophysiological stress related to temperature and moisture also limit production in most plantations. Across the state of Bahia in Brazil, operational plantations in the 1990s mid-rotation wood production increased from about 12 Mg ha-1 yr-1 with 900 mm yr-1 of rain to 25 Mg ha-1 yr-1 with 1500 mm yr-1 of rain. The TECHS project found a similar trend across tropical and subtropical regions of Brazil. An increase in precipitation of 100 mm yr-1 was associated with an increase of 1.5 to 1.8 Mg ha-1 yr-1 of wood production. However, drier sites have not only lower supplies of water but often higher temperatures and lower atmospheric humidity. Increases of 1 oC in mean annual temperature in the TECHS project were associated with declines of 2.9 Mg ha-1 yr-1 in wood production. When the effect of temperature was also included, the response to increasing rainfall was only 0.4 Mg ha-1 yr-1 for a 100 mm yr-1 increase in rainfall. On-site manipulations of water supply, through irrigation or rainfall exclusion, are needed to separate the effects of rainfall from temperature. Insights about the exact ecophysiological limitations on production may have value in both silviculture and genetic selection silviculture. If production is limited by water supply, choices about tree spacing may be fundamental for balancing stand-level growth and tree mortality. The sensitivity of leaves to low humidity might limit growth even on soils with high water holding capacity, and genetic selection might offer site-specific opportunities to balance site water supply and tree responses to dryness of the air.

Keywords: Water, temperature, humidity, production

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What's beyond wood fibre for eucalypt industrial plantations.

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The expansion of eucalypt plantations around the world, which by now would have reached 25 million hectares, has been mostly driven by industrial demand from pulp, paper and cardboard industries. Developments in genetics and silviculture have therefore been mostly targeting more productive pulpwood plantations with fibre characteristics suiting a single end product.
The societal move to a fuller and more efficient, cross-sectorial utilization of the various biomass components, beyond the strict linear chain from pulpwood to paper, in what has been referred to as The Bio-economy, challenges the use and design of eucalypt plantations as they are perceived and managed today. They will be expected to provide simultaneous production of a range of industrial goods (paper products, chemicals, energy and plantation timber) as well as other more elusive but equally relevant environmental services.

The putative declining of printing and writing paper markets, although not threatening the global pulpwood business model in the short run, will certainly change the way industrial plantations will be managed and certified hence raising new issues for forest scientists and managers to address.
In this paper we will review the implications of these recent developments on the present and future research agendas as related to eucalyptus plantations, with special emphasis on the impact they will have and the opportunities they will create in areas such as forest genetics, biotechnology and forest management.

Keywords: Pulp and Paper, Energy, Biorefinaries

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The production ecology of mixtures: From pattern to process to application

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Mixed-species plantations are often proposed as a way to increase the level of various ecosystem services, including productivity, compared with monocultures. However, while mixtures may often be superior to monocultures, there are also examples where they are not, so there needs to be a way to determine when and where mixtures are likely to be better or worse than monocultures. Despite the many studies about mixture – monoculture comparisons, it can be very difficult to know how those results can be transferred from the journal articles to a specific plantation with its unique set of silvicultural objectives, climatic and edaphic conditions. It is therefore not surprising that the vast majority of the world's plantations are monospecific.
The aim of this work was to develop an approach to determine appropriate species combinations and silvicultural treatments for specific sites and species. A framework was developed to explain the spatial and temporal changes in mixing effects that have been reported in the literature. This framework is based on the production ecology equation, which is used to determine which processes and interactions are occurring in a mixture, how resources are partitioned between species and how strongly the interactions influence productivity; just because a process is occurring faster in a mixture does not mean it has a significant effect on growth.
While this framework is useful, it is a considerable simplification of reality and cannot easily be applied by foresters because multiple types of interactions occur simultaneously in mixtures (e.g. nitrogen fixation, increased water-use efficiency) depending on the prevailing climatic and edaphic conditions, the developmental stage, stand density, etc. This complexity cannot be depicted using a simple framework. Therefore this study involved a modification of the forest growth model 3-PG so that it could be applied to mixed-species stands and to examine silvicultural treatments

Keywords: competition, facilitation, growth model, 3, PG, silviculture

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Forest outgrower programs in small and medium-sized producers in Brazil

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Outgrower programs are an alternative for supplying companies and can generate benefits for both the producer and for the community. The main reasons that lead companies to adopt this type of strategy are the reduction of investment in land purchases, lower cost of wood (at the factory), increase the diversification of sources of raw materials, as well as greater integration with landowners close of companies. Of the total of 7.84 million hectares of trees planted in Brazil in 2016, 34% belong to companies in the pulp and paper industry, 29% are independent operators and participants in outgrower schemes, and the charcoal-fired steel industry represents 14% of the planted area. In 2016, 19,900 people benefited from the outgrower programs adopted by Brazilian Tree Industry (IBÁ) member companies, planting 545,000 hectares. For rural producers, the forest development consists of an alternative to traditional income generation to their properties, which may use idle or underused areas with low technical risk due to production inputs and technical assistance provided by the companies. The most frequent outgrower modalities include providing forest species seedlings, revenue anticipation programs and wood purchase guarantee at harvest time. For the community, these include the possibility of creating new wood-based forest business and generating jobs in the region. This program prevents land concentration, makes local activities feasible, creates opportunities of additional income and assists in settling people in the countryside. From the environmental standpoint, forest fostering mitigates the pressure on native forests, recovers degraded soils and promotes soil conservation

Keywords: Forest fostering, social program, sustainability, eucalypt plantation

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Advances in remote sensing: potential to gain insight into the ecosystem services of eucalypt plantations

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Satellite remote sensing is increasingly used on agricultural and forestry sectors for spatial characterization, management and monitoring of large areas at stand or intra-stand scales. This usage will increase in the future with the expansion of the number and quality of sensors and the analysis capacities. This presentation review the main type of earth observation sensors, their physical principles, and their main usage in forestry and agronomy. Then a focus is given on the particular case of remote sensing of Eucalyptus industrial plantations for estimation of plantation area and afforestation dynamics; stand biochemical and structural characteristics; plant water status and other functional variables; cultivation practices and different aspects of stand management. Tropical and subtropical Eucalyptus plantations specificities require special attention while using generic methods or products, and often need the development of dedicated methodologies, advocating for more specific research. Successful use of remote-sensing for spatial characterization and monitoring of eucalyptus plantations (e.g. biomass, leaf area index, classification, etc.), but also main issues and knowledge gaps are illustrated with examples from Brazil. In a broader aspect, these remote sensing characterisation could be used for ecosystem services assessments such as water use, carbon sequestration, wood production and environmental impacts. This is discussed through three major development points 1) the necessary synergy between remote sensing and process-based models; 2) the watershed-scale spatialization and modelling of the spatial interactions;. 3) to take advantage of the potentiality offered by current and future satellite mission and analysis methods.

Keywords: Remote sensing, Ecosystem services, Eucalyptus plantation

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Insights from genomic studies to predict the effects of abiotic stresses on Eucalyptus wood properties

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Wood is the most abundant plant biomass on earth and an immense reservoir of fixed carbon for long periods of time. It is used for myriad applications such as construction, pulp and papermaking and as a source of renewable energy alternative to fossil fuels. Distinct wood properties are required for the different end-uses of wood as raw material and they are not necessarily the properties, which are beneficial for trees fitness and adaptation to environment. Wood is produced through a complex differentiation process leading to highly specialized xylem cells characterized by thick lignified secondary cell walls [SCWs]. Wood formation is highly plastic and involves the dynamic integration of environmental signals into complex developmental pathways, resulting in functional adaptation to environmental conditions. These adaptative strategies are crucial for trees that, as perennial long-living organisms, have to face challenging and contrasting environmental conditions enhanced in a context of global climate change. To investigate the complex transcriptional regulation controlling wood formation during development and in responses to abiotic stresses, we capitalized on recent discoveries gained from the *E. grandis* genome and we developed system biology approaches integrating genomic, metabolomic and phenotypic data. The combination of multivariate analyses, gene networks, and large-scale data integration, enabled us to correlate SCW related gene modules to wood properties and to highlight new transcription factors regulating xylem formation and responding to abiotic stresses. The functional characterization of such candidate transcription factors using poplar or transgenic Eucalyptus hairy roots will be discussed.

Keywords: Eucalyptus, wood, system biology, cold tolerance, water stress, potassium nutrition, gene networks, transcription factors, functional genomics

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Forestry and wood for rural development and poverty reduction: time to move on from romanticism and failed hopes to reality.

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The global dialogues on forests, so far driven by the conservation agenda, have delivered hundreds of reports and many CoPs, but little to lift the millions of people out of poverty, living in the forest- rural landscapes- continuum, mostly in the sub-tropics and tropics. For nearly two decades, Clean Development Mechanism (CDM), Payment for Ecosystem Services (PES) and much touted REDD+, raised high expectations of advancing forest conservation and improving livelihood of rural people. So far, these "Grand and designs" have not served much for conservation and have not enabled sustainable use of natural resources for rural development.
Economic growth, environmental care and social justice provide the foundation for poverty reduction. No nation, rich or poor, accepts a net reduction in greenhouse gas emission at the expense of economy and jobs. Economic growth and poverty reduction have been possible largely through private investments, judiciously governed by Governments, advancing public benefits. Forestry, especially based on plantation forestry including wood processing for value adding, is a rural business. It is at the intersection of challenges:
- sustainable wood production with environmental care for meeting the rising demand for wood and wood products, and contributing to national revenue,
- widening disparities in opportunities between rural and urban communities,
- urgency for targeted rural development initiatives complimenting agriculture, and
- the roles of forestry and greater use of wood as climate change mitigation measures.
These are not easy to achieve; they interact in complex ways. I present the case that sustainable commercial forestry and local value adding of wood can do a lot more for meeting these interconnected challenges.
Wood is a green, renewable, recyclable and sustainable natural resource.

Keywords: Eucalyptus, Rural devlopment, poverty reduction

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Genome diversity of commercially grown Eucalyptus species and hybrids: Towards landscape genomics for genetic resource management and molecular breeding

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Eucalyptus tree improvement depends on effective sourcing, management and selection of genetic variation for adaptive and commercial traits. These facets of eucalypt domestication and breeding can be informed and accelerated by genomics tools and resources developed over the past decade. This is particularly important as eucalypt plantation forestry faces challenges such as climate change and an ever increasing repertoire of pests and pathogens. To deploy genomic tools for commercially grown eucalypts in South Africa, we have over the past five years initiated an industry wide effort to map the genome diversity of planted eucalypts in the country. This involved establishment of genomic references (100 - 350 trees per species covering the natural range) sourced from first-generation provenance trials and conservation parks followed by genome-wide single nucleotide polymorphism (SNP) analysis using the EucHIP60K.br genotyping array. We initially focused on four species, *E. grandis*, *E. urophylla*, *E. dunnii* and *E. nitens,* as well as their hybrids, with the aim to apply genome-wide SNP marker data to analyse species and provenance differentiation, population structure and chromosome-level ancestry. Alongside this, we established genomic selection (GS) training populations for *E. grandis* and *E. dunnii* and developed genomic prediction models for a range of growth and wood property traits. More recently, we expanded our genomic references for *E. grandis*, an important hybrid partner for subtropical and temperate regions in South Africa. To elucidate the neutral and adaptive population structure of native *E. grandis*, we are genotyping over 800 plants from 240 imported

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individual-tree seed lots obtained from 40 natural stands between latitudes 16∘11' S and 32∘2' S in Australia. This information will form the basis for a species-wide analysis of genome diversity and population structure, as well as illuminating the genomic consequences of 100 years of artificial selection in South Africa. The study lays the foundation for future expansion into landscape genomics for improved genotype-by-site matching and the development of genomic resources, including an online informatics resource for breeders, to support gene conservation efforts, genetic resource management and molecular breeding of eucalypts.

Keywords: Genomics, molecular breeding, genetic diversity, landscape genomics

Dealing with genotype x environmental interactions in Eucalyptus forest companies

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Forest companies across the world, from the tropics to temperate climates, are increasingly use *Eucalyptus* plantations as the main source of wood as raw material for wood and non-wood products, such as firewood, charcoal, pulp and paper, sawtimber and essential oils. This broad adaptation and application of *Eucalyptus* are linked with the natural genera diversity (> than 800 species and thousands of provenances) in the Australia-Indonesian region associated with the artificial hybrids, planned and cloned by breeders, that open new paths of adaptation, growth and wood quality to better utilized the environments available for planting. In Brazil, due to its large area and climatic, soil and topographic conditions, commercial MAI range from 20 to 70 m3 ha-1 yr-1 over 5 to 8 years rotations using many different species and hybrids. The optimization of the deployment of the best genetic material for each site, with its own abiotic and biotic constraints, is not only a scientific puzzle but also a real issue that requires daily decisions in forest companies. Suzano has forest plantation that on the abiotic side grows from Latitude 24oS to 2oS, with MAT from 17oC to 27oC, average rainfall from 800 to 2200 mm yr-1, and soil types that ranges from well-drained sandy Entisols to poor-drained clay Ultisols. On the biotic side forest are expose to more than 15 significant native and exotic pests and diseases. To deal with all this complexity, a Genetic-Genomic, Management-Modeling and Protection-Product experimental design, called G2M2P2, was established and implemented across the landscape after detailed environment characterization based on the scientific guidelines produced by many cooperative research programs. Besides that, the inventory network of the company, from 4 month-old to 7-year-old, was integrated to environmental attributes, allowing deeper understanding of the effects of rain, temperature and soils on forest development. Finally, for a successful planning, deployment and management of clonal materials, a Continuous Forest Education program was established for all technical crew members to allow conceptual understanding of the detailed strategy of GxE as well as identifying pitfalls in the field to force the system to be improved. Two-year results of these network and education effort will be presented.

Keywords: Eucalyptus plantations, Climatic zoning, Genetic, genomic characterization, Experimental Network, Continuous Education

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Eucalyptus Pests: Expanding Frontiers

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Eucalypts (including species of *Eucalyptus* and *Corymbia*) are increasingly threatened by insect pests and pathogens, which we collectively refer to as pests. The most evident of these problems are those occurring where Eucalypts have been planted as non-natives for commercial purposes. There are two major drivers of pest problems in these plantations. These are accidental introductions of pests originally from areas where eucalypts are native or via host jumps from native trees where non-native eucalypts are planted. A more worrying situation is clearly arising were new exotic pests are becoming established in the native ranges of eucalypts. In the latter case, naïve tree species with no prior exposure to the pests can be lost. From the commercial forestry perspective, this loss of genetic potential will have long-term negative consequences but the greater impact is to the world's ecology. It is reasonable to predict that commercial plantation forestry with eucalypts will be increasingly challenged by new and often devastating pest problems. Although greater costs will likely be implied, we remain optimistic that the many new technologies available for tree improvement will make it possible to continue to propagate eucalypts both sustainably and cost effectively in the foreseeable future.

Keywords: pests, pathogens, insects, diseases, sustainable forestry

*Speaker

What causes the rapid development of eucalypt plantations and industries in China?

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Eucalypt plantations in China currently exceed 4.5 M ha, and this country has the third largest area of such plantations after India and Brazil. China's eucalypt industry now comprises a complex, multifaceted industry 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 byproducts and non-wood forest products. The combined value of output of this whole industry reached 300 billion CNY by 2015.

Since the turn of the century, the eucalypt plantation area in China has increased rapidly, with the resource expanding to over 4.5 million ha by 2015. This particularly rapid expansion can be attributed to a combination of factors including favorable government policies; forest land tenure reforms; strong and increasing demand for timber and fiber; increased grower recognition of profit potential from such plantations; technolocal surport by research and development (R&D); and, a few large pulp and paper companies endeavoring to develop large areas of plantation-based pulpwood resources. The most important factor is Chinese research and development (R&D) has been instrumental in supporting growth and development across the whole breadth of the country's eucalypt industry.

Since 2015, China's eucalypt plantations produced about 30 million m3 of wood anually, accounting for about 27% of the country's total annual domestic timber output. These plantations thereby make a substantial contribution to safeguarding the security of China's wood supply. It is also noteworthy that this substantial production of raw material is part of a complete industry that includes everything from seedling propagation, fertilizer and chemical production and supply, pulp and paper manufacture, wood-based panel production, sawn timber production, biomass energy production and a range of non-wood byproducts. Thirdly, Eucalypt plantation and its relative industry offered millions of jobs for farmers and workers, this has made great contribution for rural development and poverty reduction in southern China.

Keywords: China, eucalypt plantation, eucalypt industry, wood supply

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Ecosystem services - Oral session

Catchment management for Eucalyptus plantation production and water availability

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The use of water by broad-scale *Eucalyptus* plantations remains controversial. To minimise their potential adverse effects on water resources, a suggested way forward is to base their management on an understanding of catchment characteristics matched with the age and spatial distribution of plantations. Despite this preference of certification, regulatory and catchment management bodies, such an approach is not yet widely implemented. In this study, we examine the effects of harvesting either 30% (partial) or 100% (clear cutting) of the planted area in paired catchments managed for wood production or pasture in southern Brazil. Plantation growth and water balance were measured for six years, commencing four years before harvesting until two years after reestablishment of the next rotation. Linking a forest process-based model with a hydrological model allowed us to accurately quantify the influence of plantation management on daily water availability and monthly stand growth. Catchment streamflow was influenced by intrinsic differences between catchments such as soil characteristics, topography, riparian vegetation, land use, and rainfall distribution and intensity. Partial harvesting maintained relatively higher base flow for at least two years after harvesting when compared with clear cutting. These capabilities enable plantation age distribution and position of the harvest area in a catchment to be studied quantitatively in relation to water resources and wood production.

Keywords: Keywords: stream flow, catchment, Eucalyptus, modelling, harvesting

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The influence of species, tree improvement and cultural practices on rotation-end fibre production of Eucalyptus pulpwood plantations in South Africa

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Increasing the yield per hectare reduces the unit cost of timber. A trial series with a 24 factorial design was established across five sites within the temperate areas of South Africa. The four treatments, each tested at a superior and inferior level, were species selection, genetic improvement, silvicultural intensity and planting density. The study investigated the effects of and interactions between treatments on fibre production over a rotation. The positive growth response associated with the four main treatment factors was maintained to rotation-age, although the relative gain from the various treatments decreased over time (from an additional 60.3% fibre per hectare at age 2.5 to 27.1% at 10 years). The relative contribution of the four factors to productivity gain changed over time. The relative influence of species selection increased, whilst that of silvicultural intensity decreased over time. Thus the selection of the best suited species for a specific site was the most important factor, improving fibre per hectare by 13%. There was, in general, no interactions between the treatments. Further yield improvement was possible through genetic improvement (4%, $p > 0.10$), planting trees at the optimum density (5%, $p < 0.10$) and intensive silviculture (5%, $p < 0.10$). None of the treatments had a negative effect on wood quality.

Keywords: weed control, fertilization, genetic improvement, wood properties

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Potential of eucalyptus as source of molecules for green chemistry

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Eucalyptus is nowadays the most important wood species used for the production of short fibers worldwide. Different eucalyptus species are used in different regions of the globe, the choice being governed by the climate and soil conditions for economically viable large scale planted forests. The production of eucalyptus pulp is single-product, mass-production oriented. Bleached cellulosic fibers for printing & writing paper, tissue and personal care articles are almost the only products obtained from eucalyptus wood.
As part of the sustainable development of a forest-based bioeconomy, the development of new ways of valorizing eucalyptus for other markets is a clear priority of all industrial players. The main motivations are the needs of diversification of products to avoid the dependence on the global pulp prices fluctuations while creating new markets by supplying bio-based raw materials. The extraction of biomolecules, the so-called biorefinery, aiming at the production of chemical intermediates for green chemistry, represents the most exciting, but also one of the most challenging approaches to fulfill these expectations.

This presentation intends to highlight the potential of two classes of molecules of some eucalyptus species cultivated in South America and Southern Europe for green chemistry applications: lignins and hemicelluloses.

On lignins, the focus will be given to the possibilities of extracting them in a pulp mill from the spent black liquor for further valorization. Some recent results obtained during a French collaborative project about the lignin characterization and the heterogeneous catalytic conversion of lignin into smaller aromatic molecules will be presented.
The second part of the presentation will be devoted to the potential of extraction and valorization of of hemicelluloses by two different concepts: from wood prior the cooking or from the fully bleached pulp. The interests, advantages and drawbacks of each approach will be clearly exploited. Then, the effect of extraction conditions (aqueous liquor composition, pH, temperature, additives, etc) on the quality of recovered eucalyptus hemicellulose fractions will be described. Depending on the extraction conditions, hemicelluloses having very different chemical composition could be obtained. For example, acidic or near-neutral conditions, galactoglucomannans-rich fractions (up to 73 %) are obtained, while the fractions obtained in alkaline conditions are rich in arabinoxylans (up to 65 %). Extraction from wood are contaminated with residual lignin, but more are more soluble due to the ramification of the chains. Hemicelluloses from pulp are

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free of lignin, but hard to be dissolved as they are linear. An optimization of hemicelluloses extraction from eucalyptus by factorial design of experiment will be shown. Finally, three examples of valorizing hemicelluloses (depending on their molecular weight), recently developed in projects where FCBA is involved will be highlighted: i) sugars catalytically converted into monomers (FDCA or polyols) for the production of polymers such as polyesters and polyamides; ii) amphiphilic conjugates between hemicelluloses and fatty acids for cosmetics applications; iii) additives for papermaking after chemical modification of high MW hemicelluloses.

Keywords: Green chemistry, lignin, extractives, hemicelluloses, eucalyptus, biorefinery, bioeconomy, valorization

Eucalyptus Farmers' Preferences for Water-Saving Strategies in Brazil

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In a climate change context, changing temperature and precipitation pattern are expected to have strong impacts on Brazilian eucalyptus plantations. These impacts include a likely decrease in yields, an increase in tree mortality and in the frequency and intensity of forest fires, and an increase in the frequency of pest and disease attacks. Besides that, the behavior in the water consumption of eucalyptus plantations can have negative effects on the stream flows in the watersheds where they are located. Therefore, implementing adaptive water-efficient management practices is necessary to maintain high plantation productivity while preserving the water resources. This paper investigates the willingness of eucalyptus farmers to modify the current silvicultural practices in order to adapt to climate change. The valuation approach carried in this study is based on the choice experiment (CE) method, which explores the viability of implementing adaptive strategies based on producers' predilections. We carried out a CE with 80 eucalyptus producers in the state of Minas Gerais, Brazil, where the farmers were asked to choose between hypothetical management scenarios with different silvicultural directives and various economic incentives. We moreover analyzed how the socioeconomic and farm characteristics may influence farmers' preferences for adaptation. Our results suggest two important points regarding adaptation options that may be considered in the future. First, the adaptation is more likely to occur by reducing the length of the eucalyptus rotation, since the surveyed farmers value this strategy positively in the choice experiment, which suggests that such change could be done at no cost for them. Second, they are generally averse to reduce tree density, meaning that it would be costly to them to adopt this strategy and that some financial support would be required for this option to be implemented. When we analyze farmers' preferences heterogeneity using a 2-segment latent class model, we moreover obtain a clear and relevant segmentation of farmers' choice behavior. We detect that both groups are likely to adapt to the upcoming global changes, but not in the same way. In particular, our results show that adaptation through reducing the rotation length is preferred by the most vulnerable farmers of the sample.

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Keywords: choice experiment, climate change, drought, water resources, adaptation

Modeling the socioeconomic and environmental sustainability of forest plantations in climate change mitigation

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Most countries have ratified the Paris Agreement which aims at reducing greenhouse gas (GHG) emissions in order to keep the increase in global mean temperature below 2 C above pre-industrial levels. Land use is expected to play a key role in reaching these climate targets and large mitigations are expected to be realized by increasing the carbon stocks in natural forests and by further developing and enhancing the bio-economy. In this context, industrial forestry plantations are foreseen as a possible solution for achieving increased production of woody biomass and increased sequestration of carbon.
The growing demand for woody biomass is expected to lead to an intensification of cultivation modules. Therefore, there are several uncertainties regarding the long-term socioeconomic and environmental sustainability of a strong development of industrial woody biomass plantations.
To analyze the important trade-offs, linked to the competition for land use between agriculture, bioenergy, and forestry, a specific module is under development in the Global Biosphere Management Model (GLOBIOM). GLOBIOM is an integrated modeling framework with a detailed sectorial coverage, combining a spatially explicit representation of production technologies, land uses and greenhouse gas emissions. The module is able of accounting materials, energy and labor inputs required in plantations and to translate them into costs, energy, and labor needs. The module is based on a global mapping of yields which is combined with simulations of inputs and cultivation costs. The supply layers obtained from the cost module are matched with the future demand for material and energy from the GLOBIOM, hence the model computes the optimal expansion of plantations in the different global Regions.
Under a 2 ∘C climate target scenario, a preliminary assessment indicates that between 120 and 135 Million ha of land will be converted into industrial plantations by the year 2050. Such a strong development of plantations would come with tradeoffs (e.g. use of chemical fertilizers, biodiversity displacement). Depending on the share of different land uses converted (i.e. forest, cropland, grassland, natural land) and intensities of management, different levels of sustainability will be achieved.

Keywords: sustainability, environment, climate mitigation, integrated assessment, global modeling

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Monitoring, processing, interpreting and communicating water use information by Eucalyptus plantations in Brazil

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Eucalyptus plantations in Brazil occupies more than 6 million of hectares and they continue to expand, mainly in direction to drier regions of the country. The expansion of fast-wood Eucalyptus plantations (6 to 8 years of rotation) and high productivity (more than 40m3 ha -1 ano-1) has been occurring besides persistent concerns of many parts of society about the effects of those forests on water quantity. The Program of experimental catchments monitoring and modelling (PROMAB) was created in 1987 aiming to understand and assess effects of forest management on hydrological resources at different regions of Brazil and Latin America. Based on continuous discharge and water quality monitoring at catchment scale, currently, PROMAB has 23 experimental catchments monitored (11 are covered by Eucalyptus plantations), resulting a total of 79 hydrological years of data. In average, those plantations received annual precipitation (P) of 1400mm and they have used 1210mm of water by Evapotranspiration (ET), resulting in a ratio ET/P of 0,87. Depending of water availability on each region, it seems to be necessary to balance the water demand by plantations and water provision for other users. In other to facilitate results interpretation, many other indicators of soil recharge, base flow, runoff and stream flow regulation compound a complete assessment of effects of forest management on water availability, but the main challenge is to communicate about them to companies and society. A framework for monitoring and share information about fast-wood plantation effects on water is presented and discussed seeking to improve forest management and keep society informed about it.

Keywords: monitoring program, hydrological effects, water use data communication

*Speaker

Dynamics of CO2, CH4 and N2O concentrations throughout deep soil profiles in Eucalypt plantations subjected to contrasted rainfall regimes: consequences on soil effluxes

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The major factors driving greenhouse gas exchanges in forest soils (substrate supply, temperature, water content) vary with soil depth. Our study aimed to assess the effects of clear-cutting and drought on the temporal variability of CO2, CH4 and N2O fluxes throughout very deep soil profiles in Brazilian eucalypt plantations conducted in coppice. Stands with 37% of throughfall excluded by plastic sheets (-W) and stands without rain exclusion (+W) were compared. Every two weeks for 21 months, CO2, CH4 and N2O surface effluxes were measured using the closed-chamber method and concentrations in the soil were measured at 7 depths down to 15.5 m in -W and +W. At most measurement dates, CO2, CH4 and N2O effluxes at the soil surface were not significantly different between -W and +W. Mean CO2 and N2O concentrations in -W were 20.7% and 7.6% lower than in +W, respectively, across the sampling depths. By contrast, CH4 concentrations in -W were 44.4% higher than in +W throughout the soil profile. Across the two treatments, CO2 concentrations increased from 4446 ± 2188 ppm at 10 cm deep to 15622 ± 3523 ppm at 15.5 m, CH4 concentrations increased from 0.41 ± 0.17 ppm at 10 cm deep to 0.77 ± 0.24 ppm at 15.5 m and N2O concentrations remained roughly constant and were on average 478 ± 55 ppb from the soil surface to 15.5 m deep. A modeling approach (using the Min3P and Root Typ models) showed that the amount of water filling soil porosity accounted for a large share of the difference in gas concentration between +W and –W, and pointed out the consequences of throughfall exclusion on the areas of CO2 production throughout the soil profile. Improving our understanding of the spatiotemporal dynamics of gas concentrations in deep soil layers is important to improve the current biogeochemical models predicting the effect

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of drought periods on greenhouse gas effluxes in eucalypt plantations established in deep tropical soils.

Keywords: Brazil, greenhouse gases, deep tropical soil, drought, coppice

UAV based plantation inventory – a highly precise and cost efficient approach for optimized eucalyptus plantation management

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Inventories of forest and plantations are the essential database for a sustainable and optimized management. However, existing approaches are either expensive and time consuming (terrestrial sampling) or lack accuracy (e.g. satellite data). Recently, drones carrying sensors with high spatial resolution were developed, capable of economically covering up to 10km^2 per day. These technological advances combined with highly specialized forest algorithms provide the opportunity for single tree analyses with high accuracy. This can be a support tool of the existing inventory approaches by increasing their efficiency and accuracy. Or it can replace these approaches. In any case it provides the plantation manager with always up-to-date and detailed information about his stands for a more informed and optimized plantation management.
To test the accuracy of direct (height, number of trees and crown projection area) and indirect forest parameters (DBH, volume, biomass) we compared the UAV based parameters with terrestrial data of eucalyptus (Spain), pine (Argentina), and poplar plantations (Germany) gathered on multiple sample plots of 500m^2 each. These terrestrial data were used to establish correlations between direct and indirect parameters, and to finally derive the indirect parameters from UAV data.

Both, the direct and indirect stand parameters showed high accuracy: Heights featured low bias of 11cm (0.9%) and relative RMSE of 6%. Accuracies of tree count ranged from 87-100% (producer) and 93-100% (user). Furthermore, biomass estimates showed low relative bias of 2.1% per study area and maximum deviations of 11% on stand level.
Due to the high accuracies achieved along with low costs for data acquisition by fixed-wing drones, we recommend a) scientists to improve the prediction of indirect forest parameters and b) practitioners to exploit the potential of UAV based inventories to assist or to replace (if models are accurate enough) terrestrial plantation inventories.

Keywords: forest inventory, drone, pointcloud, biomass, canopy height model

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Evaluation of Corymbia torelliana x C. citriodora hybrids for growth and pulp wood traits

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The genus Corymbia, has recently gained widespread attention due to attributes like tolerance to drought, pests and diseases and suitability for multiple uses. Interspecific hybrids of *C. torelliana x C. citriodora* (CT x CC) can be exploited for its hybrid vigour and pulp quality. Controlled half diallele cross was carried out between nine maternal CT and six paternal CC genotypes to develop 28 hybrid families with 150 – 500 progenies each. Progeny evaluation was conducted in 3 sites with diverse agro-climatic conditions in standard RCBD design. Traits of industrial interest such as biomass, kraft pulp yield, wood basic density and specific wood consumption (SWC) were recorded at the age of three years. Analysis of variance and phenotypic stability were estimated, in addition to identifying best combiners among the parents using ASreml-R. Ten superior hybrids that showed better adaptability in tested sites with 32% higher biomass and 13.6% higher wood basic density than the commercial E. camaldulensis clones were selected. Kraft pulp yield of selected hybrids ranged from 50 to 51.6% (kappa 20) with 12.5% lower SWC than the commercial control clones, showing high potential for commercial deployment.

Keywords: Corymbia, Hybrids, Biomass, wood properties

*Speaker

Comparison of the refining behaviour of different commercial eucalyptus chemical pulps

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Refining is an essential step for paper production: development of bonding properties of the fibres between them, improvement of sheet formation, collapsibility...
This step has been practiced for several decades. Recent technological developments open up new possibilities. On the one hand, the quality and nature of the fibres have changed: new, shorter fibre species, a production process that allows for higher yields and therefore chemical compositions different from those traditionally observed 20 or 30 years ago. On the other hand, new possibilities are offered for refining parameters, allowing to propose new plate geometries that could not be designed up to 10 years ago. Thanks to a pilot refining facility, reproducing a typical industrial line, the InTechFibres team carried out a study to compare several fibre resources, all sold under the name BEKP: Bleached Eucalyptus Kraft Pulp. Several refining conditions were tested in order to evaluate the fibre response to the applied treatments. In addition, a comparison was also made with more traditionnal hardwood mix or acacia hardwood paste. The measurements carried out are: drainage, fibre morphology, properties on laboratory handsheets. The results show a high degree of heterogeneity between the different commercial pulps tested, which makes it possible, depending on the production objectives, to choose, technically, an optimal supply or another. A modelisation allowing the selection of pulp according to sheet performance criteria was developed on the basis of the results obtained.

Keywords: Fiber, refining, pulp, paper, eucalyptus, hardwood

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Natural regeneration of Eucalyptus globulus into adjacent areas: what are the limitations and the drivers that may influence its expansion?

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Eucalyptus globulus has great economic importance in the Iberian Peninsula and it is now the most widespread tree species in Portuguese mainland. This study aimed to identify the spatial patterns of recruitment of *E. globulus* (exotic species) into habitats and areas surrounding plantations in Portugal (native forest, grassland and shrubland) and to understand the drivers that may limit/enhance its expansion such as climate, propagule pressure and host site characteristics. To respond to the first objective, we looked for the recruitment success of eucalyptus in several habitats near plantations, using a spatial gradient of distance to plantations edge. We observed that the recruitment decreased exponentially from the plantation edge. The localized recruitment (92% of the recorded seedlings were located less than 15m from the plantation edge) and the lower levels of establishment from managed plantations, suggests that eucalyptus did not demonstrate an invasive behavior. To model the main drivers that influence the recruitment of this species, we surveyed 50 *E. globulus* plantations across Portugal looking at eucalyptus natural establishment (i.e. occurrence and density) in several habitats adjacent to plantations. Eucalypts presence was only recorded in 8% of the plots. Site characteristics (such as habitat type, vegetation cover, and disturbance) were the most important group of variables influencing eucalyptus' natural recruitment in comparison to climate or propagule pressure variables. Forest and grassland were the habitats with less eucalyptus expansion, while highly disturbed areas can be considered hubs for eucalypt density. The high importance of site characteristics indicates that most of the variability in *E. globulus* establishment occurs at small spatial scales. Thus, monitoring and management efforts should focus on those sites with higher establishment probability (i.e. open areas), as well as to promote native vegetation and reduce disturbance levels.

Keywords: Forest plantations, Eucalyptus globulus, exotic species expansion

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Achieving efficiency: optimizing the regularity in the delivery of high standard Eucalyptus wood to pulp mills

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Environmental concerns bring challenges and opportunities to the forest-based industry. Sustainable timber and fibers may become increasingly attractive. Global fiber demand is expected to grow 1.1% a year, reaching 490 million tons by 2030. Following the trend, Brazilian pulp industry has increased 5.9% a year in the last 15 years guaranteeing its position in the international market scenario. Meanwhile, eucalyptus timber became more expensive; sectoral inflation was 1.5 higher than the average Brazilian inflation. Forest plantations' productivity stabilized in the 2000s after a 30 year of cumulative growing. Since the 70s, Brazilian pulp industry has invested in the quality of its plantations, which means investments in issues like photosynthetic capacity and higher wood density. One of the remarkable results of these efforts is the availability of a variety of suitable genetic material for plantations. Genetic variability may now contribute to further productivity growth. The objective of this paper is to use optimized forest planning to address efficiency in the use of forest resources in terms of tons of pulp per ha per year. A long-term model was developed to deliver an adequate mix of genetic material in a yield even flow over the years. Specifically, it intends (i) to demonstrate the adoption costs of such plan and (ii) to compare it with the costs of adapting the industrial process to a flow of non-suitable mix of genetic material. An MCDM (multi-criteria decision-making) technique was used to represent a typical scenario of a Brazilian pulp mill that receives 800,000 m3 year-1 of wood from 20,000 ha, with productivity around 40 m3 ha-1 year-1. Criteria used in the model are pulp production, carbon sequestration, an adequate mix of genetic material, and costs. The results show that the cost of establishing an even-flow on wood density mix is not higher than pulp productivity deficit caused by non-suitable genetic material mix.

Keywords: Multiple Criteria Decision, Making Techniques, Forest Planning, Optimization, Eucalyptus wood, pulpwood quality, Wood supply

*Speaker

Using multispecies NIRS calibration for predicting chemical properties of eucalypts wood

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Breeding programs in Africa are generally based on growth criteria and rarely on wood chemical properties. Indeed, chemical analysis are often expensive, time-consuming and require several replicates. Then, using NIRS to predict these properties is a relevant solution. The research question focuses on the possibility of using multispecies models to predict properties of different species. This study considers 7 chemical properties (extractives, Klason lignin, acidosoluble lignin ASL, SG ratio, holocellulose, alphacellulose, hemicelluloses) based on 367 samples from 4 countries, belonging to 5 eucalypt species with hybrids (*E. robusta, camaldulensis, urophylla, uropellita, urograndis)*. Established models were validated by cross- and test-set validation. Results shows that all R2CV are greater than 0.73, and all %RMSECV are less than 8.3% except for extractives and ASL. Prediction errors (%RMSEP) are always less than 9.5% except for these 2 properties, with respectively 23.6% and 18.1%. Prediction errors are always less than the double of the error of laboratory (%SEL). This study shows that multispecies NIRS models can be used to predict chemical properties, there is no significant difference between measurement error obtained with standardized method and %RMSEP. This method is particularly well-suited for a rapid wood phenotyping of multiple samples belonging to different species.

Keywords: Near InfraRed Spectroscopy, multispecies prediction model, error of laboratory, chemical properties, Eucalyptus

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Ecosystem services - Lightening talks

Functional trait plasticity in trees of Eucalyptus grandis

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Potassium and water availability are limiting factors for tree growth. Their influence on anatomical and morphological traits is well known but their combined effects on tree growth remain uncertain. Eucalyptus grandis trees (Itatinga, SP states -Brazil) were analysed in a split-plot experimental design of one clone (ADD clone name) growing under different water regimes (37% rainfall exclusion and no rainfall exclusion) and fertilization treatments (increased potassium supply and control potassium supply). Eight trees per plot were sampled representing a total of 32 trees. Wood anatomy traits (vessel frequency, diameter and lumen area, theoretical hydraulic conductivity, ray frequency and fibre lumen/wall dimensions), morphological traits (tree height, DBH and slenderness) and wood mechanical properties (longitudinal elastic modulus and specific modulus) were studied in order to investigate how water availability and potassium fertilization influenced these traits. Fertilized trees were both taller and had wider diameters than non-fertilized trees. Vessel diameter and theoretical hydraulic conductivity were also notably higher in fertilized trees. By contrast rainfall exclusion had no significant effect on tree growth and measured traits. Mechanical properties were similar across treatments and showed relatively high values compared to values known previously for Eucalyptus. In addition to the effects of potassium, anatomical traits showed strong relationships with morphological traits of trees. But all expected wood anatomical traits modifications in response to rainfall exclusion, as vessel diameter decreased, were not observed. The results suggest that potassium has a markedly positive effect on tree growth promoting taller and larger trees and that trees, at least of this clone, have developed mechanisms that mitigate against limited water availability. Potassium supply seems to indirectly impacts anatomical traits. Indeed, results show that modification of anatomical traits is primary linked to tree height and DBH witch are driven here by K fertilization.

Keywords: Wood anatomy, tree morphology, mechanical properties, Eucalyptus, rainfall exclusion, potassium supply

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Variability of physicochemical properties of Eucalyptus robusta coppice wood according to environmental conditions and silvicultural practices in Madagascar

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In Madagascar, wood from eucalypts plantations is widely used to meet household energy needs and as an alternative to wood from natural forests. *Eucalyptus robusta* is the most planted species, and grows in various ecological conditions. Plantations are mainly managed in coppice. During the last two decades, the rotation time has been decreasing from 7 to 2 years due to growing demand. Although the growth of these coppices has been well studied, the properties of their wood have been poorly studied. This study investigates the effect of the environmental conditions and silvicultural practices on the physical and chemical properties of *E. robusta* coppice wood. One hundred and thirty-five trees, from 2 to 10 years old, were harvested from 5 regions of the Malagasy highlands. Three sites per region were sampled; they are characterized by an altitude ranging from 921 m to 1440 m, mean annual temperature from 17.6∘C to 20.1∘C, mean annual precipitation from 945 mm to 1545 mm and various soil properties. Wood density at 12% moisture content was measured using X-ray densitometry and chemical properties were predicted by Near Infrared Spectrometry (NIRS) models. Results show that tree age has an effect on both wood density and chemical properties. Wood density, extractives and Klason lignin contents increase with age, while holocellulose content decreases with age. Climate and some soil chemicals properties effects are significant for wood density. Wood density is higher in warm and dry regions with high soil pH. Wood density is lower in cold regions, on soil with high carbon and nitrogen contents. There is no evidence of the effect of plantation spacing and altitude of plantation site on the wood physicochemical properties. Optimal tree cutting age is proposed taking account of tree growth and wood properties. These results will help decisions makers for a more efficient management of *Eucalyptus robusta* coppice plantations in Madagascar and for a sustainable wood production.

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Keywords: Eucalyptus robusta, climate, coppice, rotation, soil, wood properties

Biomass and carbon pools of Eucalyptus trees in integrated crop-livestock-forest systems

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Integrated livestock production systems (iCLF), in which trees and crops are cultivated in rotation, succession or association with pastures, are alternatives for the sustainability of agriculture. This study aimed to estimate biomass and carbon pools of trees in three kinds of Integrated Crop-Livestock-Forest Systems. The systems were composed by a pasture of *Urochloa brizantha* (BRS Piatã) and eucalyptus trees (*Eucalyptus urograndis*, GG100), planted in April 2011 in single rows with 15 m spacing and 2 m spacing between plants in the rows, totaling 333 trees ha-1. Three systems were evaluated: i) crop-livestock-forest system with pasture renewal in the second year after trees planting (ICLFS-2); ii) crop-livestock-forest system with pasture renewal in the third year after trees planting (ICLFS-3); and iii) livestock-forest system, with no pasture renewing (ILFS). Each system had four experimental plots of 5,000 m2. Pasture renewal was performed with grass and silage corn(*Zea Mays* L. var. DKR 390 PRO 2) simultaneously sowed. The data were collected in April 2016, when 40 trees were harvested to determine wood volume and to gather wood rings, and samples of tree canopy and roots subsequently used to determine biomass and carbon pools. These data were used to build the equations for estimating stem volume and tree biomass. Stem diameter at breast height (DBH), at 1.3 m above the ground and tree height (H) were measured in 10% of the trees of each plot. The estimated stem volume ranged from 131.8 to 155.7 m3 and stem biomass from 56.9 to 67.5 Mg ha-1, respectively, in the livestock-forest system and crop-livestock-forest system with pasture renewal in the second year after tree planting. The most productive crop-livestock-forest system accumulated 30.7 Mg ha-1 of carbon in tree stem at five years after the system implementation.

Keywords: Eucalyptus urograndis, agrosilvipastoral, Urochloa brizantha, sustainability

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How deep can ectomycorrhizae go? A case study down to 4 meter depth in a Brazilian eucalyptus plantation under rainfall reduction

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Most often, it is recognized that mycorrhizae are only occurring in the first layers of soil and decrease drastically with depth. Unfortunately, the vertical distribution of mycorrhizal associations remains poorly understood and very few studies have investigated these symbiosis in very deep layers, the majority of studies focusing on the topsoil. In this work, we characterized, in a 5-year-old *Eucalyptus grandis* plantation in Brazil, changes in fungal community within soil profiles and whether these changes are influenced or not by a water stress using a throughfall reduction experiment. This research was conducted at the experimental station of Itatinga (ESALQ-USP). Root samples were collected between May and June 2015. Fine roots (< 2 mm) were sampled carefully layer per layer during the digging of a pit (1.5 x 4 meters) in order to prevent any contaminations between two consecutive soil depths. Ten soil layers have been sampled from 0 to 4 meter depth. An Illumina sequencing of the Internal Transcribed Spacer (ITS2) was carried out on DNA extracted from root samples to study fungal community composition and diversity. We showed that the fungal communities were dominated by ectomycorrhizal fungi (ECM).The fungus *Pisolithus* represented more than 80% of the fungal community. For

*Speaker

the first time, both ECM sequences and ECM root tips were observed along the profiles down to 4 meters. By subsampling the root tips of *Pisolithus*, we showed that *Pisolithus* populations responded strongly both to the depth and to the rainfall reduction. This work represents a step forward in the microbial ecology with the evidence, for the first time, of the occurrence of ECMs down to a depth of 4 meters. These results highlight the importance to expand these researches to other tropical perennial plants of major interest in order to evaluate the genericity of our observations made on eucalyptus.

Keywords: deep soil, ECM fungi, Pisolithus, tropical forest plantations, eucalyptus, drought stress

The Future of Eucalyptus Plantation in Malaysia: Environmental, Social and Economic Impacts

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Eucalyptus has proven to be particularly successful in tropical and subtropical regions. It is a fast growing timber species and has been widely planted in many countries, including Brazil, China, Vietnam, and Sri Lanka. Many Eucalyptus species have desirable properties, such as high wood density, rapid growth and bioenergy plantations. The prospect of Eucalyptus for commercial purposes has risen and thus, prompts questions about potential environmental effects. The study assessed the willingness of the planters and the industry in developing the Eucalyptus industry. This study will also identify several issues related to Eucalyptus plantations including environmental, social and economic impacts. Elements of environmental impact include water consumption and nutrient loss. Social and economic impacts include the contribution of Eucalyptus towards community development and employment. In this study, the questionnaire was designed to gather primary information such as demographic characteristics, planter willingness, issues and challenges faced by the Eucalyptus industry. The interview was conducted among planters and industry players. The study found that factors that motivate respondents to be involved in this industry are; income generation, the quality of the timber, and fast growth characteristics. Results showed that the planters and the industries are willing to develop this industry despite the issues and challenges they faced. Even though their response is encouraging and enthusiastic, the forest plantation sector faces some constraints which include high capital requirement, lack of technical knowledge and insufficient government incentives to boost their involvement. The finding is essential for policy makers to formulate the appropriate and relevant policy for the Eucalyptus industry stakeholders so that Eucalyptus can serve as an important species with future opportunities for growth in the Malaysian plantation and wood industry.

Keywords: Environmental impact, Social and Economic impact, willingness, motivation, challenges.

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Ecosystem services - Poster session

Natural regeneration in abandoned eucalypt plantations in Portugal

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The maintenance of biodiversity in planted forests and the understanding of the main factors that drive forest natural establishment are two major challenges for conservationists. The aim of this study was to compare three different types of abandoned eucalypt forest relative to the natural establishment of native species and simultaneously to the natural capacity of regeneration of the forest trees. For these purpose, we evaluated the density, height and cover of all species at three different forest types: i) *E. globulus* pure plantations; ii) mixed *E. globulus* plantation with eucalypt as dominant tree and iii) mixed *E. globulus* plantation with *Pinus pinaster* as dominant. In total, 24 stands (8 stands per forest type) were sampled across northern and center of Portugal. Overall, 33 shrubs and tree species were recorded across the three forest types. Individuals of *Quercus* spp. were the most abundant non-planted tree genera. Both species richness and shrub biovolume were higher where precipitation was higher and mean maximum temperature of the warmest month was lower. *E. globulus* recruitment was significantly lower than in *P. pinaster*. *E. globulus* recruitment was higher in sites with lower temperature seasonality and higher precipitation. *P. pinaster* recruitment was significantly lower in pure plantations than in the mixed plantations. In conclusion, the forest types considered had similar potential to harbor native plant species. In mixed forests, recruitment of *P. pinaster* was significantly higher than *E. globulus*, even when *P. pinaster* is not a dominant planted species. The high numbers of seedlings of native broadleaves trees, such as *Quercus* spp., registered in the understory of the forests may indicate that mature *E. globulus* plantations have a considerable potential for recover into mixed stands.

Keywords: Tree plantation, Regeneration, Eucalyptus globulus

*Speaker

Modelling Eucalyptus biomass production at regional scale in Brazil

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Among forest vegetation grown in Brazil, Eucalyptus is the most widely planted tropical hardwood genus covering approximately 5.7 million ha for an average yield of 49 m3 ha-1 yr-1. Wide differences of biomass production were observed among neighboring stands representing challenges to forestry companies to spatially estimate biomass yield in large plantation zones. The first objective of the present research was to modify the carbon allocation scheme in the process-based model Generic Decomposition And Yield Model (G'DAY), to better capture the spatial variability in growth rates of Eucalyptus as influenced by environmental constraints such as water stress. The model was parametrized and tested using experimental and long term commercial datasets in the state of São Paulo Brazil. Measured data included several variables of carbon and water fluxes and carbon stock. The calibrated model produced accurate prediction of the carbon key variables such as leaf area index, stem biomass, and gross primary production and water related variables such as plant available water and evapotranspiration. Simulating the spatial variability among commercial Eucalyptus stands at landscape scale showed reasonable prediction of plant height with r2 of 0.89 but lower level of accuracy for stem biomass. This could partially be attributed to spatial soil data differences used at regional scales which came from the Global Soil Dataset for Earth Systems Modeling dataset, at a resolution of 1 km. Testing the soil data with the use of soil type map crossed with soil profile measurements is expected to improve the soil information for higher accuracy of stem simulation at landscape to regional scale.

Keywords: Ecophysiological Modelling, G'DAY, Brazil, Regional Scale

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The ARINA project: a participative and inclusive approach for rural afforestation in Madagascar

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Fuelwood (FW) is the first source of domestic energy in Madagascar where > 90% of the population use it fuel cooking. The 2 million inhabitants of Antananarivo consume annually 240,000 tons of charcoal and 160,000 wood steres, mainly from 150,000 ha of old private *Eucalyptus robusta* coppices. However, there is a risk of rapid FW shortage due to continual decrease in stand rotation duration (< 2 years nowadays) leading to lower mean annual production and physiological coppice aging, in parallel of the + 4.5% annual population growth rate. The general objective of the project ARINA "Integrated Forest Management and Reforestation of Anjozorobe District", part of the EU FED-Program "AgroSylviculture autour d'Antananarivo" (ASA, 2015-2019), is to participate to poverty alleviation of rural populations and set the conditions of sustainable FW production for Antananarivo. Specifically, Arina aims at strengthening the FW production capacities of these populations on forest plantation management, quantitative and qualitative improvement of charcoal production, and FW marketing. Arina promotes participative and inclusive approach. Nursery owners, forest planters and charcoal producers organized themselves into professional associations that interact with local comities composed of elected and traditional authorities, and with forest administration. Arina aims at combining private initiatives and local decisions to influence the FW regional sector and profits repartition among the stakeholders of the FW value chain, increasing retribution of individual producers and cash return to local communities. Techniques are easily applicable and reproducible by rural populations (e.g. spot soil preparation, manual weeding, improved local carbonization technique). The goal of ARINA has been to establish 20 nurseries (900,000 seedlings/yr) and 2,200 ha of FW plantations (0.3-1.0 ha/stand), mainly of *E. robusta*, and to train 1500 charcoal producers. More than 4,000 people will directly benefit from the project.

*Speaker

Keywords: Fuelwood plantations, poor people, charcoal, Eucalyptus robusta, Analamanga region

Estimates of CO2 stock in eucalyptus plantation in the Central Region of Brazil

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The establishment of eucalyptus forest stands has been highly important in the current context of environmental production and conservation. It is estimated a great potential for the removal of atmospheric carbon (C) by eucalyptus stands in the Cerrado biome. Forests generally play a key role in the C cycle, absorbing carbon dioxide (CO2), and thus contributing to minimizing global warming due to the potential for mitigation of greenhouse gas (GHG) emissions. The study was conducted in the Cerrado biome (Brasília, Distrito Federal, Brazil). To determine the biomass, a hybrid planting of *Eucalyptus urophylla* x *Eucalyptus grandis* was used, at 3 x 2 m spacing, at the age of five years. Three plots of 20 x 30 m were randomly assigned and a forest inventory was carried out. After that, five representative trees of the stand were cut for cubing and determination of the dry biomass. To determine the carbon content, the CHNS elemental analyzer was used. The C stock was multiplied by the constant 3.67 to obtain the CO2 equivalent (CO2 eq). The total dry biomass stock was quantified at 90.10 t ha-1. The total C stock contained in biomass was 43.24 t ha-1. Recognizing the importance of forests, the Brazilian government has undertaken to adopt, among other measures: "reforestation actions in the country, expanding the reforested area from 6 million ha to 9 million ha, contributing to the reduction of 8 to 10 million tons of CO2 eq. " The potential of removal of atmospheric C by eucalyptus plantation was 158.54 t ha-1 of CO2 eq. One of the main concerns in the reforestation item is the monitoring of these goals, that is, the confirmation of the mitigation. The negative balance of C can be monetarily remunerated through payments for environmental services and thus contribute to climate regulation. Therefore, the importance of the information generated by the present study.

Keywords: mitigation, environmental services, carbon dynamics, climate change

*Speaker

Dry Matter Production and Carbon capture in three clones of Eucalyptus camaldulensis in Tamil nadu, India – emphasizing the need for Clone-specific biomass prediction models

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Biomass studies were conducted in plantations of *Eucalyptus camaldulensis* clones EC 3, EC 7 and EC 10 to test the hypothesis that 'significant differences occur in dry matter production and allocation in various biomass components across clones of *E. camaldulensis*'. The present study conducted across 12 sites (mean annual temperature from 28∘C to 29 ∘C , mean annual rainfall from 916 mm to 1139 mm) in southern India revealed significant difference in total dry matter production as well as dry matter allocation pattern in various biomass components. Clone EC 3 recorded greater above ground biomass production (49.74 MT ha-1) than EC 10 (45.96 MT ha-1) and EC 7 (41.48 MT ha-1). Among various biomass components studied, greater variation was registered for leaf biomass production, which varied from 1.95 MT ha-1(in clone EC 10) to 3.00 MT ha-1 (in clone EC 7). However, dry matter accumulation in stem wood biomass was greater in EC 3 (37.18 MT ha-1) than EC 10 (32.85 MT ha-1) and EC 7 (28.77 MT ha-1).
Carbon capture potential of three clones was assessed which revealed that EC-3 clone recorded the highest carbon stock of 23.58 MT ha-1 in above ground biomass, of which carbon stock in stem amounted to 15.0 MT ha-1.
Biomass prediction equations were developed individually for three *E. camaldulensis* clones using data obtained in the present study. Then, these clone specific biomass prediction equations were cross-validated with clone specific equations for each individual clone. The results revealed that there is a need for developing clone- specific biomass prediction equations to minimize the error in biomass estimation in clonal plantations.

Keywords: Intra, specific variation, Eucalyptus camaldulensis, dry matter production, clone specific biomass prediction equations

*Speaker

2nd series: Full rotation measurements of Eucalyptus badjensis trials in South

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Eucalyptus badjensis was identified in ICFR site-species trials as one of the few species with commercial potential in the temperate summer rainfall regions of South Africa. A breeding programme to investigate provenance and family differences in the species was initiated in 1993 with the establishment of a 1st series of trials at Woodstock and Geluk. The breeding population was expanded in 2000 with the establishment of a 2nd *E. badjensis* trial series planted across three sites, Hlelo and Blesbokspruit and Claimont year 2000. There were significant growth differences between the five provenances at full rotation. The Cathcart and Glenbog provenances were the top performing provenances, with Badja being the worst performing provenance at all three sites. Significant differences exist between the best and below average families at all sites. Blesbokspruit and Hlelo showed moderate to high heritabilities for dbh ($h2$ =0.29 and 0.46, respectively). Several unimproved *E. badjensis* families performed better than, or equal to, external controls in this trial series. The range in variation for growth, basic density, pulp and stem form coupled with moderate to high heritabilities in *E. badjensis,* indicates that significant gains can be expected from selection and breeding of superior trees in this species.

Keywords: Provenances, heritabilities, Eucalyptus badjensis

*Speaker

One Hundred Year Histories of Eucalypt Cultivation Technology Development in China

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In recent years eucalypt plantation has been developing very quickly, and becomes the most important consist of wood security in China. But the cultivation technology that supports the rapid development of eucalypt has not been well summarized. Summary is the foundation of innovation, based on this point of view, this paper briefly describes the present situation of the eucalyptus, summarizes the development history of eucalyptus cultivation technology in China, expected the development direction of eucalyptus cultivation technology in China, and the influence of the development of eucalyptus related problems are discussed in this paper. Eucalyptus cultivation technology development in China is divided into four stages in this paper, first stage-before the founding of New China, eucalypts were planted sporadically as 'Four-around' trees; Second stage is the eucalyptus cultivation technology starting, the mark is the establishment of Yuexi Forest Farm in 1954; Third stage is the accumulation stage of eucalyptus cultivation technology, from the late 1970 s to 1990, formed the rudiment system of technical measures for afforestation and tending; Fourth stage is a rapid development stage of eucalyptus cultivation technology, after 1990, the afforestation and tending technical measures system of eucalyptus was basically formed. Looking forward to the future, whole year afforestation technology will be developed and improved, modern eucalyptus cultivation technology system will be gradually formed.

Keywords: eucalypt plantation, introduction, cultivation, afforestation technology

*Speaker

Characterization of eucalyptus stands horizontal structure through airborne laser scanner

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The Airborne Laser Scanner (ALS) emerged recently enabling to collect forest data with high precision and faster than the traditional inventory. This technology has already been applied to some eucalyptus plantations but studies focusing methodologies to be applied in structurally complex eucalyptus stands is lacking. For that reason, this work aims to assess the use of ALS to extract the structural parameters of heterogeneous eucalyptus stands located in the central region of Portugal.

For this research were used 39 circular sample plots (with 400 m^2 of area each) distributed over an area of 100 ha, with their cental points recorded with high precision GPS. Tree height and diameter at breast height were measured for each tree. At the same time, the forest was scanned with a density of 9.5 points/m^2. After that, an area-based approach was used to process the data in software FUSION. This software provides more than 100 metrics related with the points distribution inside the plots. We select the best ALS-predictors to estimate the stand attributes of each plot needed to recover the parameters of the Johnson-Sb pdf that has been found to be the most appropriate to simulate diameter distribution of eucalyptus stands. Those attributes are: minimum, mean, median and maximum diameters, dominant height and stand basal area. An exhaustive search of regression models was undertaken using R software. The selected equations were then used as a system of compatible equations to estimate the stand parameters. Curiously, a unique and the same ALS-predictor was selected as the best predictor for all the equations, the 60% percentile of the distribution of heights of the points. All the equations present high precision, with R^2 ranging from 91% to 97%.

With these previous results, the ALS proved to be a precise tool to characterize the complex structure of eucalyptus stands in Portugal. The next step is to generate a diametric distribution of the stands through the Johnsons' Sb pdf.

Keywords: forest modelling, forest inventory, LiDAR, diameter distribution

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Growth and yield system for plantations of Eucalyptus grandis and E. urophylla at Oaxaca, Mexico

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A new growth and yield system (GYS) for stands of *Eucalyptus grandis* and *E. urophylla* commercial plantations in the southeast Mexico is proposed. The basal area projections were validated with re-measured plots not included in the GYS fitting strategy. In this case the multiple asymptote formulation behaved better for projections of basal area. The GYS can estimate total tree volume as well as merchantable fractions to any commercial top. Also the proposed GYS can estimate biomass and aerial carbon to obtain carbon (C) addition when induced grasslands are converted into forest plantations. The results suggest that at the average site index (24 m/base age 5) the yield for both species can reach 150 m3/ha at rotation age of 6 years.

Keywords: Seemingly unrelated regression, algebraic difference, biomass expansion factor

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Building resilience and improving ecosystem services in Eucalyptus plantation landscapes

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Forest plantation in Brazil are increasing in last years reaching about 6 million of hectares in 2016, due to internal and external demand growth for fiber and wood. Forest management plans are seeking both keep wood productivity and environmental resilience of plantations, however, guided by crescent restrictions enforced by Brazilian government, environmental certification and society pressure, it seems to be necessary increasing their ecosystem services provision. Based on long-term stream monitoring data of several experimental catchments installed on forest plantation areas along Brazil and Uruguay, field data collection regarding biodiversity and insect damage, we tested effects of landscape composition and structure on ecosystem services related to provision (wood and water), support (terrestrial and aquatic biodiversity) and regulation (water, soils and pest control). At the macroscale, we propose a framework for water availability assessment based on aridity and seasonality indices. At meso-scale, it was considered the inherent risk offered by natural climatic constraints combined with local physical attributes, resulting into a natural resilience. Results show that natural condition could be enhanced by forest management in order to build resilience to forest plantation and increase provision of ecosystem services. Finally, we found evidences of forest management alternatives related to water provision and regulation, erosion control, insect damage control, and support avian biodiversity that could contribute to balance ecosystem services provision and productivity in forest plantation landscapes.

Keywords: landscape management, risk management, water, biodiversity

*Speaker

Assessing hydrological resilience of Eucalyptus plantations in Brazil

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Hydrological resilience is an important catchment characteristic related to forest plantation survival and water provision to other users. Forest plantation hydrological resilience depends on physical and management characteristics Physical factors like water availability, relief and soil properties are known as the most important controllers of catchment hydrological response. On Eucalyptus plantations catchments with high evapotranspiration rates, we suggest that forest management could modify natural response increasing or decreasing natural catchment resilience. We present catchment resilience of forest catchments covered by native forest and eucalyptus plantations at southeast region of Brazil, the most affected region from recent drought events. Discharge measurements were conducted using weirs and water level loggers along 5 years of monitoring, as part of a Cooperative Program for catchment monitoring in Forest Companies (PROMAB). Annual stream flow data were compared among catchments and between normal and low precipitation hydrological years. Paired catchments data were also used in order to understand forest management effects. Results have confirmed that physical variables determine main patterns of stream hydrological resilience, showing different patterns of sensitiveness to drought. Based on results, a framework for catchment hydrological resilience classification is proposed in order to predict their response. Experimental results from catchments with similar physical conditions (paired) show that forest management could modify stream flow response, especially on less resilient catchments. Many forest management alternatives are discussed in order to avoid drought impacts and increase resilience of catchments covered by Eucalyptus plantations.

Keywords: environmental assessment, hydrological monitoring, decision support system

*Speaker

Allometric equations to estimate biomass and Carbon sequestration in young plantations of Eucalyptus grandis and E. urophylla at southeast Mexico

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Carbon sequestration at tree level requires allometric equations that relate tree variables (diameter and height) with biomass and Carbon content. In forest plantations of Eucalyptus grandis and E. urophylla located in Oaxaca and Veracruz, with ages ranging from 28 and 77 months-old, 20 trees were selected to be destructively sampled. Three components were separated and measured: stem logs, branches and foliage; these components were green-weighted in the field. Constant dry weight was obtained in laboratory. A system of equations to estimate total and component biomass was developed. The proportion of dry biomass on the stems was 88% and 85% of the total, for E. grandis and E. urophylla, respectively. With sub-sample of each component, carbon content was determined using a solid samples analyzer. Stem Carbon was 48% for both species. Finally all these equations can be combined with forest inventory data to estimate Carbon at land unit level. Concentration of total Carbon was found to be 22% of the total standing volume

Keywords: Biomass expansion factors, regression analysis, Carbon, biomass, volume relationships

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Eucalyptus seedlings production using compost of sewage sludge as substrate with different doses and sources of phosphorus

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The quality of seedlings is one of the most important factors for the success of forestry plantation. On the other hand, sewage sludge, an urban residue, is a big problem for the cities in the world, especially in poor countries. Combining these two aspects, our study aimed the use of compost of sewage sludge as substrate for eucalyptus seedlings production, comparing to a commercial substrate.
Compost of sewage sludge (CSS) was produced with bagace of sugar cane (proportion of 1:1) enriched, in the beginning of the composting process, with different concentrations (1.5; 3.0; 4.5%) of phosphorus (P) and using two sources, Triple Superphosphate (TS) and Reactive Natural Phosphate (RNP). The products were used as substrate for *Eucalyptus* hybrid (*E. grandis* x *E. urophylla*) seedlings production (cuttings), comparing to a control (CSS without P source) and a commercial substrate (Carolina Soil@). All treatments received the same fertilization for seedlings production. After 3 months (seedlings ready to be planted in the field), parameters evaluated were: heigh, diameter and biomass of plants (aerial part, roots and total), foliar SPAD indice and root quality.

The best heigh, diameter, aerial and total biomass of seedlings were promoted by TS3.0 treatment and were significantly superior to commercial substrate. In terms of root quality, all treatments were good and similar, excepcion to control and CSS with RNP. This substrate, in all P concentrations, was inferior for all evaluated parameters.

Compost of sewage sludge with 3.0% of Triple Superphosphate produced seedlings of excellent quality and can be used as substrate for *Eucalyptus* seedlings production. Other parameters as nutritional aspects are being evaluated.
Acknowledgements: To FAPESP and SABESP for financial support.

Keywords: seedlings quality, mineral nutrition, composting, urban residue

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Influence of intermittent microwave heating on mechanical properties of Eucalyptus wood (Gomphocephala)

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Recently, the global interest is oriented to use the green energy in particular, biomass, solar energy and especially biomaterials to limit the negative impact of fossil energy and synthetic materials on the environment. Wood, in particular Eucalyptus (*Gomphocephala*), is an abundant, renewable, biodegradable, and eco-friendly material. It is used worldwide as an energy source, building material, construction of bridges and for the manufacture of *paper*. Eucalyptus tree covers 18 million ha dispersed in 90 countries including Tunisia, Morocco, Algeria and Libya. The Eucalyptus wood crop plays a very important role on both the socioeconomic and ecological levels in Tunisia. However, drying was a crucial setup in transforming Eucalyptus wood into a finished product. The decreasing of moisture content improves the shelf life period, the mechanical properties and the esthetics performance of wood material. Conventional air-drying of wood is the most common process used in industry. But, conventional air-drying process was slowly and energetic costly. Nowadays, microwave heating technology is gained interest in various industrial sectors to heat dielectric materials and considered as a faster and efficient process. In microwave heating, the energy is transferred directly into the material, absorbed by molecules, and transformed into heat. The vibration of polar molecules and the movement of ions in response to microwave field oscillation at 2.45 GHz results in rapid heat generation through molecular collision.

The integration of microwave heating technology, in wood industries, to dry lumber is limited due to the missed information on the internal distribution of the electromagnetic field, internal temperature, gas pressure and moisture content furthermore the influence of microwave power on the mechanical characteristics of dried wood.

The aim of the present communication was to investigate the impact of intermittent and continuous microwave drying processes on the mechanical properties of Eucalyptus (*Gomphocephala*) wood samples. The microwave drying kinetics of Eucalyptus wood boards (30 x 5 x 2 cm3) were determined at 2.45 GHz frequency and under different powers using a laboratory microwave

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oven (BP-301). The influence of microwave powers and continuous-intermittent heating methods on the drying kinetics, modulus of rupture and modulus of elasticity in static bending and axial compression tests was determined. The temporal evolution of average moisture content and internal temperature of wood boards at various microwave powers were analyzed in terms of drying time, temperature level and heating methods. Results analysis showed that the intermittent microwave heating method present a less warp and slots propagation at the surface of wood board and the higher values of modulus of elasticity and modulus of rupture compared to the microwave continuous method

Keywords: drying kinetics, microwave, intermittent, continuous, Eucalyptus wood, moisture content, temperature, static bending, axial compression

Performance of eucalypt clones for bioenergy plantations in Thailand

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Bioenergy derived from biomass can create sustainable and reliable electricity. An estimate by Thailand's ministry of energy shows that a total of 55 million metric tonne of biomass is needed annually for generation of the targeted 5,570 MW electricity in rural areas for the next 15 years. Up to 10% of this biomass will be sought from plantation-grown trees. For several decades, eucalypts have been planted in Thailand for production of pulpwood and for poles. With the increasing interest in bioenergy from renewable resources, eucalypts are high on the list because they are very adaptable, fast growing and respond well to being coppiced, a prerequisite for bioenergy crop on short rotation of 2-3 years.

Fifteen *Eucalyptus* clones selected from genetic improvement program in Vietnam were introduced to Thailand for field test on two sites which were different in physical and chemical properties of the soil but similar in the mean annual rainfall and temperature. Local commercial hybrid clones were included for comparison with the imported clones. These clones consisted of pure species and hybrids among *E. camaldulensis*, *E. brassiana*, *E. deglupta*, *E. pellita* and *E. urophylla.*

Results at aged 3 years showed considerable differences among clones in volume index and aboveground biomass but not heating value. The heating value determined for the clones was 18.2 – 18.4 kJ g-1 which is within the range reported for most fuelwood species. No clones were superior in volume index and aboveground biomass at both trial sites but the two local commercial hybrids *E. camaldulensis x E urophylla and E. camaldulensis x E. urophylla* were consistently ranked above the overall average. The mean volume index and aboveground biomass of pure species *E. camaldulensis* clones from Vietnam (396 m3 ha-1 and 90 t ha-1 respectively) were comparable to that of local commercial clones at one site but considerably poorer at another site (178 m3 ha-1 and 34 t ha-1 respectively). Pure *E. urophylla* clones showed moderate growth rate while hybrids *E. urophylla x E. pellita* and *E. pellita x E. brassiana* were least productive. The results indicated that eucalypts are suitable for bioenergy. However, new clones introduced from another country must be field tested before deployment.

Keywords: Eucalyptus species, Clonal test, Bioenergy plantations

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The impact of AFRI project in rural and urban communities in Southern Togo

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Natural forests are depleting at all alarming rate ill Togo. As a response, the national department of forestry development of the country is planting trees like *Eucalyptus* to resolve fuel wood challenge and livelihood income needs. Faced with deforestation and climate instabilities, good management of natural resources could be the best approach for the Togolese government today to improve the annual rainfall, increase production and create jobs. To remedy this situation and respond to the need to supply urban centers and mainly the capital town with fuel wood, the government has launched a reforestation program for the country, which has begun concretized by the creation of the AFRI project. Plantation forestry based fast-growing trees, especially species of Eucalyptus has expanded rapidly in Togo during the two decades the increasing demand of fuel wood and charcoal. Currently, approximately 4500 hectares of Eucalyptus plantations have been established in south Togo. Jobs have been created for local community as employees in the nursery with 80% being women and during the plantation. 80% of household in the capital town have adopted the new form of improved stoves. The aim of this study was to improve the social issues. The results of the study revealed that 80% of household in the capital town have adopted the new form of improved stoves. The present document describes a fuel wood and energy priority action program for Togo forestry development. Its goal is to foster massive and urgent action to meet the critical energy needs of populations in south party. Fuel wood will continue to play an essential role in insuring energy both for survival and development in tropical areas.

Keywords: Afri project, eucalyptus, plantation, Togo

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Productivity gain in the selection of clonal families of Eucalyptus grandis Hill ex-Maiden

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The objective of this work was to propose a new method for breeding to *Eucalyptus* in order to obtain genetic material for commercial planting by the following studies: a) evaluate the gain, in wood volumetric productivity, in the selection applied to a clonal population of *Eucalyptus grandis* coming from a selected clonal mixture obtained in cross-pollinated progenies (full sibling); b) evaluate the genetic variability using microsatellite markers obtained in a selected clonal population when subjected to different environmental conditions and levels of selection. Using the seeds obtained in the hand pollination, an experimental plantation was established, in 2001, at the Ribeirão Grande Farm in the municipality of Salesópolis, State of São Paulo, Brazil, owned by Suzano Pulp and Paper. At the age of 6 years old, a selection of clones was carried out based on silvicultural traits and wood density. Fifty-seven clones were selected, propagated and used for mixed plantation in a clonal garden to subsequent production of seedlings for commercial planting. This genetic material (initial clonal population) was recommended for planting in 2010. For this study, three commercial areas planted with these genetic materials at ages ranging from 3.3 to 3.5 years old were selected. On each site, 3 plots of 100 trees were established and the silvicultural evaluation of trees was made. The 40 trees / plot with the highest DBH values and good shape of the trunk were selected, totaling 360 trees. The genetic profile through microsatellite markers was conducted for selected trees, for clones that form the initial clonal population and for parental clones. The Annual Average Increase in shell to the 7 years old (IMA7; m3 / ha.year) was estimated per plot and 10, 20, 30 and 40% selection of levels. The results show that the method selection and improvement in clonal populations of *E. grandis* is promising, decreasing the time for obtaining genetic materials for commercial plantation.

Keywords: controlled crossing, Eucalyptus grandis, full sibling, multiclonal planting, selection in clonal population.

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LIFE Eucalyptus Energy: producing electricity and biochar from Eucalyptus residues

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In the EU, Spain and Portugal are significant producers of eucalyptus, with a total cultivated area of 1.4 million ha. Eucalyptus globulus is one of the most common sources of short fibres for the production of wood pulp. This species generates a significant amount of biomass residues, estimated for Spain and Portugal at 2.8 million tonnes/yr. Tree residues left on the forest floor increase the risk of forest fires, diseases, etc. However, there is potential to transform the waste eucalyptus branches and leaves to make new products locally. "LIFE Eucalyptus Energy" (Eucalyptus Integrated Wood Processing, LIFE12 ENV/ES/000913) is a demonstration and innovation project which mean objective is to increase the efficiency of the valorisation of eucalyptus residues. The project has designed and constructed a demonstrative pilot plant in Asturias (North of Spain) which maximizes the residues of eucalyptus forestry by means of pyrolysis in order to generate power energy (electricity) and to transform them into co-products (biochar and bio-oil). The main aims of this project are: 1) to produce electricity from eucalyptus sub-products (branches and leaves) through pyrolysis; 2) to use biochar as a sustainable carbon capture technology, 3) to implement of small scale biomass plants (less than 5 MWh) for the transformation of biomass into energy and reduce transport cost biomass, 4) to use potential pyrolysis liquids (bio-oil) as a biofuel and for producing valuable chemicals, 5) to develop intelligent pellets from biochar; and 6) to explore the potential of using other biomass sources, such as municipal green waste or agricultural residues, to supplement the eucalyptus materials. As a result, the use of Eucalyptus biomass improve the quality of the forest, reducing waste and environmental threats, is an environmental alternative store carbon, provide forests with a sustainable fertilizer and at the same time as improving the economic activity of rural areas.

Keywords: Eucalyptus globulus, biomass, co, products, pilot plant, Spain

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Impact of Acacia spp. on Eucalyptus globulus biomass increment in Portugal

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Eucalyptus globulus is planted in Portugal and has great economic importance for the pulp & paper industry. *E. globulus* wood production varies substantially with resource availability and may be limited by other plant species that co-occur in the plantations. In order to develop sustainable management practices, it is essential to evaluate the factors that limit growth and biomass production.
Tree invasions cause important ecological problems, such as changes in plant community composition and landscape structures, as well as vegetative growth and yield impacts in co-occurring species. Indeed, competition for water and nutrients are often associated with exotic invasive species.
The Australian *Acacia* have been widely planted worldwide for different purposes. Some species have spread and altered the native ecosystem functions to the extent of being considered economic and ecological threats. The *Acacia* spp. were introduced in Portugal for ornamental and soil support purposes. These species are often associated with roads, rivers and disturbed areas, acting as an invader in natural and human-altered landscapes such as intensive plantations.
This study aims to quantify the loss in productivity of *Eucalyptus* stands which are affected by *Acacia* spp. associated to different management strategies, under different climate and soil conditions in Portugal. The control of invasive plants involved manual cutting, herbicide application disk harrowing and/or slashing.
Invaded *E. globulus* stands were evaluated and tree growth was compared before and after *Acacia* spp. control. The vegetative increment (tree height and stem diameter) of *Eucalyptus* took place during two consecutive years in plantations with different age.
Results indicate that the impact of the *Acacia* on *E. globulus* biomass depends on edaphic-climatic conditions and the control measures used. Moreover, it is clear that efficient and sustainable forest management, requires effective control of exotic invasive species, such as *Acacia* spp.

Keywords: Invasive plants, Eucalypt plantation, Competition, Short, rotation forestry, Forestry management.

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Fallouts of Plantation Eucalyptus Species in Kowsar Aquifer Station/Fasa/Iran

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The Kowsar Floodwater Spreading, Aquifer Management, Training and Extension Station, located in the Gareh Bygone Plain at 1140 m above mean sea level with arid climatic conditions,190km southeast of Shiraz, Iran was established in 1982. Thirteen spate irrigation systems covering 2445 ha were designed and constructed during the 1983-2003 period for the artificial recharge of groundwater (ARG. *Eucalyptus* and *Acacia* species have always been considered for plantation due to drought resistance, flexibility in harsh habitat conditions, and the use of wood and other by-products for forestry in arid areas. Results of previousfield experiments showed that *E. microtheca* and *A. salicina*, *A. victoriae*, *E. oleosa*, and *E. camaldulensis* were very successful with more than 80% survival in the station. Therefore, according to the metioned results, more than 600 hectares of extensive and 100 hectares of intensive forest plantations with *Eucalyptus* as a main trees and *Acacia* species have been established in the region. The study of carbon storage capacity in *Eucalyptus* and *Acacia* forests in station has estimated annual 7.8 t / ha by using weed and weighing methods and organic carbon measurements in the laboratory. The average total dry biomass on the surface of *E. camaldulensis* trees in this area during the growth period (16 years), was calculated 247.07 tons/h, of which 136.66 tons were related to trunk timber, 46/72 tone were of leaved branches and 39.94 tons were skin. The flowering period of Eucalyptus species in this area provides a permanent cover for the year. For example, pollen and flower nectar are available throughout the year for beekeeping. The average honey produced at this station was 11 kilograms/hive. Moreover, the area attracts many eco-tourists, particularly during the holidays all over the year because of the beautiful landscape of the forest in a desert region. As *Eucalyptus* species is a prodigious water consumer, it proposed to replacing it with less water demanding trees.

Keywords: Eucalyptus, Aquifer Management, Biomass, Beekeeping, Eco, tourism, Carbon storage, Fasa, Iran

*Speaker

Improved carbonization techniques for rural production of Eucalyptus charcoal in Madagascar: the Arina project approach

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In Madagascar, most people living in towns used charcoal for cooking. The 2 million inhabitants of Antananarivo consume annually 240,000 tons of charcoal, coming mainly from 150,000 ha of old *Eucalyptus robusta* coppices. However, there is a risk of rapid charcoal shortage due to continual decrease in eucalypt stand production, in parallel of the + 4.5% annual population growth rate and the increase in charcoal consumption (+ 210 % between 1993 and 2017). One major concern is the low gravimetric yield (≈ 12%) got with the traditional technique as well as poor charcoal quality. One specific objective of the project ARINA "Integrated Forest Management and Reforestation of Anjozorobe District", part of the EU FED-Program "Agro-Sylviculture autour d'Antananarivo" (ASA, 2015-2019) was then to increase the quantity and quality of charcoal produced in the Analamanga region. The Improved Carbonization Technique (ICT) inherited from 20 year-experience in local development projects, aims at smoothly changing the local practices to enhance ITC acceptance and diffusion by charcoal producers (CP). No additional equipment or investment (e.g. metallic chimney, red bricks) is needed to practice ICT. Harvested stems dry during 3 weeks before being charged in the kiln that is oriented upwind. These practices as well as *ad hoc* wood stacking, aeration holes or firing point positioning allow to increasing gravitational yield to 20%, with negligible percentage of un-carbonized wood. Moreover, charcoal produced by ICT is denser and much less friable than traditional one. In a first step, CPs recognized by the local communities for their competences are trained to ICT. Thereafter, they train in turn other CPs (> 1500 in total). CPs who master and actually practice ICT receive a specific certificate, as demanded by forestry administration in the next future to produce charcoal. ARINA supports formation of cooperatives of certified CPs that facilitate their members to buy eucalypt standing coppices for their own account, and to look for ITC charcoal buyers in Antananarivo. CPs can therefore generate higher profit (higher quantity of

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charcoal of better quality) than when they apply traditional carbonization techniques and work on behalf of charcoal wholesalers.

Keywords: Eucalyptus robusta, charcoal gravimetric yield, cascade training, charcoal producer cooperatives, Antananarivo

Carbon and water fluxes in Eucalyptus plantations and Savanna in Brazilian Tropics

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In Brazil the Eucalyptus plantations area is higher than 5.7 million ha, stand out for Mato Grosso do Sul State which had led the expansion over the last five years. One potential method to increase the productivity on new sites rely on better understanding the interactions between tree physiology and environment. To address this issue, we used the eddy-covariance technique to compare the carbon and water fluxes between a native Savanna forest (SAV) and eucalyptus plantations (EUC) during December 2012 to August 2013. The sum of the annual net ecosystem exchange (NEE, -1136 g C m-2) indicated that the ecosystem with EUC was a carbon sink, in contrast, for the SAV ecosystem (256 g C m-2) indicated to be a carbon source. However, the gross primary production (GPP, 3833 g C m-2) and the ecosystem respiration (Reco, 4080 g C m-2) for SAV were greater than EUC with 2678 and 1542 g C m-2, respectively. These higher differences may be assigned to the presence of small trees, shrubs, and high level of organic matter accumulated in the soil, wherein contributing with high photosynthesis and respiration. The total evapotranspiration (ET) at the SAV and EUC were 948 and 1050 mm, respectively. Although ET was higher in EUC, the GPP was strongly higher in SAV, hence the water use efficiency was greater in SAV (daily mean 4.3 g C kg-1 H2O-1 ± 69) than in EUC (2.7 g C kg-1 H2O-1 ± 43.7). Leaf area index in SAV varied 3.8 to 1.9 m-2 m-2, and in EUC varied 4.7 to 3.2 m-2 m-2, during wet and dry period respectively. The SAV was a weak carbon source (2.5 t C ha-1), and EUC was a strong carbon sink (11 t C ha-1). The results indicated that the Eucalyptus plantations in savanna biome are well adapted and the current land-cover change from pasture to Eucalyptus plantations can help the restoration of degraded areas in the savanna biome, improving a number of ecosystem functions.

Keywords: eddy, covariance, carbon flux, silviculture, wood production, net ecosystem exchange

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Influence of climatic conditions on wood specific gravity of eucalyptus grown across Brazil

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In plantations, the genetic materials associated to environmental conditions determine the site's productive potential and show fundamental importance on wood quality and understanding this behavior is essential for forest planning. The aims of this study were: i) to evaluate the influence of climatic conditions on wood specific gravity of eucalyptus clones; and ii) to verify the potential of wood specific gravity estimation by means of meteorological variables. The wood specific gravity of four Eucalyptus clones was analyzed at 4 years after planting in 11 sites in Brazil, representing a wide range of climatic characteristics with precipitations from 649 mm.year-1 to 1618 mm.year-1. Precipitation, maximum vapor pressure deficit, soil water deficit, seasonality of temperature and precipitation were used to characterize the sites during the growing period. The hierarchical grouping was performed from the sites, and the behavior of wood specific gravity and mean annual increment (MAI) of wood within the groups were analyzed. To identify the potential wood specific gravity estimator, linear regression equations were adjusted between the most influential meteorological variables on wood specific gravity. Four groups were formed and, among them, wood specific gravity ranged from 9.3% (0.43-0.47 g.cm-3), 9% (0.44-0.49 g.cm-3), 14% (0.42-0.49 g.cm-3) and 10% (0.45-0.55 g.cm-3) for each clone, respectively. In general, drier sites show higher wood specific gravities due to a decrease in growth rate. This behavior is intrinsic to each clone and does not establish a defined ratio. Wet sites do not show clear patterns. The maximum vapor pressure deficit and soil water deficit were the most significant variables with the best potential to estimate the wood specific gravity. Although specific gravity is an inherited characteristic, there is a significant influence of climate.

Keywords: Climatic conditions, Wood density, Eucalyptus

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Initial growth of Eucalyptus after pure and composted sewage sludge application

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The use of sewage sludge as an organic fertilizer, besides being an alternative for the final disposal of such waste, improves the soil properties, since it is a material rich in nutrients and organic matter, which may favor the development of plants. This work objective was to verify the effect of different doses of composted and pure sewage sludge in the initial development of a hybrid Eucalyptus. The experiment was conducted in plastic greenhouse and was composed of 48 vessels containing 50L of dystrophic medium texture. It is a factorial experiment, with two factors: SILT (pure and composted) and dose (20, 30, 40 and 50 Mg ha-), plus two additional treatments (absolute control and mineral fertilization indicated to species). Each treatment was composed by four repetitions. The height and stem diameter were measured monthly, during seven months and total dry mass (leaves + trunk branches roots) was calculated at the end of the experiment. The data were subjected to analysis of variance, complemented with tests of multiple comparisons and adjustments of polynomial regression models to evaluate the effect of doses, at 5% level of significance. Seven months later, the sludges and chemical fertilization provided the same effect on the diameter of the plant, being that the dose which promoted maximum average diameter (27.3 mm) was 39.98 Mg ha- for the three treatments. The composted sludge provided the best effect on height and in the production of dry mass of plants, independent of the dose. For both sludge, the dose that maximized the response in height was 46.2 Mg ha-, and dry mass of 46.94 Mg ha-, providing the maximum average plant height of 205 cm and total dry mass of maximum 842 g, respectively. The fertilization with pure or composted sludge promoted similar gains in the initial development of eucalyptus in relation to mineral fertilization. By the parameters evaluated, the recommended dose should be 45 Mg ha- of composted sewage sludge.

Keywords: Urban residue, fertilization, biomass production, mineral nutrition

*Speaker

Technical and economic evaluation of forest projects with eucalyptus hybrids in different space arrangements

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Brazil is a world reference in the productivity of planted forests. The analysis of the productivity of these plantations is of utmost importance for the fulfillment of the goals of the Brazilian government to reduce tropical forests deforestation. Among the environmental benefits they can generate we can name mitigation of the effects of climate change and reduction of pressure on native forests. The study analyzed technical and financial parameters of forest plantations with hybrids of *Eucalyptus urophylla* x *Eucalyptus grandis* and *Eucalyptus camaldulensis* x *Eucalyptus tereticornis* in the Cerrado biome. Each individual occupied an area of 9 m^2 (spatial arrangements of 3 m x 3 m and 6 m x 1,5 m). For the financial analysis, the Internal Rate of Return (IRR) and Net Present Value (NPV) methods were adopted, and the productivity and costs of implementation and maintenance of the projects were evaluated until it reach 6 years old. The second rotation with budding management was analyzed considering the same cost scenario of the first rotation, with a reduction of 10% in productivity. The spatial arrangement directly influenced the implementation costs, being 24% larger for the arrangement 3m x 3m, and the cost of forest maintenance was 18.1% higher in the 6m x 1,5m arrangement. The average annual increment was higher for the 3 m x 3 m arrangement. The highest income, due to the higher productivity, was related to the hybrids of *E. urophylla* x *E. grandis* in the 3 m x 3 m arrangement, providing higher IRR and NPV. The hybrid *E. camaldulensis* x *E. tereticornis* was financially unfeasible, as the IRR was lower than the 10% Minimum Investment Attractiveness Rate. The individuals of the same species and with the same area present distinct growth as a function of the spatial arrangement, and the appropriate arrangement depends on the final destination of the wood. Despite the high productivity of Brazilian plantations, the sector falls short of the demand for planted timber, and productivity must be intensified in order to meet this demand.

Keywords: Productivity, space arrangement, financial viability.

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Challenges for the success of Eucalyptus clonal forestry in Kalimantan, Indonesia

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PT. Korintiga Hutani (KTH) has started to plant *Eucalyptus pellita* (*E.pellita*) and *Acacia mangium* in Central Kalimantan, Indonesia in 1998. The climate in the region is tropical rain forest receiving 3000 -4000mm of rainfall per year.
Plus tree selection of E.pellita has started since the establishment of *E.pellita* seedling plantations and the first clone trial was established in 2002. In 2005, KTH has started to use some of the selected clones for the commercial operation and the best clone called ID30 has been used as main operation clone since 2010. Due to the strong demand on new clones with faster diameter growth and better wood quality for sawlog, KTH added 3 new clones in the commercial operation since 2015. Because of the increasing damage of *A.mangium* by pest & disease, KTH decided to plant only *E.pellita* clones for the operation since 2016. With a long history of effort, KTH succeeded in the implementation of *E.pellita* clonal forestry. However, there are still various challenges on the success of the clonal forestry in KTH.
Wind damage is the most serious problem in the 1st and 2nd year of our plantation. Our clone trial result showed that *Eucalyptus deglupta* and *E.pellita x E.brassiana* have higher wind resistance than *E.pellita.* Sapling quality also seems to affect the wind resistance since root coiling is observed on many of the fallen trees.
Broken, fork and/or swollen stems due to coffee borer (*Z. coffeae*), tip damage by *Eucalyptus* tip wilter bug and die back by unknown cause have recently been observed in our plantation area. These are the potential threats for our future plantation operation.
Leaf blight disease is a common problem in the *Eucalyptus* plantations in tropical countries. However, our *E.pellita* clones are resistant to leaf blight disease and such problems have not been found in the plantation.
Together with improvement sapling quality and plantation management, we have focused on the development of new hybrid clones to recover the above problems. Current main focus of the combination is crossing between wind resistant species and leaf blight resistant species. Preliminary result of hybrid progeny and clone trial indicate that some of the *E.camaldulensis x E.pellita* clone can make great improvement on both survival rate and unit volume growth in our region.

Keywords: Eucalyptus, pellita, breeding, Indonesia, hybrid, clone

*Speaker

Micropropagation of Corymbia torelliana × C. citriodora hybrid for improved rooting

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Establishment of Corymbia hybrid clonal plantations is limited by difficulty in clonal propagation using conventional cuttings due to poor rooting (1-2%). Micropropagation was attempted to produce clonal propagules of selected Corymbia hybrids.
Primary shoots were initiated *in vitro* using nodal and shoot apical explants on MS media with 4.4 μM benzyl adenine (BA) and 1.1 μM α-naphthaleneacetic acid (NAA), further multiplied and elongated on media with 2.2 μM BA, and 1 μM BA + 1 μM Kinetin (K) respectively.

Improved rooting (30-40%) was observed on a liquid MS medium (pH 5) containing 2% Sucrose, 3 mg/l Glutathione, 50 mg/l Ascorbic acid, 50 mg/l Riboflavin, 100 mg/l Polyvinylpyrrolidone, 2.5 μM indole-3-butyric acid (IBA) under low light (2500 Lux) and exposure to higher level of CO2 (1000 μmol/mol). Rooting was observed only after 3rd subculture while better rooted plants were produced from shoots of 5th subculture.

Rooted plants produced by micropropagation were used to establish a clonal micro-garden that enabled routine clonal propagation.

Keywords: Key words: Corymbia hybrid, Micropropogation, Rooting.

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Better Eucalyptus Project

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In Portugal, *Eucalyptus globulus* is the most utilized species for Pulpwood production and it plays a major role in small landowners' income. Furthermore, eucalyptus is the base of an industry which contributes up to 1,4% of the Portuguese GDP and for thousands of direct and indirect jobs.
Nevertheless, nearly half of the eucalyptus stands owned by private non-industrial producers present poor forest management or inadequate practices. Consequently, even though these stands are generally planted in adequate soil and climatic conditions, their production and yield are often bellow its potential, with increased fire risk and pest exposure. On the other hand, plantations managed by the pulp and paper industry are recognized to be sustainable and more productive in similar conditions.

Considering this, CELPA – Pulp and Paper Association which assembles Portugal's major paper and pulp production companies, launched 'Projecto Melhor Eucalipto', a communication project targeted to forest producers, technicians and contractors. This project aims to share best practices with stakeholders, encouraging them to be more aware about the benefits of a sustainable forest management in subjects such as forest nutrition, soil preparation, planting or pest control, helping them to make their investments more profitable and environmentally responsible towards forest certification.
Since its beginning in 2015, the Project has created a website - http://www.celpa.pt/melhoreucalipto/ - with over 60 thousand views and shares, developed yield and financial simulators, films concerning eucalyptus silviculture, informative spots on local radios and flyers. Also, several local activities were developed with demonstration fields and workshops all over the country, reaching thousands of interested landowners, local authorities, technicians and forest contractors. Nowadays, "Melhor Eucalipto" is recognized as a reference to get information about best practices in Portuguese eucalyptus plantations.

Keywords: eucalyptus, silviculture, information, best practices, sustainability

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High temperature drying properties and basic drying schedule of Eucalyptus pellita from 4 provenances

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Lumbers of different provenances could react differently during drying process. This study investigated the effect of different provenances and sampling position on trees on *E. pellita* tendency to develop drying defects under high drying temperature (100∘C) and determine its basic drying schedule. The study used modified terazawa method and samples from Papua New Guinea and Indonesia provenances. All samples (25-mm (thickness) x 80 mm (width) x 200 mm (length)) were dried at 100∘C. Defect development was observed every 3-4 hours until the samples reach moisture content below 5%. The results show *E. pellita* samples from Indonesia provenance has the lowest tendency to develop initial check/split (score 0-1). Bottom-part samples from North Kiriwo PNG and South Kiriwo provenances and top-part samples of South Kiriwo, PNG provenance have the lowest tendency to deformation (score 5). The bottom-part samples from North Kiriwo PNG provenance also have the lowest tendency to develop internal check (score 2). The drying condition proposed for Indonesia provenance is 40-65∘C and 14-83%. The bottom- and top-part samples from South Kiriwo provenance share the same temperature range (38-50∘C), but different humidity conditions. The top-part samples from North Kiriwo and Serisa Village provenances need milder drying condition than their bottom-part samples.

Keywords: Eucalyptus pellita, provenances, drying defects, drying schedule

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Abiotic changes - Oral session

Domesticating durable, low growth-strain eucalypts in New Zealand

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Eucalypts are the most widely planted hardwood in the world, with millions of hectares primarily dedicated to the production of wood pulp and biofuels. These are markets in which New Zealand does not have comparative advantages.
In 2008 the New Zealand Dryland Forests Initiative started domesticating 5 eucalypt species for the production of durable, low growth-strain wood. The breeding program targets the production of naturally-durable posts, veneers and other solid wood products, with trees growing in the East Coast of the country, in environments with rainfall from 500 to 1000 mm/year.

The NZDFI program emphasises very early screening of wood properties (ages 2-6 years) for thousands of individuals, which relies on the development of easy, low-cost phenotyping. Durability screening is non-destructive, using near-infrared reflectance spectroscopy to estimate heartwood extractive contents from increment cores of 6-year-old trees, over multiple sites. In contrast, we use a destructive splitting, single-site test on 2-year-old trees to discriminate for low and high growth-strain at the family level. Individual-tree and family-level information is later combined via selection indices.
We present examples of the structure of the current evaluation populations and early results for genetic parameters and selection progress in *Eucalyptus bosistoana*. Finally, we discuss the successes and difficulties in our early screening approach for solid wood products in eucalypts.

Keywords: growth strain, wood durability, extractive content, early selection, NIR

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Cold tolerant eucalypt trials and plantings in China reveal Eucalyptus camaldulensis to have unexpected potential for frost-frequent environments

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Worldwide many eucalypt species have been tested as candidate commercial plantation species for cooler, frost-frequent environments. From such work, the most successful species adopted for larger scale plantations in such environments include *E. nitens* in winter rainfall, drier summer regions and *E. dunnii* in summer rainfall regions. However, these and most other eucalypt species with better cold tolerance are not readily amenable to commercial scale vegetative propagation. In China this latter trait, particularly with *E. dunnii* for which seed production can also be problematic in exotic plantation environments, has seriously inhibited cold tolerant eucalypt plantation development.

Results from a detailed review of cold tolerant eucalypt trials and plantings in China, including plantings of up to 50 years of age or more, reveal selected provenances of *E. camaldulensis* to have good potential in environments requiring higher levels of cold and/or frost tolerance. These findings accord with work carried in the USA during the 1980s and 1990s, also briefly reviewed, which lead to development of some commercial clonal, cold tolerant *E. camaldulensis* plantations with growth rates of up to 45 m3 ha-1 y-1.

Unlike most cold tolerant eucalypt species, *E. camaldulensis* is relatively easy to propagate vegetatively. This latter trait in combination with the species proven cold tolerance, and also its crown form traits (making it less susceptible to breakage from ice and snow) means *E. camaldulensis* warrants wider consideration as a superior parent species for creating cold tolerant hybrid eucalypt varieties. The success of subtropical and tropical varieties of *E. camaldulensis* in China, and elsewhere, as a parent species for commercial plantation hybrid varieties, is briefly reviewed. Such success as a hybrid parent for warmer plantation environments suggests the species will also have great potential as a parent for future commercial cold tolerant eucalypt hybrid varieties.

Keywords: vegetative propagation, frost, tolerance, clonal hybrids, Eucalyptus camaldulensis

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Potassium fertilization mitigates the negative effect of reduced water availability on hydraulic lift and growth in Eucalyptus grandis plantations

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A passive phenomenon called hydraulic lift (HL) allows some plant species to take up water from deep moist soil layers and redistribute it in the upper dry soil layers. Soil fertilization, particularly K, can also alleviate water shortage and increase plant water use efficiency (WUE) on poor and acidic tropical soils. The present study aimed gaining insight on the role of HL and K fertilization in increasing both wood productivity and WUE for stemwood production (WUEp) of eucalyptus plantations under undisturbed and 37% throughfall exclusion. Tree transpiration was measured over 21 months in a large-scale throughfall exclusion plantation of *E. grandis* in Brazil. HL was estimated by measuring the density and direction of water in shallow roots over 18 months. Tree biomass, leaf and whole tree hydraulic conductance (Kleaf and Ktree), soil water storage from surface to the water table, at a depth of 17 m, and photosynthetic activity through A-Ci curves measurement were also assessed. The monthly density of water redistributed by roots was significantly increased by K-fertilization. This density decreased with throughfall exclusion, probably due to a lower tree transpiration under that condition. Potassium increased WUEp by about 200% through an increase in the partitioning of dry matter to produce stemwood. That change in the partitioning of carbon between tree organs was possible because: K-fertilization increase leaf longevity and decreased limitations in the use of light through an increase in the photosynthetic efficiency, so trees with +K did not need to allocate much C in leaves; and potassium decreased limitations on water supply through an increase in stem hydraulic conductance and HL, so trees did not need to allocate much C in roots. The results

*Speaker

indicate that fertilizing *E. grandis* plantations with potassium is beneficial to increase both wood biomass production and WUEp, even with a 37% decrease in rainfall. However, K fertilization also increase the water demand and therefore could pose a risk of plant hydraulic failure under very extreme drought.

Keywords: forest plantation, soil fertilization, tree transpiration, tropical soil, water use.

Potassium fertilization affects hydraulic responses to height growth in Eucalyptus trees

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Climate change and in particular the increase in frequency and duration of drought is affecting the functioning and growth of *Eucalyptus* plantations. Drought-induced dieback of Eucalypt plantations has already been reported over large areas in Brazil and are expected to increase in the future. These effects are expected to be particularly acute on tall trees, which commonly show decreased xylem hydraulic conductance and thus a reduced ability to transport water from soil to leaves. Potassium (K) fertilization may be a crucial managing tool to mitigate the negative effect of drought on Eucalypt plantations, as it has been reported to strongly affect tree structural and physiological adjustments to water deficit. Here, we present results from a split-plot experimental design set up in June 2010 within a highly productive *E. grandis* Hill ex Maid clone that includes 4 treatments: two K supply regimes (commercial K fertilization versus no K addition) crossed with two rainfall regimes (1/3 rainfall exclusion versus unaffected rainfall) applied in three blocks. The responses of sapflow-derived canopy conductance, leaf area (Al), sapwood area (As), leaf-specific hydraulic conductance and soil–leaf water potential gradient to height growth were investigated over a 6-year period (from planting to harvesting). Al and As were both significantly reduced in the absence of K, but in contrasting proportions, which resulted in a strong increase in As:Al ratio in K-depleted treatments. A sensibility analysis conducted using a model based on Darcy's Law showed that these allometric adjustments in K-depleted plots partly compensated the expected decrease of leaf-specific hydraulic conductance and canopy transpiration with height growth. The implications of our findings for the management of Eucalypt plantations in the face of climate changes, and the role of K fertilization in future management guidelines will be discussed.

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Keywords: Fertilization, tree hydraulic, leaf area, sapwood area, transpiration, water exclusion experiment

Eucalyptus camaldulnesis genotypes from contrasting climates differ in their response to long-term precipitation treatments

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Warmer and drier conditions projected for the future are expected to impose significant stresses on forest trees, and may reduce forest productivity. Importantly, forest trees capacity to respond to environmental change (i.e. phenotypic plasticity) may be determined by the climatic regime to which they are adapted. In this experiment, we grew eight genotypes (clones) of *Eucalyptus camaldulensis* (River Red Gum) representing different climates throughout the species climate range, in the ground under six large rainout shelters (12m long x 8m wide x 7m tall) located in Richmond, NSW, Australia. Within each shelter, we imposed a low precipitation (275 mm yr-1) and high precipitation (750 mm yr-1) treatment. Treatments represented the mean annual precipitation at the low and high end of the species distribution. Tree growth (e.g., dry mass production, leaf area) and physiology (e.g., photosynthesis, stomatal conductance) were regularly measured for 1.5 yrs. We tested the hypotheses that: 1) genotypic differences in growth and physiology will be linked with climate of origin, 2) plant growth will be reduced under low precipitation, and 3) genotypes from warmer-drier climates will be less responsive to changes in precipitation compared to genotypes from cooler-wetter climates (GxE interaction). In general, we found that genotypes from cooler-wetter climates grew faster and were more productive under high precipitation, but were responsive to reductions in growth and photosynthesis under low precipitation. In support of our hypothesis, genotypes from warmer-drier climates showed smaller reductions in net photosynthesis and stem production under low precipitation, compared to genotypes from cooler-wetter climates. Our results indicate that genetic adaptation influences tree sensitivity to precipitation. Understanding how adaptation influences plasticity could inform tree breeding and forest management decisions under climate change.

Keywords: drought, GxE, photosynthesis, plasticity

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Daily stem radial fluctuations in Eucalyptus reveals the dynamic of the genetic determinants of trees response to environment

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In trees, daily stem radial fluctuation (DSRF) constitutes a remarkable dynamic trait in response to environmental variations. This circadian rhythm integrates two major processes: i/ the variation in water content determined by transpiration and water absorption, and ii/ cell division in the cambium and subsequent cell expansion (secondary xylem and phloem). DSRF can be measured at a high resolution scale using automatic dendrometers placed on the trunk. While it has been largely studied by ecophysiologists, the genetic basis of DSRF and its interplay with the environment remain largely unknown. The objective of this study was to characterize the genetic architecture of the DSRF in *Eucalyptus,* to learn about the dynamics of genotype-by-environment interaction (G×E). To this end, we analyzed two years of sub-hourly data collected on 220 full-sibs of *E. urophylla* x *E. grandis*, i.e. about 200,000 data points per tree. Two components of the circadian cycle were studied: the daily amplitude of radial shrinkage (DA), and the difference between successive daily maximum trunk radius values (ΔR). These two variables in relation with environmental factors (temperature, air vapor pressure deficit, soil water content, global radiation) enabled us to study the QTL×E interaction. At the phenotypic level, DA and ΔR were on average not correlated during the studied period. They showed clear differences in environmental plasticity: DA being positively correlated with several atmospheric variables at the daily scale. Conversely, ΔR showed low correlations with environmental variables at this time scale. These two traits presented a very different genetic architecture suggesting that different genes are indeed involved in DA and ΔR variation. Moreover, the study of the genetic architecture revealed a temporal instability of the genetic control for DA and ΔR. For DA, this instability was clearly related to seasonal variations, and well-illustrated by two QTL regions on the linkage group 3 of the *E. urophylla*. Interestingly, these QTLs colocalized with two major QTLs involved in the genetic control of mature wood properties. These results reinforce the hypothesis that tree response to environmental variation at the juvenile stage could be a key driver of many properties at an older developmental stage.

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Keywords: Trees response to environment, genetic and environmental determinants, daily stem radial fluctuations

Efficiency of multi-trait genomic selection in two contexts of Eucalyptus breeding

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In this study we explore the performance of multi-trait genomic selection (MT-GS) using the single-trait version (ST-GS) as the baseline. We implemented the approaches in two *Eucalyptus* breeding schemes.

In Congo, where commercial plantations of *E. urophylla*grandis* are dedicated to pulp production, we considered height increment between 8 and 18 months (H8_18), critical trait to avoid weed competition, and volume at 55 months (V55), the target trait, to analyse the interest of MT-GS. We used 3303 SNP to define the relationship matrices and to estimate breeding values of 1130 cloned hybrid progenies. The prediction accuracy was estimated through a cross validation process (75% of tree in the training set). For H8_18, the accuracy was 0.354 and 0.370 for ST-GS and MT-GS respectively. For V55, the accuracy attained 0.414 and 0.424 for ST-GS and MT-GS respectively. Although MT-GS presented higher accuracies, estimates were not significantly different. This result was explained by the low heritability of V55 and H8_18 (h2=0.26 and h2=0.13) and the relatively high genetic correlation (ρa =0.77).

In Madagascar, where *E. robusta* small-scale plantations are grown for fuel wood, the volume at 49 months (V49), the total lignin (TL) and the holo-cellulose (Holo) are the targeted traits for breeding. 2919 SNP were used to define the relationship matrix and estimate breeding values of 415 individuals of a provenance trial. Accuracies were estimated through the same procedure. For V49, the prediction accuracy attained 0.30 for both ST-GS and MT-GS. For TL, the prediction accuracy was near zero whatever the approach (0.05 for ST-GS and 0.04 for MT-GS).

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Similar results were observed for (V49, Holo). This result was mainly explained by the weak genetic correlation between V49 and wood traits (ρa =0.30). Heritability was very low for wood chemical traits: h2=0.23, h2=0.05 and h2=0.09 for V49, TL and Holo respectively.
These two examples of breeding schemes showed that MT-GS improves the efficiency of selection when the heritability is low but the correlation is sufficiently high.

Keywords: GBLUP, multi, trait selection, growth traits, wood traits, Congo, Madagascar

Early growth response to elevated [CO2] within a eucalypt breeding population

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Introduction. Under projected emissions scenarios atmospheric [CO2] may double by the end of the century. The associated increase in photosynthesis and increased carbon gain will drive enhanced tree growth and potential productivity gains. Evidence for genetic variation in plant responses to elevated [CO2] (e[CO2]), including within a single species, suggests that selection for responsive genotypes is possible. While presenting the opportunity for breeding strategies aimed at maximising e[CO2] responsiveness, it remains unclear whether variation in growth responses to e[CO2] exist within breeding populations of eucalypts.
Method. We conducted a comparative glasshouse study of $>$ 4000 *Eucalyptus globulus* ssp. *globulus* seedlings from 130 open-pollinated families from the Southern Tree Breeding Association's breeding population in controlled environments that exposed seedlings to ambient (400 ppm) or elevated (640 ppm) [CO2]. Seeds were germinated and grown under these conditions for 35 days post radicle emergence after which time they were destructively harvested, partitioned into root and shoot components and weighed and sampled to determine stable isotopic composition.

Results. We observed a highly significant ($p< 0.0001$) average increase (29.8%) in total dry mass in response to e[CO2] for all families. Mass-related traits demonstrated moderate narrow-sense heritability. Family rankings were highly stable between CO2 environments, with negligible family-by-CO2 (GxCO2) interaction.
Discussion. Our results suggest that while nursery performance is likely to be enhanced under e[CO2] in commercial settings, genotypes are likely to respond to e[CO2] uniformly. Similarly, e[CO2] is unlikely to alter competitive dynamics between genotypes during early establishment of wild stands. While our results may not reflect longer-term GxCO2 or interactions that may be important both in plantation and wild stands, these interactions are extremely challenging to study.

Keywords: heritability, total dry weight, CO2 fertilisation, Eucalyptus globulus

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Understanding the interaction between genetics and environment shows potential to maintain and increase Eucalyptus productivity

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Investments in silvicultural practices, tree improvement, and knowledge of soil and climate

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over decades leaded Brazilian *Eucalyptus* plantations to reach high levels of productivity. The key strategy to maintain and increase the productivity relies on better understanding the interactions between genetics and environment. To address this issue, we developed the TECHS-IPEF project (Tolerance of *Eucalyptus* Clones to Hydric, Thermal and Biotic Stresses), installed in 2012 with 36 sites from Equator to 33 oS in Brazil and Uruguay, across a gradient of temperature (10 to 30oC) and rainfall (600 to > 2000 mm yr-1). Each site contains 11 different *Eucalyptus* varieties (tropical and subtropical clones). Additionally, throughfall exclusion was installed to test the effect of removing 33% of rainfall.
Mean annual increment (MAI at age 5 years) ranged from 17 m3ha-1year-1 on areas with intense soil water deficit (SWD) (consecutive 6-8 months with 600 mm cumulated annual deficit) to 65 m3ha-1year-1 on areas with > 1200 mm of annual rainfall, evenly distributed over the year (more than 100 mm every month; rainfall relation: R2=0.65, p< 0.001; SWD relation: R2=0.79, p< 0.001). Significant differences of responsiveness to water availability among clones were found. Changing from the average clone to the best clone at each site resulted in 50% increase in MAI. All clones reached productivity over 40 m3ha-1year-1 in at least one site. The best clone on the best site showed MAI of 95 m3ha-1year-1. Throughfall exclusion effect on productivity ranged from almost none on wet sites to 30% reduction on dry sites, with clones responding significantly different. The effect of throughfall exclusion increased with SWD (R2=0.33, p=0.01). Leaf area index ranged from 1.5 to 6 m2m-2 among years and clones, showing significant relation with productivity (R2=0.45, p< 0.001).
Improve our understanding regarding the interaction between genetics and environment is crucial to optimize genotypes zoning.

Keywords: Clonal plantation, Zoning, Silviculture, Wood production

Changes in carbon partitioning driven by climatic gradient affects wood productivity of Eucalyptus clones

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Patterns of carbon partitioning among tree components are a combination of genetic and environmental effects. Studies have shown that these patterns in *Eucalyptus* plantations are sensible to environmental variation at different spatial scales, especially related to soil water availability. Overall trend shows that aboveground partitioning, particularly to wood production, is positively correlated to increase in water availability. Despite the importance of understanding carbon fluxes and partitioning, we lack knowledge related to the effects climate on different species. We studied 4 sites covering a wide range of annual precipitation (600 to 1,600 mm) and soil water deficit (0 to 800 mm). At each site we studied 5 contrasting *Eucalyptus* clones (pure or hybrid *E. grandis, E. urophylla, E. camaldulensis and E. brassiana*). Gross primary production (GPP) was calculated during two consecutive years (_˜1.5 to 3.5 years) by the sum of aboveground net primary production (ANPP), total belowground carbon flux (TBCF), and autotrophic respiration. Partitioning was calculated by ratios among fluxes.
Carbon fluxes and partitioning were different among sites (environmental effect) and clones (genetic effect). Comparing sites, clones and years, ANPP ranged from 282 to 5,494 gCm-2year-1, and TBCF from 550 to 2,925 gCm-2year-1. Comparing sites, ANPP:GPP increased from 0.30 to 0.42, and TCBF:GPP decreased from 0.60 to 0.19, with increasing with soil water availability (R2=0.78, p< 0.01). Comparing clones, ANPP:GPP increased from 0.31 to 0.38 and TCBF:GPP decreased from 0.42 to 0.28. Clones with higher partitioning aboveground also showed higher partitioning of ANPP to wood production. Changes in partitioning patterns are more responsive to differences among sites than differences among clones.

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Improving our understanding on how carbon fluxes and partitioning are affected by climate and genetics will help zoning strategies to optimize wood productivity and cope with climate variability.

Keywords: Drought, Carbon allocation, Climate variability

Eucalyptus plantations & deep groundwater: the effects of different potassium and water supply regimes on soil water uptake and water table depth.

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Although large amounts of potassium (K) are applied in tropical crops and planted forests, little is known about the interaction between K nutrition and water supply regimes on water resources in tropical regions. This interaction is a major issue because climate change is expected to increase the length of drought periods in many tropical regions and soil water availability in deep soil layers is likely to have a major influence on tree growth during dry periods in tropical planted forests.
In this study, we described a modeling approach to quantify water fluxes in a *Eucalyptus* throughfall exclusion experiment in Brazil to gain insight into the combined effects of K deficiency and rainfall reduction (37% throughfall exclusion) on the water used by the trees, soil water storage and water table fluctuations over the first 4.5 years after planting.

Although the mean water withdrawal from depths of over 10 m amounted to only 5% of canopy transpiration in K-fertilized plantation with undisturbed rainfall (+K+W), the proportion of water taken up near the water-table was much higher during dry periods. Under contrasted K availability, water withdrawal was more superficial for –K than for +K. Under rainfall exclusion,

*Speaker

water was withdrawn in deeper soil layers for –W than for +W, particularly over dry seasons.

A comparison of canopy transpiration in each plot with the values predicted for the same soil with the water content maintained at field capacity, made it possible to calculate a soil-driven tree water stress index for each treatment. The soil-driven tree water stress index was 166% higher over the first 4.5 years after planting for –W than for +W, 76% lower for –K than for +K, and 14% lower for –K–W than for +K+W.

Over the study period, deep seepage was higher by 371 mm yr–1 (+122%) for –K than for +K and lower by 200 mm yr–1 (–66%) for –W than for +W. Deep seepage was lower by 44% for –K–W than for +K+W. At the end of the study period, the model predicted a higher water table for –K (10 mbs for –K+W and 16 mbs for –K–W) than for +K (16 mbs for +K+W and 18 mbs for +K–W).
Our study suggests that the depth of the soil should be a major criterion for the selection of future afforestation areas and that flexible fertilization regimes could contribute to adjusting the local trade-off between wood production and demand for soil water resources in planted forests.

Keywords: Water resources, Nutrients, Groundwater, Brazil, Eucalyptus, Deep roots

Managing the nutrition during large scale transition from Acacia mangium to Eucalyptus pellita in short rotation plantation in South Sumatra, Indonesia

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Acacia mangium plantations have been a major source of wood for pulp mills in Sumatra due to its rapid growth rate (22-35 m3/ha/yr) and 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, nutrient input, inter-rotation practices promoting conservation of site organic matter and weed control were deployed.
Incidences of *Ganoderma* root rot and rapid spread of *Ceratocystis* wilt disease have caused tree mortality so high that growing *A. mangium* was no longer viable. An earlier trial showed that *Eucalyptus pellita* emerged as the next best candidate species. More than 650,000 ha of *A. mangium* plantation have been replaced with *E. pellita* in Indonesia and Malaysia as of the end 2017.

Slash retention has been the common practice during the last decade. In a study now in the fourth rotation, the growth rates of first rotation *E. pellita* decreased by 10.5% if acacia slash and litter were removed compared to slash and litter retention, and growth rates increased by 21.2% when P was added to plots where slash and litter have been retained over successive rotations. Other results showed wide spread response to P at sites were acacia slash and litter were retained over two rotations and previous trees were fertilized with P, the response declined with age. So far we have not found response to N, Ca and K.

Keywords: change of species, productivity, site management, sustainability

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Unexpected Root Growth and Functioning in Very Deep Rooted Eucalyptus Tree Plantations: Ontogeny or Adaptation to Abiotic Stresses?

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Functional and architectural plant root models simulate root architecture, growth dynamics, mortality, fine root distribution and water and nutrient uptake within the whole soil profile but with a unique set of parameters, usually measured within the topsoil only. They implicitly hypothesize that root growth and functioning is homogeneous throughout soil depth. Moreover, various observations have shown that trees have the capacity to explore very deep soil layers whatever soil and climate conditions, even where no drought is encountered. However, deep rooting strategies are often assumed to result from an adaptation of trees to withdraw water at depth when topsoil dries out. Here we report on changes in fine root behavior, morphology and anatomy with soil depth when comparing shallow roots to those growing down to 17-m in eucalypt plantations in Brazil, using various methods: root intersect measurements on pit walls, permanent pits equipped with (mini)rhizotrons, in-growth and sequential cores, analyses of rhizosphere properties and root anatomy, as well as modeling approaches. We show that very small densities of deep fine roots can have a key functional role for tree survival during extreme drought periods and make it possible to take up nutrients at depth, leached from the upper soil layers or naturally present in the subsoil. Unexpectedly, lower fine root mortality, higher elongation rate, fewer number but larger xylem vessels, higher increase of organic C and available K concentrations in the rhizosphere were found for deep compared to shallow fine roots. Very fast fine root exploration at depth > 4m was found in humid tropics, with no water stress conditions and high resource requirements of trees. Our results suggest a territorial strategy providing access to resources at great depth, suggesting an ontogenetic determinism in addition to the effect of the environment on deep fine root colonization.

*Speaker

Keywords: Eucalyptus grandis, deep rooting, root anatomy, root mortality, root turnover, water, nutrients, drought, Brazil

Very deep rooting in tropical eucalypt plantations: consequences for management under climate changes

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Global models predict that the occurrence of extreme climatic events will increase in the next decades, while the depletion timeline of phosphorus and potassium reserves will strongly affect fertilization regimes. There is therefore an important concern about the future productivity and survival of crops and planted forests. The exploration of deep soil horizons by the root systems could be a crucial plant feature in order to mitigate and adapt to these global changes. Recent studies have shown that the root system of eucalypt seedlings and clones reach very deep soil layers the first years after planting. Changes of fine root behavior with soil depth have been studied down to 17 m in Brazil using various methods: soil coring, permanent trenches equipped with minirhizotrons, in-growth cores, analyses of rhizosphere soil and root anatomy, sampling of greenhouse gases, application of isotopic tracers, monitoring of soil water contents, as well as modeling approaches. These recent studies improved our understanding of the role of very deep roots for tree water and nutrient uses. They show in particular that very small densities of deep fine roots play a key functional role in tree survival during extreme drought periods and allow taking up nutrients leached from upper soil layers. An unexpectedly low mortality of fine roots after clearcutting in stands managed in coppice contributes to limit carbon and nutrient losses before canopy closure. After a brief presentation of recent findings showing the role of deep roots in eucalypt plantations, silvicultural guidelines will be proposed to reduce mortality risks under increasing abiotic stresses. The depth of the soil should be a major criterion for the selection of future afforestation areas, weed control practices, as well as fertilization regimes (type and timing of fertilizer applications). Research avenues will be proposed to gain insight into the role of deep rooting on tree functioning in eucalypt plantations.

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Keywords: Eucalyptus, root, water, nutrient, drought

The proper dose of parental gene when hybridizing E.urophylla and E.grandis

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Hybridization is a critical mean for eucalypt breeding. *Eucalyptus urophylla* and *E.grandis* are maybe the most important pair of hybrid parents in eucalypt as most important hybrid clones in the world are from them. Their superior growth, excellent form and good adaption are well reported. For these important parents, to better use their potential and look for better combinations, We tried different ways of mating between them, and used from 25% to 100% "booldline" of each of them to create hybrids. To see the affects of each parents in growthvariation and survive in Southern China.
There were 40 families parented by 5 *E.urophylla* individuals, 7 *E.grandis* and 3 *E.grandis*×*urophylla* individuals. Employing 6 ways of mating combinations: G×U, U×G, GU×G, GU×U, U×GU, U×U. Take E.urophylla and E.grnadis open pollinated families as checks.
The results from 1.0yr up to 9.0yr showed: the difference in performance of the combinations and families within combinations were mostly significant. The combinations can generally be divided into 3 groups by their growth. The best group was the G×U and U×G hybrids (50%G+50%U). They had constantly and significantly advantages on both stem volume and survive rate over the others. The second group included: U×GU (75%U+25%G), GU×U(75%U+25%G) and U×U(100%U). Their volume growth were about 81% of the best group, but with survive rate not significantly different from it. The 3rd group's volume growth was about 51% of the best's and survive rate was about 7% lower. GU×G (75%G+25%U), the open pollinated *E.grandis* and *E.urophylla* were in this group. Meanwhile, variations of the first and second group were not significantly different. Their volume CV were between 46%-48%. The 3rd group's volume CV was about 67% and was significantly higher that of the first 2 groups'.

Keywords: eucalypt, hybridization, parent, E.urophylla, E.grandis

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Screening Eucalyptus camaldulensis clones for drought tolerance and productivity across diverse sites in Southern India

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Short rotation clonal eucalypt plantations are raised in diverse climatic and edaphic conditions in India. A few *Eucalyptus camaldulensis* clones are often planted across sites with annual rainfall range of 500 to 1000 mm giving low yield in rainfed conditions. Field trials of 86 E. camaldulensis clones were laid out (16 tree plots and 5 replications) in low (500 mm rainfall) and high productivity (1000mm rainfall, irrigated) sites to evaluate stress related yield variation in clones. The clones were compared using indices that estimate drought tolerance to identify potential genotypes suited to each site. Seven indices – Drought tolerance index, Harmonic mean stress (HM), Susceptibility index (STI), Geometric mean productivity (GMP), Yield index (YI), Yield stability index (YSI) and Modified stress tolerance index (K1STI) were estimated from mean girth at breast height (GBH) and wood volume in the clones at two locations at three years. The productive site had 29% higher overall GBH than the arid site and low yield correlation between clones at both sites. The indices MP, HM, GMP, and STI showed positive correlation with GBH at each site enabling selection of clones suited to each site and accurate prediction of yield at good and poor sites based on response of clones to stress, compared to TOL, SI and YSI indices.

Keywords: Eucalyptus Camaldulensis, Productivity, Stress Tolerance

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Genomic selection modelling of growth and wood properties in Eucalyptus dunnii

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Eucalyptus dunnii is an important eucalypt species in the temperate areas of the summer rainfall regions of Southern Africa and is the most widely planted hardwood species due to its higher wood density and good pulp yield. The development of genomic resources, like the sequencing of the *Eucalyptus* genome and the development of genome-wide genotyping tools, has made genomic selection (GS) approaches more accessible in Eucalyptus species, with the aim of improving tree selection efficiencies, by shortening breeding cycles. GS models were developed for key traits, in E. dunnii, critical to the pulp and paper industry based on genome-wide genotypes using a 60,000 SNP Infinium chip (EucHIP60K.br, GeneSeek). After marker filtering, 9 102 SNP markers were analysed in 840 progeny from 89 half-sib families. Three different GS modelling analyses were applied (GBLUP, Bayes C and Bayes Cπ) with a 10-fold cross validation. GS models were developed for dissolving pulp yield (0.50), tree height (0.33), tree volume (0.42), diameter at breast height (0.38) and basic wood density (0.51). Validation of the GS models will be performed on the progeny of the training population. Despite the low linkage disequilibrium in the open-pollinated training population, the results obtained are promising for the application of genomic selection.

Keywords: Genomic selection, Eucalyptus dunnii, SNP markers

*Speaker

"R&D - Operation Gap in plantation forestry: perception or real?

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"R&D –Operation Gap" in plantation forestry: perception or real?
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Imagine you are at a table with corporate managers who hold the cheque for R&D dollars. You will be told, very likely, about the widening "R&D- Operation gap" - a mismatch, between volumes they have been shown in plots of new clones or other innovations and the amounts of wood delivered in the yard. You may also hear that "we are cutting costs", unless it is a rare day of enlightenment when R&D is viewed as an investment and not a cost. Government budget for forestry research has been retreating to a trickle. Therefore, this "gap" is a threat to R&D partnerships and science. How to address this? I will present examples of the very few studies on long term trends in production as a basis for exploring the yield gaps. Long term pre-harvest inventory data are largely treated as a stock take, shelved away in pointless confidentiality. In this data bank, there is valuable embedded knowledge of production over space and time, founded on operational realities, which is seldom explored by scientists. Partly because of this, impact of outcomes from R&D on incremental operational productivity gains, if and when they arise, are not demonstrated convincingly. Results from plot studies showing "significant" increases in early growth to individual variables (e.g. new clones, intensive silviculture) seldom hold up when scaled up against the vagaries of operations and climate. For bridging this gap, R&D groups should pursue more *adaptive research* at relevant scales in partnership with managers as a challenge. Lessons from them can lead to insights for prioritising research and for closing the gap. For advancing sustainable forestry scientists should use the best science available to challenge the ill-informed criticisms levelled against plantations, *Eucalyptus* in particular.

Keywords: R&D, operation gap, adaptive research, public, priavte partmership

*Speaker

Full-rotation carbon, water and energy fluxes in a tropical eucalypt plantation

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Eucalyptus plantations in Brazil are among the most productive forests of the world, reaching mean annual increments of about 50 m3 ha-1 yr-1 over short (6-7 yrs) rotations. In order to better understand the factors contributing to such high productivities we continuously monitored water vapor, CO2 and energy flux through the eddy-covariance method over a 9 year-period encompassing two successive eucalypt rotations in southeastern Brazil (Sao Paulo State), including the last 2 yrs of the first stand rotation, its harvest, replanting, and a full (7yrs) second rotation. Tree growth, Leaf Area Index (LAI), water table depth, and soil water content (SWC) down to 10 m depth were also monitored. Rooting depth and vertical fine root distribution were assessed at various ages.Mean annual evapotranspiration (AET; 1383 mm yr-1) represented 90% of the annual precipitations (P; 1539 mm yr-1). AET reached maximum values (1598 mm yr-1) about 2-3 years after planting (a.p) when LAI peaked and when deep rooting (about 15 m deep 2.5 yrs a.p) provided access to the large amount of water stored in deep soil layers during the first months after clear-cutting and replanting. Most (88%) of the available energy (3852 MJ yr-1) was partitioned to the evaporation process (latent heat fluxes), with very low sensible heat fluxes over the rotation, except after harvesting and replanting when LAI was low, and later in the rotation during dry events. Deep drainage after harvest of the first stand allowed the water table (WT) to rise from -18 to -12 m over the first 2 years after replanting. Then, WT progressively declined due to groundwater lateral flow and root uptake in the capillary fringe above the WT during seasonal droughts. Both measurements of SWC and model simulations showed that deep water storage and subsequent uptake played a major role in supporting the very high wood production and dampening seasonal droughts.

Keywords: Fast, growing plantations, eddy, covariance, latent and sensible heat fluxes, LAI, wood

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production, carbon sequestration

Changes in maximum distance of nutrient uptake (horizontal and vertical) throughout the rotation in Brazilian Eucalyptus plantations

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Climate changes will increase the probability of exceptional droughts, which may dramatically increase tree mortality. It is therefore urgent to gain insight into tree behaviour in response to drought. Our study aimed to assess the maximum distance from the trunk where *Eucalyptus* fine roots take up mobile nutrients in deep Ferralsols during the dry season. 15N-NO3- was injected at several soil depths in commercial eucalypt plantations of the same genotype (one *E. urograndis* clone) at the end of the rainy season. The 15N marker was applied in the middle of the inter row (3 replications): at 5 depths (from 0.1 to 6 m) at age 7 months, at 4 depths (from 0.1 to 9 m) at age 1 year, at 5 depths (from 0.1 to 12 m) at age 2 years, and at 6 depths (from 0.1 to 15 m) at age 6 years. 15N atom% was determined in leaves sampled in dominant and supressed trees at different distances from each injection point after the dry season. While dominant trees take up 15N-NO3- down to a depth of 6 m between 7 and 12 months after planting, the maximum depth of uptake for supressed trees was between 3 and 4.5 m. From 1.5 to 6 years after planting, 15N was mainly detected in leaves for 15N -NO3- injected in the upper 3 m and only for a few trees at a depth of 6 m. Very low 15N -NO3- uptake rates were detected between 2 and 4-5 m from the trunk. Most of the uptake of 15N occurred within 2 m of horizontal distance from the trunk, whatever tree age and tree social status. Eucalypt fine roots can take up nitrates at depths between 6 and 8 m the first year after planting. However, the velocity of exploration of deep soil layers depend on the social status of the trees. Fertilizers must be applied within 2 m of the trunks in eucalypt plantations to be taken up by all trees. When fertilization is concentrated in the first months after planting, nitrate leaching in deep soil layers might increase the heterogeneity of the stands since deep nitrates could only be available for dominant trees.

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Keywords: climate changes, fine roots, 15N, eucalypt plantations, Brazil

Water deficiency and potassium supply trigger interconnected signals to modulate wood formation in Eucalyptus

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Fast growing *Eucalyptus* tree is well adapted to various soils and climate environment, but its growth varies strongly according to these factors. Thanks to potassium fertilization, productivity in the south of Brazil is one of the highest in the world. The development of more sustainable cultural practices requires an improved understanding of mineral nutrition, especially in interaction with water stress, which is more and more threatening plant culture. We aimed to characterize the effect of water availability and nutrition supply on wood formation and quality. An experimental design was set up on field with a highly productive *Eucalyptus grandis* clone planted in a split-plot design, with 2 factors tested in interaction: water availability set up with rainfall exclusion system, and K+ fertilization. We analyzed wood properties and performed large scale analysis of transcriptome (RNAseq) and metabolome in developing xylem. These data were integrated using multivariate statistical analyses and co-regulation networks. We identified promising transcription factors potentially involved in the regulation of wood formation. The functional characterization of one candiate in *E. grandis* transgenic roots demonstrated its implication in secondary cell wall biosynthesis, confirming the potential of our system biology approach to indentify new key regulators of wood formation in woody plants.

Keywords: System biology, Correlation networks, Omics integration, Drought, Nutrition, Xylem, Transcription factors, Eucalyptus.

*Speaker

Clonal Composites: life insurance for Fibria's Eucalypt plantations

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Fibria is the world largest eucalypt pulp producer, with three operating mills supplied by more than 600,000 hectares of clonal plantations established in different regions of Brazil. During the last two decades, climate changes have challenged those plantations with new biotic and abiotic stresses, causing productivity and investment losses. Huge efforts have been made to develop clones tolerant to pests, diseases and adverse environmental conditions (e.g. drought), as well as to reduce the genetic vulnerability of plantations. As part of this endeavor, in 2014 Fibria developed a strategy for deploying Clonal Composites, clusters of different improved clones that are phenotypically similar, though genetically unrelated, and have the ability to perform, as a mix, as well as or better than individually within a block. In 2015, the company established the first commercial pilot areas with clonal composites and now there are more than 20,000 hectares, distributed along different environmental conditions. Inventories are pointing out that clonal composites plantation blocks present survival rates, uniformity and productivity similar or superior to monoclonal blocks, with lower incidence of pests and diseases. Moreover, the overall genetic variability of commercial plantations increased at least five times since the company started using this deployment strategy, bringing extra security against future adverse events.

Keywords: Eucalyptus Clones, Clonal Forestry, Genetic Vulnerability

*Speaker

Ca and Mg nutrition and its application in Eucalyptus and Pinus plantations: A review

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In Europe and South Africa, the application of lime in forest plantations began in the 1970s to counter soil acidification, but in all cases, high application rates resulted in a reduction in stand growth. A new series of studies was then implemented, with lower lime rates, and also included highly weathered soils of the southern hemisphere, which resulted in stand growth improvements. Our objective with this review was to understand the possible benefits of Ca and Mg applications in planted forests through the use of lime, gypsum, or other base cation rich materials, with a specific focus on the effects in highly productive, short rotation *Eucalyptus* and *Pinus* plantations. We started by identifying the Ca and Mg demand of these forest plantations and the efficiency of absorption, use, and cycling of these nutrients. We subsequently collated research according to the main hypothesis and evidence to explain the mechanisms developed by these species to tolerate acidic soil conditions. We also reviewed research on the response to Ca and Mg application. Despite the high tolerance to acidic soils, specifically to Al toxicity, both genera demand large quantities of Ca and Mg to reach high levels of productivity. The mechanism of tolerance to acidic soils appears to incur a cost of carbohydrate allocation, which may explain the reported modest reductions of stand volume growth. We found a strong relationship between the exchangeable Ca and Mg in the soil and the response to Ca and Mg application, indicating that higher responses are achieved when the Ca and Mg availability is lower than 4 and 2 mmolc dm-3, respectively. We conclude that the main benefit of lime application in these forests is improving the Ca and Mg availability. Liming to improve the soil pH is beneficial only in soils with very high or toxic levels of solubilized Mn, since species of both genera seem to have only a limited ability to avoid the uptake of Mn when present in high concentrations in the soil solution.

Keywords: Liming, Gypsum, Al toxicity tolerance, Fertilization with Ca and Mg, Ca and Mg accumulation.

*Speaker

Eucahydro: Predicting water use sustainability of Eucalyptus genotypes – an opportunity for managing GxExS interactions on intensively managed plantations

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Predicting water sustainability (water use, water use efficiency and efficient use of water) and productivity of Eucalyptus plantations under a climate change scenario is a key challenge for the development of an advanced silvicultural program. Selection of Eucalyptus genotypes that may allow to capture genetic x environment x silvicultural interactions (GxExS) on use of water resources may help managers to maximize forest production but also fulfill environmental and society needs. Our study investigated the potential of physiological variables evaluated at different stages of development to predict water sustainability and productivity of 16 selected contrasting Eucalyptus globulus, E. nitens x globulus, E. globulus x camaldulensis clones and E. nitens seedlings established under contrasting water availability conditions (summer irrigated vs control) at two atmospheric demand contrasting sites. Physiological measurements including photosynthesis, stomatal conductance, water use efficiency, predawn/midday water potential and seasonal individual plant were made in the field during the first year of stand development. Annual growth and biomass estimates together with continuous sapflow sensors (Granier) were evaluated from 2 to 3 years of stand development in the field. Detailed physiological assessments at nursery stage of the same genotypes were carried in a drought nursery experiment under semi-controlled environment conditions evaluated at 0, -1,5 and -3,0 MPa soil water potentials. Strong relationships were found between early plant development physiological assessments and stand

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productivity. Our results suggest that key physiological assessments may provide a potential tool (Eucahydro Model) for evaluating water use and water use efficiency of Eucalyptus genotypes. This tool may support the strategic allocation of genetic materials to contrasting drought risk sites but also by selecting genotypes with less impact on areas where water resources use conflicts exist.

Keywords: water use efficiency, efficient water use, growth, drought resistance, ecophysiology

Patterns of additive and non-additive genotype by environment interaction for growth of Eucalyptus globulus in southern and central Chile

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The success of any tree improvement program requires reliable and accurate predictions of the average performance of each genotype across a range of multiple environmental conditions. In this context, the knowledge of the magnitude and structure of genotype by environment (GxE) interaction is one of the major challenges facing tree breeders. In this study, factor analytic mixed model approach have been used for the analysis of multi-environment trials (MET) data for total stem volume measured at ages 3 to 7 years old. The MET dataset comprised 20 genetically well-connected progeny trials for *Eucalyptus globulus* Labill. spp. *globulus* grown in a range of environments across South-Central Chile. Prior to conducting combined-site analyses across multiple test sites, spatial analysis based on a two-dimensional separable auto-regressive process (AR1xAR1) was used in order to account for spatial variation within trials that occurs routinely. After the raw data were spatially adjusted, mixed model analysis with an extended factor analytic (XFA) variance structure of the additive (GCA) and non-additive (SCA) GxE effects and separate variance for the errors for each trial was performed. Results indicate that preliminary spatial analysis provided a substantially better fit to the data, single-site heritabilities improved around 11% and varied between 0.13 and 0.52 across the twenty sites. This study shows that extended factor analyses using two factors (XFA2) captured 93% and 86% of GxE interaction variance for additive and non-additive effects, respectively. In addition, factor analytic (FA) models provided a reliable and parsimonious estimation of genetic correlations between all pairs of groups soils /trials. These results suggest three groups of soils identified by cluster analysis and biplot of best linear unbiased predictions (BLUP) that can be used as deployment groups in order to maximize genetic gain within each deployment zone. Moreover, the genotype scores from the FA model can help to test commercial genotypes for the selected deployment zones. In this sense, the patterns found from this investigation can be used to examine alternative deployment strategies and suggest that a new regionalization as a response to GxE interaction could have significant implications both for breeding and deployment programs.

*Speaker

Keywords: Linear mixed model, Factor analysis, Spatial analysis, Cluster analysis, Genotype by environment interaction, MET, Eucalyptus globulus

Simplicity and complexity in selection in tree breeding

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SD Verryn and AA Myburg
Theoretically a breeder stands to make most overall genetic gains by including all traits of interest in the breeding program from the outset. This has, on occasion, led to rather exhaustive and comprehensive selection indices (BLUP). As one includes more selection traits, one is also forced to dilute the selection pressure on traits which may be of prime and pressing importance? How do we strike the balance? How should breeders address this dilemma?

Another source of complexity in tree breeding is the fact that we tend to measure the 'same' trait multiple times, whether directly or indirectly or through measuring highly correlated traits or genotypes. This can result in erroneous or complex BLUP models and can also result in collinearity (instability) in the BLUP analysis. We propose guidelines as to when one should be concerned about instability and what can we do about it.

A further layer of information and potential complexity arises with the potential of using genomic information in the selection process. The current challenge lies in integration and management of large amounts of data and reducing these data to simple and robust models and selection processes. To a large extent, tree breeding is data management, and we share how we are developing tools to aid the breeder in the process.

Keywords: Selection, BLUP, Database, instability, multitrait

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Eucalyptus Bio-energy Plantations: Importance of Harvest Planning

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The introduction of *Eucalyptus* in Florida USA began in the 1870's. During the 1960's, there was further effort with eucalypt plantations in Florida. Lack of adequate eucalypt plantation silviculture as well as limited availability of improved seed or clones made these early efforts largely unsuccessful. There has been renewed interest in bio-energy eucalypt plantations in Florida for wood pellets, biofuel, combined heat and power as well as co-generation. The eucalypt species showing promise have been *E. benthamii*, *E. macarthurii*, *E. grandis*, *E. amplifolia* and the hybrid *E. urograndis* (*E. grandis* x *E. urophylla*). Eucalypt plantation wood yields in Florida are lower in the northern part of the state (MAI 9-18 green tonnes/ha/year with a rotation of 6-8 years) compared to the southern part of the state (MAI 18-36 green tonnes/ha/year with a rotation of 5-7 years). A recent commercial eucalypt harvest in Martin County, Florida, USA, yielded a green weight with bark MAI of more than 60 tonnes/ha/year at age 6.5 years. Bioenergy eucalypt plantations with rotation lengths of 2-3 years and high stocking rates can have yields approaching 50 tonnes/ha/year. Harvesting systems in Florida for bioenergy eucalypt plantations typically will be a three machine combination consistent with regional pine logging operations to include a rubber tire feller-buncher with a saw head, rubber tire skidder, and a knuckle-boom loader with a delimbing attachment. Eucalypts are hauled to wood manufacturing facilities in the longest lengths possible for efficiency and moisture retention in the wood. Utilizing standard pine harvesting equipment has less to do with what is optimal and more to do with operating costs as well as parts availability. Reconfigured forage harvesting systems would include a biomass harvester with a chipper and a chip trailer tailored to suit the harvesting sites with pre-designed eucalypt plantations. In programs managed by the authors, forest harvesting plans and systems are considered and agreed upon before site preparation, planting and silvicultural management. This gives the forest manager and the bioenergy facility considerable cost control on delivered wood feedstock cost which then impacts conversion to renewable bioenergy and cost of that bioenergy to consumers.

Keywords: Eucalyptus, bioenergy, silviculture, harvesting, short rotation forestry

*Speaker

Abiotic changes - Lightening talks

egoSELF: An Integrative Biology approach to study the molecular basis of inbreeding depression in Eucalyptus globulus

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In Portugal, the main commercial *Eucalyptus* species (*E. globulus*) and their hybrids have a major impact on National economy, supplying wood for an important solid and pulp and paper industry sector, and they are also becoming important sources of bio-energy. Besides these plantations have a large impact on local environment and economies, being source of work revenues and providing protection to marginal soils from erosion. INBREEDING DEPRESSION (ID) is characterized by the reduction of fitness of the offsprings relatively to the parents as result of an increased homozygosity of individuals (due self-fertilization or biparental inbreeding). In Eucalypts, inbreeding leads to severe ID of survival, and reductions on growth, basal diameter and diameter height breast, as well as volume of the trunk, and several fecundity traits. In these species, the increased homozygosity of loci harbouring deleterious genes are recognized as the main genetic mechanism contributing for ID. Despite the recognition of the importance of ID in breeding programs, the molecular mechanism are still far from being elucidated. The understanding of ID molecular basis in Eucalyptus is thus an opportunity and a challenge to identify of key genes and regulatory mechanism associated to the plant productivity, towards a better management of breeding programs and sustainability of forest plantations. EgoSELF (FCT funded project PTDC/AGR-FOR/0931/2014) aims at identify and validate key genes and /or alleles, and molecular regulation mechanisms underlying the modulation inbreeding depression in *E. globulus*. A total of 20 SELF and Open pollinated progenies were generated. These families were evaluated for the success in seed production, germination rates, and physiological parameters. The results obtained suggest a large effect of the genetic maternal background on the parameters used to compare SELF and OPEN pollinated progenies. Genotype by sequencing started been applied to these families in order to explorer the molecular and genetic mechanisms involved in inbreed depression. We expected that the results of this study provide new insights on Inbreeding depression understanding, and thus a better management of the genetic resources in Eucalyptus.

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Keywords: Eucalyptus globulus, GBS, physiology, germination, inbreeding depression

Using controlled release (coated) fertilizers significantly improves the nutrient use efficiency in establishment of Eucalyptus

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Fertilization at planting gives the possibility to substantially boost the growth and productivity of Eucalyptus forestry. Investment in fertilization can increase volume growth and wood density simultaneously (du Toit et al. 2001, du Toit and Drew, 2003) which are both beneficial for pulp producers. However, fertilization practices with conventional fertilizers are under review because of negative environmental impact (Nitrogen losses by leaching and volatilization) as well as increasing costs due to manual applications and transport into the plantations. Especially in more remote areas (hilly sites) application of fertilizers can be complicated and effectivity is reduced.

Controlled Release (coated) Fertilizers (CRF) have been tested intensively the last years in various regions in the world as a new way of fertilization at planting. The advantage of CRF is that the NPK fertilizer is protected by the coating from leaching, volatilization and possible fixation in tropical low pH soils. Since the amount of nutrients released daily is small and goes in line with plant uptake requirements, this type of high-tech fertilizers are an ideal tool to reduce nutrient losses and optimize the NUE (Diara et al., 2014; Terlingen et al., 2016).

Due to the fact that the coating protects the fertilizer from immediate availability, it is possible to apply CRF's locally, in the planting hole or directly next to the young seedling. Because of the higher NUE and localized applications, rates of fertilizer could be reduced up to 2/3rd of the conventional fertilizer applications with similar but mostly improved growth during research programs of 3 years. Additional benefits found were higher survival rate, lower fertilizer application, lower transport costs and improved options to apply the CRF mechanically at the same time of planting.

Keywords: Controlled Release Fertilizers (CRF), Nutrient Use Efficiency (NUE), Eucalyptus establishment, Fertilization

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Low cost breeding and Genomic projects : New generation of FCBA frost tolerant eucalyptus clones for sustainable biomass production

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FCBA (formerly AFOCEL) will release this year a novel generation of varieties based on the hybridization of E gunnii and E dalrympleana, leading to hybrid varieties nicknamed GUNDAL. We will present operational-scale data about growth and productivity of the earliest gundal selections and describe the further breeding activity. While our target is biomass, the physical wood properties are good to very good. Due to very low flowering and small capsule size, our baseline is simple massal selection within HS families from elite mothers. With a high selection pressure put on both deep-frost tolerance and ability for vegetative propagation, cuttings are submitted to multisite clonal field trials for growth and form performance at a range of highly demanding testing sites regarding cold, drought and soil. Basic molecular breeding tools have been implemented for 15 years and regularly updated. Beside this very simple approach, we took full advantage of the interplay between basic genomic studies and our breeding activities to setup an improved selection process. We setup with huge effort a full-sib family from a pseudo-backcross between one of the best gundal (very good on many traits but with average frost tolerance) and an extreme cold-tolerant gunnii (of poor form and limited vigor but acceptable propagability). While a reduced set of candidate selections were engaged in extensive field testing aiming to provide data for official registration by 2018/19, the whole FS family was cloned and established on two contrasted field trials sites. While early phenotyping took place, this germplasm was used for comparative genetic mapping then transcriptomic and epigenetic studies. We are currently running projects aiming on comparison of alternative solutions for genotyping and genomic selection. Meanwhile, In vitro rootstocks of the new selection will be soon provided to commercial nurseries for cutting production and technology transfer to industrial TC labs is in progress.

Keywords: sustainable biomass, productivity, cold tolerance, deep frost, applied molecular breeding, genomic selection

*Speaker

Eucalyptus's response to thinning intensity in a silvopastoral system at a drought-prone environment.

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The adoption of silvopastural systems in Brazil has grown over the past years, despite few information about its response to silvicultural treatments. Growth, yield and pasture biomass responses to different thinning intensity were examined in a silvopastural system (SSP) experiment with *Eucalyptus grandis x urophylla* (clone AEC 1528) planted (9x3 m spacing) in 2011 in consortium with *Brachiaria brizantha* at Correntina-Brazil. In 2015, systematic thinning were applied alternating the following intensity (%) between rows described by the treatments: T1 (0%-0%), T2 (50%-33%), T3 (100%-0%), T4 (50%-50%), T5 (50%-66%), T6 (100%-33%), treatments residual density [trees.ha-1]: 370, 235, 185, 185, 174, 142, respectively. Basal area (BA) increment since thinning to 2017 was higher in T4 (2.87), T1 (2.57), T2 (2.55) and T5 (2.50) than T3 (2.16) and T6 (1.80) (m^2.ha-1; P> 0.05). Basal area relative periodic annual increment (PAI) [(PAI BA/initial BA) x100] presented an increase as thinning intensity increased T1 (20%), T2 (34%), T3 (39%), T4 (40%), T5 (40%), T6 (43%) (P> 0.05). The lowest biomass pasture production was observed in T1 (0.52), while T6 (1.74) presented the highest (tDM.ha-1; P> 0.05). The combined analysis indicated T2 and T4 as the most advantageous treatment by resulting in a satisfactory production of wood and pasture.

Keywords: Forestry Management, Eucalypt, Silviculture, Agroforestry System.

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First step to obtain new hybrids combination: Selection of stable and productive mother trees

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There are a large number of eucalypt species available in natural and in planted areas, however only a few are used in commercial plantations around the world, and there is a lack of information concerning the species adaptability, mainly to hybrid materials. Brazil has reached high productions from either pure or hybrid genotypes of eucalypt, however productivity breaks could occur due to increasing occurrence of biotic and abiotic stresses. An option to deal with the stresses is the introgression across species of tolerance characteristics, which can be obtained with new hybrid combinations. The objective of the work is to obtain hybrids of several eucalypt species, using *E. grandis* and *E. urophylla* as mother trees. In order to obtain these hybrids mother trees were selected from advanced breeding generation of the two main species in Brazil. For both species, individuals of stable and productive families were selected across contrasting climatic conditions. They were cloned, by grafting, obtaining an orchard to carry out the controlled pollination. Then, the mother trees will be pollinated by several species from different sections of *Symphyomyrtus* subgenus. This should generate different stress tolerances, since each section has specific characteristics.

Keywords: Genetic by environment interaction, biotic and abiotic stress, productivity and stability, species diversity

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Selection of cold-tolerant Eucalyptus species for frost-susceptible, humid regions southern China

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Hunan province in China has a subtropical monsoonal climate with hot and humid summers, relatively cold winters, an average of 60 to 100 frost days a year, and absolute minimum temperatures of -6 to -10oC. Precipitation peaks during spring and early summer, with mean annual rainfalls of around 1400 mm. Late summer through early autumn features high to very high temperatures and little precipitation, despite persistently high humidity.
Eucalypts were first introduced to Hunan in the 1920s, and a range of planting initiatives over the next 50 years generally ended in failure due to use of inappropriate species and provenances. Surveys in the mid 1980s revealed some of these plantings had not only survived but grown well, inspiring establishment of new species-provenance trials. Today there are 60,000 ha of eucalypts plantation in Hunan, most of which are *E. dunnii*.

From 2001 to 2004 64 provenances representing 22 species were included in new trials established in southern and central Hunan. Species having the best growth and survival at age 6 years were *E. amplifolia, E. benthamii, E. dunnii* and *E. dorrigoensis*, whilst some single site results suggested *E. saligna x botryoides* and *E. deanei* warranted further testing. *E. macarthurii* had the best cold tolerance across these trials but had relatively poor growth and survival. *E. tereticornis* and *E. camaldulensis* demonstrated reasonable cold tolerance, thought showed substantial variation among provenances.
From a long history of research, it has been concluded that selected provenances of *E. dunnii, E. benthamii, E. dorrigoensis* and *E. macarthurii* have proved adapted to Hunan's extremes of hot and humid summers, frequent winter frosts and occasional severe cold events and have good potential for plantation establishment in some Hunan environments. This article discusses selection of cold-tolerant *Eucalyptus* for Hunan and the opportunities and challenges for the eucalypt plantations in such environments.

Keywords: cold tolerance, frost, ice damage, species, provenance selection

*Speaker

Abiotic changes - Poster session

Use of EUChip60K for the genetic diversity characterization of an Eucalyptus dunnii breeding population in Argentina

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In Argentina, the *Eucalyptus* breeding program is mainly carried out by INTA (National Institute of Agricultural Technology) with the aim to provide an improved material for forestry sector.
In a climate change context, *Eucalyptus dunnii* has been included in INTA's breeding program due to its tolerance to low temperatures. In order to apply molecular breeding strategies into the genetic program, different genotyping platforms are being used.

The multispecies EUChip60K represents an outstanding tool to address population genomics questions in *Eucalyptus* and to empower Genomic Selection (GS), Genome Wide Association Studies (GWAS) and the broader study of complex trait variation in this species.

In this work, an *E. dunnii* progeny trial population (308 individuals, coming from 6 different geographic Australian origins and a local selection), which has already been phenotyped for 7 different traits related to wood quality (NIR analysis) and 3 traditional growing traits, was genotyped with the EUChip60K (NEOGEN, USA) for future GWAS and GS analysis.

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The 64638 markers of the chip were filtered by minor allele frequency (MAF) lower than 0.05 and a percentage of missing data up to 20%, keeping a total of 14123 SNPs, with only 3.39% of missing data, according to Silva-Junior *et al* (2015) who reported 17014 SNPs with MAF > 0.01 for this species. Based on the reported SNP genomic position, a uniform distribution of these markers across the *E. grandis* genome was also observed. The expected and observed heterozygosity were 0.322 and 0.326 respectively across the total 308 samples, which were separated by DAPC analysis into two genetic groups, one of them with 87% of the individuals.
To our knowledge, this is the first report of applying EUChip60K to a breeding population of *E. dunnii* for molecular breeding purposes, validating its usefulness in this species.

Keywords: Eucalyptus dunnii, EUChip60K, SNPs, Molecular breeding, Climate change

Simplified elite eucalyptus hybrid clone breeding for high propagability and cold tolerance

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FCBA (formerly AFOCEL) will release this or next year a novel generation of varieties based on the hybridization of E gunnii and E dalrympleana, leading to hybrid varieties nicknamed GUNDAL. We setup with huge effort a full-sib family from a pseudo-backcross between one of the best gundal (very good on many traits but with average frost tolerance) and an extreme cold-tolerant gunnii (of poor form and limited vigor but acceptable propagability). Obtained seeds were sown in sandbed after stratification. As soon as seedlings where tall enough to be used as micro rootstock, they were used for cutting propagation. A first selection was operated to discard the clones with less than 50% rooting. The resulting clonal material was engaged a few month later into a frost-tolerance testing using a large cold chamber. LT50 were computed based on at least 3 repetitions of 3 copies at three different minimal temperature (-9 to -15∘C, without prior cold hardening) per clone beside control material under a randomized design. At this stage occurring one year after seed sowing, a further selection was done to remove too much frost sensibility. While the whole FS family was cloned and established on two contrasted field trials sites, further cutting propagation was pursued to refine the assessment of both frost tolerance and ability for vegetative propagation, leading to a short list of clones engaged in an extensive multisite clonal testing designed for establishing growth and form performance per se and their stability.

Keywords: eucalyptus, frost, sustainable biomass, productivity, cold tolerance, vegetative propagation

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Photosynthesis and carbon allocation are both important predictors of genotype productivity responses to elevated CO2 in Eucalyptus camaldulensis

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Intraspecific variation in biomass production responses to elevated atmospheric CO2 (eCO2) could influence tree species ecological and evolutionary responses to climate change. However, the physiological mechanisms underlying genotypic variation in responsiveness to eCO2 remain poorly understood. In this study, we grew 17 *Eucalyptus camaldulensis* subsp. *camaldulensis* genotypes (representing provenances from four different climates) under ambient atmospheric CO2 and eCO2. We tested whether genotype leaf-scale photosynthetic and whole-tree C allocation responses to eCO2 were predictive of genotype biomass production responses to eCO2. Averaged across genotypes, growth at eCO2 increased *in-situ* *A*net (29%) and leaf starch concentrations (37%). Growth at eCO2 reduced the maximum carboxylation capacity of Rubisco (Vcmax, -4%) and leaf nitrogen per unit area (Narea, -6%), but Narea calculated on a total non-structural carbohydrate free basis was similar between treatments. Growth at eCO2 also increased biomass production and altered C allocation by reducing leaf area ratio (LAR, -11%) and stem mass fraction (SMF, -9%), and increasing leaf mass area (LMA, 5%) and leaf mass fraction (LMF, 18%). There were few significant CO2 genotype (within provenance) interactions, yet a significant interaction was observed for Vcmax, indicating that photosynthetic down-regulation at eCO2 varied among genotypes. Genotypes that showed the largest increases in total dry mass at eCO2 had larger increases in root mass fraction (RMF) (with larger decreases in SMF) and smaller decreases in photosynthetic nitrogen use efficiency (PNUE) with CO2 enrichment. These results indicate that genetic differences in photosynthetic nitrogen-use efficiency and carbon sink utilization (in roots) are both important predictors of tree productivity responsiveness to eCO2.

Keywords: carbon sequestration, clone, down, regulation, elevated CO2, GxE

*Speaker

Consequences of potassium deficiency and throughfall exclusion on fine root distributions down to 17 m depth in Brazilian Eucalyptus grandis plantations

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In many tropical regions, climates changes are expected to cause longer drought periods. Potassium fertilization (K) can have a positive effect on plant water use efficiency. Important morphological and physiological traits are modified by K availability and water supply regimes. Our study aimed to assess the combined effect of K fertilization and soil water availability on deep roots exploration of *Eucalyptus grandis* trees. A throughfall exclusion experiment was used to compare stands with 37% of throughfall excluded (-W) and stands without rain exclusion (+W), with and without K fertilization (+K and –K, respectively). Eucalypt fine roots (diameter $<$ 2mm) were collected along the soil profile down to the water table (17 m depth) in 12 plots (4 treatments x 3 blocks), at 2 and 3 years after planting. Total fine root biomass was twice as high in +K+W than in -K+W (507.5 and 253.2 g m-2 respectively) and 62% higher in +K-W than in -K-W (501.4 and 308.7 g m-2 respectively), 2 years after planting. The same patterns were observed at 3 years of age. The total fine root biomass almost doubled for all treatments between the second and third year of growth. At 2 years of age, the root front for all treatment was found from 7 meters depth for –K+W to 10.6 meters depth for +K-W. At 3 years, *Eucalyptus* trees in +K-W reached the water table at 17 m depth while no fine roots were found down 15 m depth in the other treatments. Potassium fertilization increased total fine root biomass and allowed *Eucalyptus* trees to reach the water table earlier when 37% of throughfall was excluded from the stand. Our study suggests that K fertilization increases the exploration of deep soil layers by fine roots, which is likely to improve tree tolerance to drought over the early growth of *Eucalyptus grandis* plantations, providing a fast access to water stored in deep soil layers.

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Keywords: Eucalyptus grandis, throughfall exclusion, potassium, fine roots, deep soil

Eucalyptus response to nutritional stress based on gene expression analyses: preliminary steps for defining ideotype

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Tackling the question of defining a new eucalyptus ideotype, more efficient to use nutrients, can be done through different strategies. Analysing the genotype by nutritional stress interaction in an adequate experiment is among the most consistent strategies. The recent advances of high-throughput molecular technology has opened up new perspectives, giving an easy access to transcriptome resulting from gene expression Transcriptome data have become relevant to gaining insights into plant biology and provide complementary information to the classical methods based on ecophysiological and growth variables. To address these questions and facilitate the understanding of tree functioning, we implemented a field experiment (Botucatu, SP, Brazil) with three *Eucalyptus grandis* clones facing contrasting nutrient deficiencies (non-limiting fertilisation (NLF) considered as the baseline; NLF - N: N deficiency; NLF - P: P deficiency; NLF - K: K deficiency). Gene expression obtained by RNA-seq technology was the variable analysed to improve our understanding of tree response to the stressing nutritional environments tested. After filtering process, 21698 expressed genes were obtained for leaf and 21443 for xylem. For both tissues, the number of genes differentially expressed between the three clones was very high: around 3500 to 4000 genes down and up regulated. The genes differentially expressed for leaf were only observed for N deficiency treatment. The number of genes up regulated was 116 and 99 genes were down regulated at FDR p value$<$ 0.05. The same pattern was observed for xylem but the number of genes differentially expressed for N deficiency was much higher, 1403 for up and 569 for down, at FDR p value$<$ 0.05. This result based on gene expression was consistent with the first phenotypic observations in our field experiment showing that tree growth from 6 to 18 months after planting was much more affected by N deficiency than by P or K deficiency. The next steps will consist in identifying major genes involved in N deficiency response by using network approach and analysing the co-variation between gene expression and eco-physiological and growth variables.

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Keywords: transcriptome, eucalyptus grandis, genotype by environment interaction, limiting fertilisation

Domestication of tropical mallee eucalypts: results from international trials in Australia and India

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Mallees are short, multi-stemmed eucalypts. They coppice repeatedly with low stump mortality and without loss of vigour. There are numerous species, the majority naturally occurring in arid and semi-arid conditions. Research in temperate Australia has shown that mallee plantations can be used for simultaneous production of bioenergy, activated charcoal and essential oils while ameliorating dryland salinity. A joint research project between Australia and India screened hitherto untested mallee species suitable for biomass and essential oil production in subtropical and tropical drylands.
Method: 18 species were tested across 8 sites, 6 in Queensland, Australia and two in Tamil Nadu, India. One or two provenances per species were tested using randomised complete block designs at each site. Tree height and crown width of all trees were measured, and above-ground biomass was determined for a subsample. Steam distillation followed by gas chromatography-mass spectrometry was used to determine the yield and composition of essential oils.

Results: Several productive species, both for biomass and essential oils, were identified. There was marked variation between the two countries in terms of the best-performing species. In Australia E. bakeri, E. exserta, E. infera, E. polybractea and E. viridis had good biomass productivity. E. infera, E. bakeri and E. polybractea also have good prospects for essential oil production. In India, E. chlorophylla, E. gillenii, E. herbertiana and E. normantonensis performed well. E. bakeri, E. infera and E. viridis performed very poorly in India, exemplars of significant country-by-species interaction.
Implications: Testing of tropical mallees involving more provenances of prospective species and as-yet untested species in Australian, Indian and other tropical drylands is likely to result in identification of new taxa that may be useful for biomass and essential oil production on land that is marginal for food production.

Keywords: mallee eucalypt, biomass energy, essential oils, tree breeding

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Induction of Eucalyptus sp. seedlings to tolerance to water deficit by using plant regulators

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Water deficit is an important abiotic factor in forest species. Water availability on soil may limit growth and development, and the seedling phase is the most sensitive. The use of plant regulators may be a relevant management tool. The objective of this work was to analyze the performance of *Eucalyptus* seedlings submitted to water deficit after application of plant regulators. The experiment was conducted in a greenhouse at Matology Advanced Research Center (NUPAM) in São Paulo State University "Julio de Mesquita Filho" (UNESP) in a 7x2 factorial scheme, with eight replications and in a completely randomized design. The first factor was composed by plant regulators at the dose 200 g ha-1: salicylic acid; methyl salicylate; and 1000 g ha-1 for: jasmonic acid; methyl jasmonate; dihydro jasmonic acid and methyl dihydro jasmonate, in addition to two controls, one irrigated and the other not. The second factor was composed by two contrasting clones regarding the tolerance to water stress. Irrigation was suspended seven days after the application of the treatments, except for the irrigated control, whose water replacement was equivalent to the amount of water lost through transpiration. The water deficit tolerance was verified analysing the electron transport rate, water consumption, leaf water content, CO2 net assimilation rate; stomatal conductance and internal CO2 concentration. The relationships were also calculated: water use efficiency and carboxylation efficiency. The use of salicylic acid induced the tolerance of eucalyptus seedlings to water deficit, reducing water consumption and maintaining high: leaf moisture content; electron transport rate; CO2 net assimilation rate; stomatal conductance; water use efficiency and the carboxylation efficiency; even surpassing the control that did not have the irrigation suspended.

Keywords: Hydrical stress, salicylic acid, water consumption

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Wood architecture remodelling in the trade-off between abiotic stress resistance and growth in Eucalyptus

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High genetic variability in the genus *Eucalyptus* has allowed a wide distribution of Eucalyptus species around the world. Beyond eco-geographic adaptation these species differ by productivity and wood quality and a trade-off between these traits is obvious.
In previous studies cold treatment has proved to affect xylem and wood properties in *Eucalyptus*. On the other hand CBF transcription factor group known as a master regulator of cold response was found to be dramatically expanded in this tree which is strongly exposed to winter frosts. In addition CBF characteristics (gene number and expression under cold) are suggested like adaptive features of Eucalyptus to cold. These findings prompted us to analyse the wood phenotype in E urophylla x E grandis transgenic lines overexpressing this TF.

The poster describes histological, biochemical and transcriptomic analysis of the xylem in the transgenic lines. The phenotype evidences anatomical and chemical modifications in xylem vessels and fibres together with a change in cambial dynamics associated with CBF overexpression. The data strongly suggest that this TF may participate in the trade-off between growth and cold resistance through a control of wood formation under stress. These results open new prospects in integrating growth, abiotic stress resistance and wood properties in *Eucalyptus* genetic breeding programs.

Keywords: Eucalyptus, cold resistance, productivity, wood properties, CBF transcription factor

*Speaker

Frost tolerance of Eucalyptus globulus Labill. clones and interspecific hybrids nursery plants submitted to different fertilisation doses during autumn

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Eucalyptus species are widely used in productive plantations, but freezing temperatures limit their geographic distribution and reduce crop productivity. Therefore, it is important to understand how nursery fertilisation could affect the frost tolerance and field performance of plants after transplanting. To this end, the effect of two mineral nutrients (N and K), applied during autumn-winter in the nursery, on frost tolerance of a commercial clone of *E. globulus* (G1) was assessed. In addition, this clone and other seven clones, including interspecific hybrid clones were compared for a standard fertilisation treatment. All clones belong to the breeding program of *ENCE, energía y celulosa Inc.* The experiment comprised eight fertilisation treatments in which four N and two K doses were combined. The main effects (N and K) resulted significant, as well as the interaction NxK. The freezing resistance of the G1 clone varied from -5.3 to -6.8 ^{o}C, and it was concluded that to set the dose of one nutrient, it must be taken into consideration the ratio N/K. On the other hand, significant differences were observed among clones (in a range from -3.7 ^{o}C to -7.2 ^{o}C), with G3, H3 and H4 being the most tolerant, and H1 the least tolerant.

Keywords: cold tolerance, mineral nutrients, hybrid Eucalyptus, Eucalyptus globulus.

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Early and late molecular and phenotypic responses during tension wood formation in Eucalyptus globulus

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The formation of tension (TW) and opposite (OW) wood under a gravitropic stimulus is a remarkable example of wood plasticity in Angiosperm trees. In these trees, wood properties are determined by the complex anatomical features and by the phytochemical composition of secondary cell walls.
Contrasting anatomical and chemical changes during the differentiation of TW and OW were profiled in Euclayptus globulus, and the significant impact of gravitropism stress in cell wall properties confirmed.
Whole-coding transcriptome dynamics revealed by the deep sequencing of 12 *E. globulus* mRNA libraries produced from TW and OW tissues formed under 1 week (early response) and 3 and 4 weeks(late response) different periods of gravitropic stimulus, allowed for the identification of 2493 loci differentially expressed. Tissue fate rather than bending stress period was evidenced as the most determinant factor of differentiation during the induction of TW and OW.
Distinct carbon partitioning priorities and dynamic carbon fluxes to the different cell wall components and to energy metabolism were revealed. Critical transcriptional modulation and hormonal regulatory mechanisms of E. globulus xylogenesis were also highlighted.

Keywords: tension wood, opposite wood, carbon allocation, candidate genes

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New Auxin Transcription Factors Regulating Lignified Wood Cell Formation

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Wood, also called secondary xylem, draws attention worldwide for its pivotal role in economy and environment. Wood is composed by particular cells with lignified secondary cell walls that is tightly regulated by developmental signals such as hormones and by environmental stimuli. Auxin is known to regulate wood formation, but the molecular mechanisms involved remain obscure. With the aim to identify key auxin regulators in wood formation, we focused on the Aux/IAA and ARF families, two major components of the auxin-signaling pathway. Taking advantage of *Eucalyptus grandis* genome sequencing, we performed a genome-wide survey of all the members of these two families. We then combined comparative phylogenetic analysis and large-scale gene expression studies in a large panel of organs, tissues and environmental conditions to identify the candidates the most likely involved in the regulation of wood formation. Reverse genetic approaches were used to investigate the function of these candidates. We first transformed Eucalyptus gene in Arabidopsis that develops wood cells in the basal part of inflorescence stems and in hypocotyls. We obtained interesting xylem phenotypes when overexpressing three genes (*A2, A4* and *A9*) in Arabidopsis. Overexpression of *EgrA4m, A9m and A2* (mutated version of *EgrA4* encoding stabilized protein) strongly inhibited lignification of interfascicular fiber cells, moreover the overexpression of *EgrA9Am* also promoted the development of vessels. These phenotypes strongly support that these genes are key auxin-dependent regulators during formation of xylem in *Eucalyptus*. To further characterize these genes and other candidates, we used tomato as a novel experimental system, because we have a world unique collection of tomato mutants affected in auxin signaling (over and down regulated *Aux/IAA* and *ARF* genes). We performed histochemical analyses to identify mutant lines showing alteration in xylem cells. The results of this screening will be discussed.

Keywords: Wood formtion, auxin, transcription regulation, Fiber

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Genetic diversity and genomic selection in Eucalyptus benthamii

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Cold and frost-tolerant Eucalypt species has been very interesting for the forestry sector in many countries. Currently, one of the main species which shows good development in subtropical areas is *Eucalyptus benthamii.* The aim of this study is to investigate genetic diversity and the ability of genomic-wide selection to predict breeding genomic values of a *E. benthamii* trial. The seeds were originated from a mix of 10 trees located at Wentworth Falls. The whole individuals (115) were genotyped with 13 microsatellite loci, and their diameter at breast height (DBH) and total height (HT) were measured. The data analysis was carried out by using the software: Structure, Popgene, GDA and R. Predictive ability, heritability and standard errors markers were estimated for 122 alleles originated from 13 microsatellite markers based on the RRblup method. The mean of alleles per locus was nine, and the polymorphism level for each locus varied from 3 to 17. The average expected heterozygosity (0.655) was very similar to observed heterozygosity, and these results corroborate this population is in Hardy-Weinberg equilibrium for the most locus. The inbreeding level estimated for this population ($F = 0.02$) was very low. The genetic diversity of trail can be considered elevated because the natural occurrence range was narrow and the trial sampling demonstrated values of diversity similar to the natural forests. By using Structure and the Evanno's method it is possible to infer that the individuals of the studied trial came from two original populations. So, considering the existence of two groups in the population, genetic values were performed considering separately the individual from each group. The genetic diversity levels calculated within populations are very similar, even when the genetic mean distance among them was elevated (0.81). The heritability estimated from genomic selection for phenotypic traits was very low, leading to a low predictive capacity. The trial suffered two selective thinning, which hampered the possibility to achieve higher genetic gains. However, some samples population should be used to improve variability in breeding populations. Moreover, the individuals showing more genomic breeding values should be used to established orchard seed and hybrids development.

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Keywords: genetic parameters, tree breeding, microsatellite markers, genome, wide selection, frost, tolerance

Fine-root distribution of three Eucalyptus species with different levels of drought tolerance

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In forest plantations, water and nutrients uptake are predominantly carried out by fine roots found in the first 30 cm soil layer. However, some studies have shown that small quantity of Eucalyptus fine roots may reach deeper layers of soil, supplying water for trees in drought periods. This study investigated the fine roots distribution ($<$ 2 mm of diameter) in seven sequential soil depths up two meters, for 13 months old *Eucalyptus* species with different levels of drought tolerance (*E. grandis*: low tolerance; *E. cloeziana*: intermediate tolerance; and *E. camaldulensis*: high tolerance). The experimental area is located at Itatinga-SP, in Brazilian southeast. Nine replications per plot were evaluated to the determination of specific root length (SRL) and specific root area (SRA) by digital images with software WinRhizo, while fine root biomass (FRD) was determined by weighing. The SRL and SRA were higher in the *E. camaldulensis* in almost all layers (19%-194%; 8%-91%), conferring higher capacity for soil profile exploration. *E. grandis* showed higher values of FRD in 0-30, 50-100 and 150-200 cm of depth (5%-163%; 41%-126%; 8%-80%) (LSD, $p < 0.05$), resulting in a more limited soil deeper exploration with more thicker and shorter roots.

Keywords: Forest management, water deficit, E. grandis, E. cloeziana, E. camaldulensis

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Morphological and physiological performance of four Eucalyptus species in a drought-prone site in Central Chile

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The value of this report is to highlight early survival, growth and physiological performance of a range of species in tough environments, thus indicating which species have potential and which should no longer be considered. We evaluate the potential of *Eucalyptus* species to be established in the Mediterranean drylands of central Chile. A field trial to examine survival, early growth and physiological performance of four *Eucalyptus* species was implemented in a site with Mediterranean climate, low annual rainfall (< 500 mm year-1) and low fertility. The species *E. tereticornis*, *E. camaldulensis*, *E. globulus* subsp. *maidenii* and *E. globulus* subsp. *globulus*, were established following a randomized complete block design with 3 replications of 49 trees per plot at a spacing of 3.0 x 1.0 m. At age one of plantation tree height, root collar diameter and survival were measured. In the maximum evapotranspiration period, predawn water potential (Ψpd), with a pressure chamber, and gaseous interchange parameters (i.e. net photosynthesis, stomatal conductance and transpiration) with a portable photosynthesis system (LICOR 6400 XT), were also measured. The results indicated that the species *E. camaldulensis* and *E. tereticornis,* despite showing a good growth rate, high survival and a low water stress, they had a low water use efficiency under the stress conditions of the plantation site. On the other hand, the species *E. globulus* subsp. *maidenii* had a high water use efficiency, but low growth and survival, and a high water stress. This study corroborates that *E. camaldulensis*, from its Lake Albacutya provenance, is a productive and cost-effective alternative that can increase incomes for small land owners in the Mediterranean regions of Chile; however, many land owners still do not recognize its valuable timber, usefulness for fencing, firewood and charcoal.

Keywords: Water use efficiency, survival, water stress, drylands, Eucalyptus camaldulensis

*Speaker

Unexpectedly, clearcutting does not increase fine root mortality down to 17 m deep in eucalypt plantations conducted in coppice in a Brazilian throughfall exclusion experiment

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Tree growth is highly dependent on the absorptive function of fine roots for water and nutrients. Improving our understanding of the spatiotemporal dynamics of fine roots down to the root front is a key component to identify more sustainable silvicultural practices for planted forests. Our study aimed to assess the effect of clear-cutting and drought on fine-root production along the soil profile down to the water table in Brazilian eucalypt plantations conducted in coppice. Fine roots (diameter < 2mm) were sampled down to 17 m in a throughfall exclusion experiment comparing stands with 37% of throughfall excluded by plastic sheets (-W) and stands without rain exclusion (+W). Twenty-four minirhizotron tubes were installed in two permanent pits down to 17 m in +W and -W. Root dynamics were recorded over 1 year before cutting the trees and over 2 years in coppice, after harvesting. A spectacular fine-root production at more than 9 m deep was observed in both treatments, lasting 2 months from the end of the dry season each year. After the harvest, root growth was observed in deeper soil layers (> 13m) and, surprisingly, root mortality remained extremely low whatever the depth in both treatments even after the harvest. Down to 17 m depth, total fine-root biomass in coppice was 1266 g.m-2 in -W and 1017 g.m-2 in +W, 1.5 year after the harvest. Specific root length and specific root area were about 15% higher in -W than in +W. Proliferation of fine roots at great depths could be an adaptive mechanism for tree survival, enhancing the access to water. Coppice management in eucalypt plantations can be an advantage against water stress because trees take advantage of the root system already established in very deep layers where water availability can be higher. Carbon investment belowground to produce fine roots is therefore minimal over the early growth of eucalypt trees in coppice, which might contribute to explaining the very fast growth of the stem after the harvest.

*Speaker

Keywords: Eucalyptus grandis, deep root growth, throughfall exclusion, very deep soil, coppice

Nutrient export and cycling at harvest of Eucalyptus dunnii Maiden

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Recently, there has been an increase in the areas of Uruguay dedicated to forest plantations for pulp production, with *Eucalyptus dunnii* Maiden being one of the more common species used. It is known that eucalyptus plantations require more or less important nutrient extractions. The actual amounts extracted depends on soil type, species and plantation age (*Morais et al.*, 1990; *Herbert,* 1996; *Goya et al.*, 1997; *Santana et al.*, 2000; *Laclau et al.*, 2000). The export and cycling of the nutrients also depend on the harvest and residue management method (*Spangenberg et al.*, 1996; *Gonçalves et al.*, 1997). In addition, decomposition rates are affected by climatic conditions and characteristics of the residues; in general, the woody materials decompose more slowly, (*Rezende*, 2001; *Burgess et al.*, 2002). Since large scale forestry has recently been established in Uruguay, information about harvest residue decomposition for Uruguayan soils and climatic conditions is rather limited. The knowledge of the process will contribute to improve the residue management practices as well as plan the fertilizer applications for the next turn.The objectives of this study were to quantify nutrient export of *Eucalyptus dunnii* Maiden and to characterize decomposition of harvest residues and the potential recycling of nutrients to the soil. In conclusion of work, the majority of the harvested biomass corresponded to commercial logs (73%), nutrient export did not surpass 45% of the total absorbed if the logs were de-barked on site (range 19-45). The nutrient export increased to between 53 and 80% if the logs were taken off site with the bark. In order to maintain the site productivity, the recommended harvest method should include de-barking on site. This is important not only to avoid an increase in fertilizer needs in the future (especially for Ca, Mg, and P), but also to ensure other positive effects of harvest residues, since the C input is essential to maintain the soil organic matter.

Keywords: Eucalyptus dunnii, nutrient export, nutrient cycling

*Speaker

Study on wind-resistance level and Genetic Analysis of Eucalyptus urophylla Hybrids in South China

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[Objective] Select the wind-resistance and fast-growing hybrids of Eucalytpus for the coast area in Southern China. [Method] Using the method of analysis of variance and BLUP to estimate the heterosis, breeding values, SCA and GCA of the traits which is from the data had been investigated and analyzed including of 46 artificial-hybrided Eucalyptus progenies, 9 free pollination progenies of parents and 1 control family at 2 different age in Gonghe town, Jianmen City of Guangdong, China. [Result] There were significant differences among growth traits in 56 families. There were the SV values of 23 or 6 hybrid families to exceed the 0.2079 m3 or the 0.3369 m3 optimal value of No. 128 parent family at 9 or 11.5 years old, and the same of 6 hybrid families' to exceed the value of No. 56 which can wind-resistant and fast-growing in the trials. There were 6 families including of No. 37, 40, 66, 54, 49 and 56 to exceed overall average value according to the SV had 18.63% and 15.99% heterosis than the highest value of No.128 parent in 2 different forest age; The SV and wind-resistant breeding value of 4 hybrids including of No. 49, 37, 40 and 45 had reached 0.05 and their phenotype values had a same variation trend; [Conclusion] By the GCA and SCA value analyzed at 11.5 years old, 5 females such as 21, 64, 22, 2, 15 and 5 males such as 21, 2, 29, 56, 22 could be the elite parents for the next step breeding in future, and the highest SCA value including of 3 hybrid families and 173 trees would be cloning as the optimal material to the last breeding program for their higher values than 0.08 SCA's and 33% relative effect SCA's.

Keywords: Eucalyptus urophylla, wind_resistance value, heterosis, breeding value, SCA and GCA

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Studying ecophysiological patterns to improve the management of high-productivity Eucalypt plantations: the EUCFLUX project

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Global climatic changes may deeply affect the functioning of *Eucalyptus* plantations, especially through the increase in frequency and duration of droughts and storms. However, the long-term responses of trees to the interactions of the different changing environmental factors remain largely unknown. It is therefore crucial to gain knowledge on the drivers of *Eucalyptus* productivity, carbon (C) allocation and resource-use efficiency in order to ensure a sustained productivity. These data are key to improve the productivity of Eucalyptus plantations and reduce their impacts on natural resources towards sustainable management. Building on the innovative results obtained in its first phase (2007-2017), the second phase of the EUCFLUX project, initiated in 2018, aims to enhance our knowledge on Eucalypt plantations functioning at various spatiotemporal scales. The EUCFLUX study site is located on a commercial clonal plantation of *ca* 260 ha in the state of São Paulo, Brazil. The project will specifically 1) quantify the fluxes of energy, C and water along a complete rotation (7 years) using the Eddy Covariance technique, girth inventories, litter and C content surveys and flux chambers; and

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assess the effects of forest plantations on soil water availability down to 10m and water table 2) use high-resolution dendrometers and anatomical analyses to study the determinism of growth and C allocation 3) combine field data, high resolution remote sensing and ecophysiological modelling to upscale our knowledge of Eucalypt functioning from site to regional scales and 4) compare the functional responses of more than 16 Eucalypt genotypes (clonal and seed-origin) in a common-environment field trial, in order to evaluate the generality of the results obtained on the main clone, but also to evaluate how different are the functional responses of coppice and planted Eucalypt trees. This poster will describe the EUCFLUX project and discuss how it can help designing new adaptive management guidelines.

Keywords: Ecophysiology, Eddy covariance, water use, remote sensing, ecophysiological modelling, carbon allocation, sustained productivity

How does site water availability and clonal drought sensitivity impact water use efficiency in fast growing Eucalyptus plantations?

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As climate change continues to drive changes in temperature and precipitation, understanding the tradeoffs between wood growth and water use is becoming increasingly important. Resource use efficiency (the amount of wood growth per unit resource used) is an important metric to understand growth dynamics in individual trees and stands and while a large number of studies have focused on resource use efficiency of stands, less attention has been directed to individual trees. Our previous work showed that larger, dominant trees had higher rates of wood growth, water use and water use efficiency (WUE) than smaller trees and this pattern persisted with increased water supply in irrigated plots. Here, we expand on this work and examine WUE for a drought sensitive (*E.grandis x E. urophylla*) and drought tolerant (*E. urophylla*) *Eucalyptus* clone growing at three climatically different sites (annual precipitation from 600 to 1,600 mm and soil water deficit from 0 to 800 mm) within the IPEF-TECHS research platform across Brazil. At each site, we measured WUE for each clone in control and rainfall reduction treatments. We are testing two hypotheses; 1) larger trees use more water and have higher WUE than smaller trees and; 2) this pattern persists across all treatments and sites regardless of drought sensitivity of the clone. Preliminary data indicates mean annual increment (MAI) was 10-30% higher in control versus rainfall reduction treatments and dominant trees grew faster than dominated trees. Final results for our hypothesis tests will be available in June 2018 when destructive biomass sampling and sapflow measurements are completed.

Keywords: Resource use efficiency, forest production, ecophysiology, productivity

*Speaker

Unlocking the mechanisms of Eucalyptus plasticity and resistance

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The genus *Eucalyptus* is economically and ecologically important, and consists of over 800 species. At the global scale, approximately 20 million hectares of dense eucalypt plantations are grown for timber, firewood, oil and pulp for paper. In Australia, *Eucalyptus* species dominate 92 million hectares of native forests and woodlands, with their range spanning many diverse, and sometimes extreme climatic regions. This incredible plasticity and capacity to thrive in different environments is due, in part, to the ability of *Eucalyptus* species to produce an extensive array of specialized metabolites. Specialized metabolites – such as terpenes, formylated phloroglucinol compounds (FPCs), phenolics and cyanogenic glucosides – play a vital role in moderating interactions with the environment, such as mediating biotic and abiotic resistance.

Using a full "omics" toolbox, our research platform aims to characterize how *Eucalyptus* species regulate specialized metabolite production; constitutively, and in response to stress. Our improved metabolomic platforms enable the identification, localization and quantification of different specialized metabolite classes, including volatile and non-volatile constituents. Transcriptomic and proteomic analyses facilitate the identification of specialized metabolite pathway genes, and function is characterized by transient expression (in *Nicotiana benthamiana)* and biochemical analyses.

Using this cross disciplinary approach, we have begun to unlock the mechanisms of how different *Eucalyptus* species respond and adapt to a changing environment. This provides insight into resistance mechanisms, which may provide molecular tools for commercial pursuits and breeding programs. Furthermore, the knowledge generated expands our fundamental understanding of *Eucalyptus* plasticity, which will ultimately aid the conservation of these most iconic trees.

Keywords: specialized metabolism, metabolomics, transcriptomics, abiotic resistance, pathway discovery

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Genetic evaluation and association analysis for pest susceptibility in Corymbia species

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Insect pests pose threat to the cultivation of spotted gums, a potential pulp wood species for paper industry. Infestation of leaf miners and defoliators were observed in evaluation trials of three species, *Corymbia torelliana* (CT); *C. citriodora* ssp. *citriodora* (CC) and *C. citriodora* ssp. *variegata* (CV), introduced from 14 Australian provenances. Intensity of infestation was recorded in a scale ranging from 0-4 in three species at an inland and coastal sites in Southern India. Foliar damage was relatively high in CT followed by CC, whereas CV was tolerant with 42-45% of trees being free of attack and more than 50% of trees showing low infestation in both locations. Overall infestation was higher at coastal site (31% trees) with families from Mt Perry, Monto SF and Mt Sturgeon were relatively tolerant than other provenances with certain common families across both sites. About 168 individuals of C. variegata representing 40 families of 9 provenances were subjected to DArTseq genotyping for SNP discovery. An association analysis was carried out based on mixed linear model (MLM) using 2500 highly informative SNPs for growth traits and pest tolerance. Of 2500 SNPs, 16 were found to be significantly associated with tolerance to pests explaining 11% average phenotypic variation. No common SNPs were observed for biotic stress and growth traits, although insignificant negative correlations were observed in tree height, lignin and GBH. Further, a selection panel was developed using the 16 SNPs with 9 positive and 7 negative allelic effects for pest tolerance to be used in informed breeding programs for pest control.

Keywords: Corymbia, Biotic stress, DArTseq, SNPs, Association analysis

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Evaluation of interspecific hybrids of Eucalyptus camaldulensis and E. urophylla across two sites for deployment in southern India

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Controlled pollinated interspecific hybrids were developed between 13 *Eucalyptus camaldulensis* (Ec) and 10 *E. urophylla* (Eu) trees selected from genetic trials of both species in southern India. Interspecific hybrid families were tested at an inland and coastal site for adaptability, growth and pulp yield. Ec x Eu crosses had 15 and 30% higher survival than their reciprocal crosses at inland and coastal sites respectively at two years. Hybrids with 20% higher growth than Ec commercial clones and 47-50% pulp yield (PY) were selected for cloning and evaluation in multiple sites. Majority of the selections (70%) were from Ec and Eu parents with high General Combining Ability (GCA) and low variability (cv) in progeny growth. The hybrids are being evaluated for deployment as clones for yield improvement and as a mitigation strategy against pests and diseases.

Keywords: Eucalyptus hybrids, General Combining Ability, Variability, Growth, Pulp yield

*Speaker

Acacia changes litter and soil microbial indicators associated with C and N cycling in intercropped Eucalyptus plantations

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Forest management strategies, like intercropping Eucalyptus plantations with nitrogen-fixing Acacia can improve C and N inputs, stimulating biogeochemical cycling and nutrient availability in the soil. However, our knowledge on the participation of the microbiota in specific parts of these processes is still incipient. In an effort to understand the C and N dynamics going on in pure and intercropped *Eucalyptus grandis* and *Acacia mangium* plantations, we decided to characterize the microbial and enzymatic activity in soil and litter and the metabolic profile of the soil microbial community, looking for correlations between them. We collected bulk soil samples (0-20 cm) from a field experiment with four treatments, pure *E. grandis* (E) and *A. mangium* (A) plantations, pure *E. grandis* with N fertilizer (E+N) and an intercrop of *E. grandis* and *A. mangium,* 27 and 39 months after planting. The soil organic fraction (OF) presented a higher mass in A and E+A, with a greater N and C content. Microbial C was significantly lower in the E and E+N and higher in the A and E+A stands, at 27 months after planting, with a higher qMic-C index. The metabolic quotient (qCO2) increased with time and in both epochs, and there was a tendency for higher values in E and E+N. Urease and amidase activity were always significantly higher in the E and E+N treatments and there were no significant differences between treatments regarding the degradation potential of the evaluated C substrates by the microbiota. However, we verified significant differences in the amounts consumed of some of the C sources when comparing periods, mainly in the A (16 sources) and E+A (5 sources) treatments. A canonical redundancy analysis showed interactions between litter and soil attributes and some soil microbial attributes, separating A and E+A from the others, in both periods. These results allow us to infer that C and N accumulations in OM fractions of intercropped plantations are due mostly to a great stimulation of all microbial processes by Acacia trees. This phenomenon is of utmost importance in areas with sandy soils containing extremely low levels of organic matter, because it improves nutrient availability in the soil and results in better tree nutrition.

Keywords: forest soil, soil biology, mixed, systems, C, N cycles, organic matter

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Genotype-by-environment interaction,in Corymbia citriodora hook

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Corymbia citriodora is one of the most cultivated forestry species in Brazil, it combines a high growth rate with high wood density. Its timber is used in products, such as poles, railway sleepers, posts, scantlings, wharves and construction lumber. Genotype-by-environment interaction (GE) is one of the most important elements in the management of a tree breeding program. It is used to define breeding zones and to select genetic material which can be targeted to address specific environmental conditions. The aim of this research was to estimate genetic parameters and to understand GE patterns based on *C. citriodora* progeny tests. The experiment was established using 56 open-pollinated families in three different locations within the Luiz Antônio's experimental station, Brazil. The three sites differ contrastingly on their soil type (1: Red Latosol, 2: Quartzarenic Neosol, 3: Clay Latosol). The following traits were measured at 30 years of age: height (HT), diameter at breast height (DBH), stem form and survival. Based on this data the individual stem volume (VOL) was calculated. The MHPRVG (harmonic mean relative performance of genetic values) predicted by BLUP was used to analyze productivity, stability and adaptability. The GE was not found to be significant regarding all growth traits. A complex GE was detected only for survival, confirming the importance of choosing the correct genetic material of the species for specific sites. The joint analysis showed a significant difference between families for DBH, survival and VOL. In the individual analyses, family growth trait performances were different only in site 2. The estimated gains presented low and moderate values peaking at 11% in site 2. In summary, the material studied here presents the potential to obtain genetic gains through selection. However, to keep these gains continuous over the next selection cycles it is necessary to incorporate new genetic materials in order to increase the diversity observed among the progenies

Keywords: progeny test, tree breeding, genotype, by, environment interaction.

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Can lignotubers affect silvicultural traits of Eucalyptus plantations in dry areas?

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Lignotubers are organs that provide forest tree species increased tolerance to different levels of stress as drought. The aim of this study was to understand the relationship among lignotubers, stress and silvicultural traits by estimating genetic parameters and phenotypic correlations. Experiments were conducted with two *Eucalyptus* species, their hybrids and backcrosses, in two contrasting environments as edaphoclimatic factors. We evaluated height (H), circumference at breast height (CBH), and presence/absence of a lignotuber. Estimates of the genetic parameters did not detect heterosis and epistasis in the evaluated genetic material. For joint analysis of experiments indicates significance for treatments in relation to lignotuber presence. Thus, the phenotypic correlation was significant for all traits and environments for the hybrid, except for one of the sites, it was only significant for *Eucalyptus urophylla*, suggesting that there is an association between silvicultural traits and lignotuber presence with biotic/abiotic stress. In addition, plants with lignotuber showed less vegetative growth, indicating that the lignotuber is an important structure in plant development and a strategic factor to be considered in choosing genotypes for regions with high environmental stress. Lignotubers are a crucial trait in regions with periods of severe drought because plants can survive in such conditions, although with lower growth rates. Obtaining clones with this trait can be considered an adaptive and strategic element of breeding programs.

Keywords: Forest breeding, Genetic parameters, phenotypic correlation

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Soil boron fractions and forest residues management in Eucalyptus grandis plantations

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In Brazil, boron (B) lack in eucalyptus plantations may result in significant losses of productivity, especially in regions with high water deficit. Even with the application of borated fertilizers (3 to 5 kg ha-1 of B), the organic matter decomposition/mineralization in soil may also contribute considerably as a source of B to plants, avoiding dieback disease. This study aimed to quantify the contribution of forest residues to B fractions in a red-yellow Oxisol (20% of clay). It was evaluated soluble, exchangeable, bound to organic matter, bound to Fe oxides and soil residual B fractions, in response to the maintenance or the removal of all forest residues (ex. Forest litter, leaves and branches of harvest). Residues management did not change the total soil B content (9 - 10 mg kg-1). However, the removal of these residues decreased 40% of soluble B. Despite contributing with just 5-7% of total B, the soluble B is readily available to plants. Thus, the maintenance of forest residues in the growing site may be very important to the appropriate plant nutrition with B.

Keywords: soil fertility, plant nutrition, B availability, maintenance of forest residues, water, soluble form of B

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Morphological characterization of Eucalyptus urophylla roots via diazotrophic bacteria inoculation in seeds

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Technological innovation stands out as an instrument to achieve specific characteristics in eucalyptus plants. The use of beneficial microorganisms in this sector has become an option to improve production. The beneficial effect of the application of rhizobacteria on eucalypt rooting has recently been demonstrated. The objective of this study was to evaluate the morphological characterization of Eucalyptus urophylla roots inoculated with diazotrophic bacteria. The work was conducted in a greenhouse at the Rondônia's Federal Institute, Campus Colorado do Oeste. The experimental design was completely randomized with 17 treatments and 16 replicates, of which 12 strains isolated from *E. urophylla* - AEC144 (*Azospirillum amazonense*: IFROL1, L2, L3, L4, L5 and L6; *Stenotrophomonas maltophilia*: IFROL 7; *Pantoea agglomerans*: IFROJV1, V4 and (*Azrobacter chroococcum* AC 1, *Azospirillum amazonense* Aam 82 *Burkholderia tropica* BR11366 and *Rhizobium tropici* BR322) and control. The results were obtained using the WinRHIZO Arabidopsis program, coupled to a professional EPSON XL 1000 scanner. The strains IFROL1, L4, L6, L7, JV2, JV5 and BR322 showed better results to total root volume when compared to the other bacteria. For volume and root surface variables, strains IFROL1, L3, L4, L5, JV2, JV3, JV4, JV5, BR11366 and BR322 were highlighted. The IFROL1, L2, L3, L4, L5, L6, JV2 and BR11366 strains obtained higher values of volume and surface area of fine roots compared to the other strains. Root results are beneficial effects provided by auxin synthesis, in addition to biological nitrogen fixation, gibberiline production and phosphate solubilization. This morphological change of the root system allows a greater influx of nutrients and larger volumes of soil explored by the plant.

Keywords: biological diversity, biological nitrogen fixation, hormones.

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Differences in leaf traits among sixteen Eucalyptus genotypes suggest contrasting strategies to cope with climatic conditions

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Eucalyptus plantations in Brazil cover approximately 5,7 million hectares and are distributed from 0O to 32O S, covering a wide range of climatic conditions. To develop adapted genotypes to this climatic gradient, breeding programs use species with different leaf anatomic, morphologic and structural traits. We selected 16 highly planted *Eucalyptus* genotypes (*E.grandis*, *E.urophylla*, *E.camaldulensis*, *E.saligna*, pure and hybrids, clonal and seed-origin) across different regions in Brazil, and grew them at a single location to assess their genotypic variability in leaf structure, anatomy and morphology, and how these leaf traits may be related to strategies to cope with environmental conditions. Most genotypes exhibited similar leaf anatomy, with about 5% of leaf thickness constituted of cuticles, 11% of epidermis, 26% of palisade parenchyma, and 58% of spongy parenchyma. The only exception was the clone *E.grandis x E.camaldulensis*, with no spongy parenchyma and thick palisade parenchyma (84% of the leaf thickness). The clones had hypostomatic leaves, except two genotypes with amphistomatic leaves (*E.grandis x E.camaldulensis and E.grandis*). Significant relationships were found between leaf inclination angle (LIA) and shape, and stomatal density and size. Genotypes with lower leaf area per tree showed higher mean LIA ($R2=0.23$, $p< 0.05$). Negative correlations were also found across genotypes between stomatal density and stomatal size ($R2=0.67$, $p< 0.001$), and between LIA and stomatal density ($R2=0.61$, $p< 0.001$). Genotypes with higher LIA showed more narrow and long leaves ($R2=0.57$, $p< 0.001$). From wetter to drier conditions in the regions where the clones were selected, the main trend was a decrease in leaf area per tree and in stomatal density per area of leaf, as well as an increase in LIA, and stomatal size. Improving our understanding of the trade-offs among leaf traits can help tree breeding programs to select genotypes able to cope with specific climatic conditions.

*Speaker

Keywords: Fast growing Eucalypt plantation, leaf traits, tree breeding

Effect of mating system in genetic parameters estimates for Eucalyptus species

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Species with mixed system differ from those that are completely allogamous or autogamous as they include a mixture of individuals with different degrees of inbreeding. Inbreeding affects individual phenotypic values as well as genetic variance; therefore, the effects of selection are more complex in mixed-mating species. In this study, five provenances of *Eucalyptus camaldulensis* (species with high outcrossing rate) and six of *Eucalyptus pellita* (mixed mating system species) were analyzed. Field trials were installed in 2014, using a randomized block design with ten replicates, seven and six plants per plot for *E. camaldulensis* and *E. pellita*, respectively. At two years of age, diameter at breast height (DBH) and height (H) were measured. For DBH, the coefficients of genetic variation of 15.90% and 8.59% and mean heritability among progenies were 0.99 and 0.68 for *E. pellita* and *E. camaldulensis*, respectively, were high, indicating the potential of these species for breeding programs. The narrow-sense heritability were 0.51 and 0.17 to DBH and 0.86 and 0.12 to H, for *E. pellita* and *E. camaldulensis*, respectively. The genetic gains for *E. pellita* were corrected using the kinship coefficient, demonstrating that when the reproductive system is disregarded there are substantial reductions (from 56.6% for narrow-sense heritability to 75.4% for heritability within progenies) in genetic gains, confirming the hypothesis that the genetic gain is biased by the reproductive system. The incorporation of molecular data into quantitative genetics improves our understanding of genetic parameters and enables the acquisition of genetic gains that are more suitable for each type of species.

Keywords: heritability, forest improvement, mixed reproduction system, Eucalyptus camaldulensis, Eucalyptus pellita

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Climatic limitations to growth of Eucalyptus clones in Brazil and Uruguay

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Commercial *Eucalyptus* plantations are distributed across a wide range of climatic conditions in Brazil and Uruguay, with contrasting intra and inter annual patterns of temperature and soil water availability. To cope with the significant climatic variation, tree improvement programs continuously develop adapted genotypes to different locations. However, we lack detailed information regarding how climate limits growth. To identify limits of low temperature and soil water deficit to different genotypes at different climatic conditions, 9 pure or hybrid *Eucalyptus* clones were planted on 8 experimental sites, from 3o to 33o South (mean annual temperature from 10 to 30∘C, and annual rainfall from 800 to 1800 mm). We measured bole cross-sectional area increment every 15 days for three years, approximately from 2 to 5 years after planting. Continuous growth was found on sites with annual rainfall above 1500 mm, evenly distributed across the year (at least 20 mm every month), and mean temperature of 16oC. Soil water deficit higher than 40 mm for consecutive 30-45 days stopped growth. On sites with no soil water deficit, mean temperature over the period of 15-30 days below 10oC stopped growth. Significant response differences to climate among clones were found and will be discussed. Measurements will be performed until July 2018 to complete the dataset and perform the final analysis. Understanding the limits of temperature and water availability to different genotypes at different climatic conditions will help to assess the impact of climate variability on productivity of *Eucalyptus* plantations.

Keywords: Drought, Temperature limitation, Wood productivity, Eucalyptus clones

*Speaker

Green manure in eucalypt plantations, case study from Portugal - first results

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The green manure studies reported here, the first in Portuguese eucalypt plantation context, were established seeking a more environmental friendly solution for the fertilization of plantations. Besides being considered an interesting alternative to nitrogen (N) fertilization, green manure has several advantages over mineral fertilizers including a more effective protection of soils from erosion, improves aeration and enhances water infiltration rates and water retention capacity. Nonetheless, issues that are going to be addressed in the present study remain regarding the feasibility and effectiveness of its use in a forestry context, the supply of N and other elements, its invasive nature and possible impact on the risk of forest fires. In autumn 2017, clovers (*Trifolium* sp.) and lupine (*Lupinus luteus*) seeds were applied to two *Eucalyptus globulus* stands at a planting stage. Soils at the two studied sites were classified as Leptosols (over schist bedrock) and Regosols (over sandstone bedrock), respectively. Experimental design included 5 treatments (control with no green manure, lupine without and with fertilization and clovers without and with fertilization), replicated three times. Soil samplings were performed to assess fertility. Eucalypt plantations were regularly monitored for survival and biomass production. Seeds germination started few days after sowing and these were the first plants, besides eucalypts, to settle up in the area. In both trials, the survival rate of eucalypts was 100%. The sowing remained confined and although with less exuberance in comparison with the fertilized option, sows without phosphate fertilization revenge and established equally well in trials. In both trials, the clovers provided higher ground cover and reached lower heights than the lupine which can have implication on fire risk assessment. Considering these first results, green manure seems technically feasible and with potential to be applied in a forestry context.

Keywords: Green manure, clovers, lupine, Eucalyptus, forest nutrition, fertilization, soil fertility

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Relating water availability and temperature with response to fertilizer application

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The response of *Eucalyptus* plantations to fertilizer application can be highly influenced by weather conditions. However, the climate is hardly ever considered when recommending fertilization. We conducted an experiment where *Eucalyptus grandis* was grown for two crop rotations (R1, planted in 2004; R2, clear felled and re-established in 2012) with and without N, P, K, Ca, and Mg application. The soil of the experimental site was Brazilian Oxisol. Our goal was to identify the role of weather in the current and accumulated response to nutrients. For this, the stem growth of fertilized and unfertilized trees was measured monthly, and the wood volume and total biomass were measured every 12 months. In the absence of K, the wood volume decreased drastically (approximately 70%), and this effect was observed until the end of the rotation. On the other hand, in the absence of N, P, Ca, and Mg, the wood volume decreased from 20 to 50% at 2 years of age. This response decreased with age, disappearing at the end of the rotation for N and was approximately -10% for P, Ca, and Mg. The fertilization treatment was highly responsive to weather variation, showing basal area increase of approximately 1.2 m2 ha-1 month-1 during the rainy season and values less than 0.2 m2 ha-1 month-1 during the dry season. The absence of K fertilization resulted in a slow but constant growth of approximately 0.2 m2 ha-1 month-1. This high influence of water availability on the current response to fertilizer application may change the response in terms of accumulated wood volume. In R1, the response to P was -15% at 2 years of age, and this decreased to -2% ($p > 0.10$) at 5 years of age. Because of a high rainfall period of 3 years (2009–2011), this response improved to -10% ($p < 0.05$) at 7 years of age. During R2, the clear trend of reduction in the Ca and Mg response ended in 2015 because of high rainfall (1768 mm) after a long and atypical drought in 2013 and 2014.

Keywords: Eucalyptus, stem growth seasonality, forest nutrition

*Speaker

Eucalyptus and Acacia mangium tree growth and stand production in pure and mixed-species plantations along an ecological gradient in Brazil

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The association of *Acacia* could increase *Eucalyptus* plantations productivity through a positive balance between facilitative effects and competition between species. In Brazil, the development of mono-specific stands of *Acacia mangium* (100A) and *Eucalyptus sp.* (100E) was compared with nitrogen (N) fertilisation treatment (100E + N) and mixed-species plantations in a 1:1 ratio (50A:50E). The study was conducted in Itatinga-SP, Sinop-MT and Colinas-TO with mean annual temperature of 19.4, 25.0 and 27.5 ∘C, mean annual rainfall of 1320, 2640, and 1850 mm, and dry season duration of 3, 5 and 7 months, respectively. The soils are sandy to sandy-clay. At 36 months, *Eucalyptus* height in 100E was 18.9, 10.9 and 13.7 m, in SP, MT and TO, respectively. For *Acacia* the corresponding values in 100A were 14.2, 13.5 and 10.8 m, respectively. This pattern, also observed for diameter at breast height, showed that Eucalyptus was proportionally more adapted to the ecological conditions than Acacia in SP, the opposite

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being found in MT. Stand basal area (SBA) was 2, 10 and 3 % higher in 100E+N than in 100E in SP, MT and TO, respectively. SBA was 7 and 1 % higher in 100E (8.33 and 3.70 m2 ha-1) than in 100A (7.77 and 3.66 m2 ha-1) in SP and TO, respectively. By contrast, SBA was 69 % higher in 100A (7.54 m2 ha-1) than in 100E (4.47 m2 ha-1) in MT. SBA was 6 and 4 % higher in 100E than in 50A:50E in SP and TO, respectively. By contrast, SBA was 21 % higher in 50A:50E than in 100E in SP. The occurrence of higher stand production in mixed species plantations of *Eucalyptus* and *A. mangium* than *Eucalyptus* monocultures depends on ecological conditions. When conditions permit high eucalypt stand yield as observed in SP, the potential N facilitation by *Acacia* cannot balance the lower potential of growth of *Acacia* trees, which are also deeply competed by *Eucalyptus* trees. By contrast, as observed in MT mixed plantations are likely more productive than *Eucalyptus* monoculture when the environmental conditions (hot and humid climate) are more favourable for acacia than eucalyptus and when the soils are deficient in N. Adverse conditions for both *Eucalyptus* and *Acacia* (e.g. extreme high temperatures, marked dry season) as found in TO are likely to prevent any efficient facilitation processes between species.

Keywords: mixture, forest plantations, environmental conditions, competition, facilitation.

Modeling of growth and phyllotaxis pattern in Eucalyptus grandis.

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The study aimed to identify the ontogenetic, environmental and phyllotactic growth components, observed in *Eucalyptus grandis*. The trees grown in Itatinga Experimental station near Sao Paulo (Brazil) were affected by two treatments: addition of Potassium and rainfall partial exclusion. Tree growth data correspond to the retrospective measurement of the length of successive internodes along the main stem. The growth of eucalyptus main stem was decomposed into three components: (i) an ontogenetic component structured as a succession of roughly stationary phases at coarse scale (ii) growth fluctuations corresponding to the impact of the changing climatic conditions at an intermediate scale and (iii) a more or less systematic alternation of long and short internodes at fine scale. The ontogenetic component shows three main growth phases: an establishment phase, a maximum growth phase and a drift phase. The Potassium addition and the rainfall partial exclusion do not affect the succession of growth phases but only,for the Potassium addition, the growth level within the phases. The alternating pattern was a direct consequence of phyllotaxis and strongly depends on the mean internode length. We show that this alternating pattern can be disrupted in case of meristem death.

Keywords: growth components, plant architecture, ontogeny

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Are there differences in the mycorrhizal colonization of Eucalyptus and Acacia roots between the deep layers of the soil?

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Mycorrhizal fungi help plant growth, increasing the absorption of mineral nutrients from the soil and transporting them to the roots. Our objective was to evaluate the mycorrhizal colonization of Eucalyptus and Acacia, either alone or in consortium. Our experiment was composed of three treatments: monocultures of *E. grandis* and *A. mangium* and a consortium between them. We collected fine roots and soil samples in four depths: 0-10, 10-20, 20-50 and 50-100 cm. We quantified the spore number of arbuscular mycorrhizal fungi (AMF) in 50 g of soil and the colonization rates by AMF and ectomycorrhizal fungi (EMC). In addition, was evaluated the chemical attributes of roots and soil. There were no significant differences in colonization between treatments (Tukey 5%), except for the fact that we did not find AMF colonization in Acacia roots. However, we observed differences between the depths in Eucalyptus, with higher colonization rates in the superficial layers (0-10 cm), ranging from 26% to 30% for AMF and 32% to 49% for EMC, and with lower colonization rates in the deeper layers (50-100 cm), ranging from 9% to 15% for AMF and from 14% to 22% for EMC. Generally, we found higher EMC colonization than for AMF in *E. grandis* roots. Even though we did not detect the presence of arbuscules, the most commonly observed structure in AMF-colonized roots was hyphal coils, typical characteristics of the Paris type. In all treatments, viable AMF spores were found, even in the areas with Acacia. In the 0-10 cm soil layer, we found a maximum of 32 spores, while in the 50-100 cm layer we found only two spores. The chemical attributes of roots and soils indicate that *A. mangium* presented a higher concentration of nutrients, especially of total nitrogen, in the forms of NH4+ and NO3- in the soil. Understanding the interactions mycorrhizal and what factors influence them are extremely important for the sustainable management of forest ecosystems.

Keywords: monoculture and consortium systems, arbuscular mycorrhiza, Paris type structure, ectomycorrhiza, chemical attributes of roots and soil.

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Acacia influence on the structure and abundance of the fungal community in the Eucalyptus rhizosphere

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The tree root system exudes organic compounds and stimulates the microorganism growth in the rhizosphere (e.g. fungi). In this case, fungi community has an important role in the organic matter decomposition, improving the nutrient cycling. Our aim was to compare the structure and abundance of the fungi community in *Eucalyptus grandis* and *Acacia mangium* rhizosphere. Soil rhizosphere samples were collected at the Itatinga Forest Experimental Station, São Paulo, Brazil, at different depths: 0-10, 10-20, 20-50 and 50-100 cm, in the treatments: *E. grandis* (E) and *A. mangium* (A) monoculture and a consortium of both species (EC and AC). The plants were two years old. For assessing fungal community structure, we extracted the DNA from the samples and applied the Terminal Restriction Fragment Length Polymorphism approach using ITS1f-FAM and ITS4 primers set and HaeIII restriction enzyme. Regarding fungi abundance, we applied quantitative PCR (qPCR) using SYBR® Select Master Mix kit with ITS1f and 5.8s primers. The Principal Coordinate Analysis explained 32.75% in fungal profile variation. In order to clarify the similarity between fungi profile, ANOSIM similarity analysis was performed. The E was significantly different ($p < 0.0001$) when compared to the other treatments, but shared groups with EC (RANOSIM 0.5013, $p < 0.0006$). Treatments A and AC presented a dispersed profile that, although significant ($p < 0.003$), there was no separation of groups when compared to each other (RANOSIM 0.11212). Comparing the treatments within the same layer, fungi abundance showed no significant difference between treatments (Tukey 5%). However, we find differences when comparing fungi abundance along the soil profile, which reduces with soil depth, except in AC, which did not show differences between the layers, indicating that the Acacia in the consortium increases the abundance of fungi. The consortium system can be improve the fungi diversity and abundance in the rhizosphere of *E. grandis* and *A. mangium*.

Keywords: monoculture and consortium, soil depth, T, RFLP, qPCR, ITS region

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Development of high yielding Eucalyptus Urophylla clone for paper making - JKSC U283 Turbo

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In India, Paper Industries are developing sustainable raw material resources through agro & farm forestry plantation systems with small land holders. More than 85% farmers are small and marginal having less than 2 ha of land holding. Mostly Indian paper Industries are using *Eucalyptus Camaldulensis*, *E. Teriticornis* species clones for plantations and paper making. The productivity of these clones was 20-30 m3/ha/Year in 5 year rotation cycle. Similarly, the bleached pulp yield is 40-42% with higher lignin content which is not favourable of paper making process. JK Paper Limited is leading organisation in India producing fine varieties of writing printing paper, photocopier, wood free coated paper and coated duplex paper board having 2 integrated plants at JKPM Rayagada, Odhisa and CPM Songadh, Gujarat producing 4.55 Million T of paper and paper board annually. JK Paper Limited has put pioneering efforts and working with the farming communities in Gujarat, Maharashtra, Odhisa and Andhra Pradesh for meeting its raw material requirement by promoting short rotation pulp wood plantations through advanced clonal technology. JKPL has started intensive plantation research and development activity from the year 2008. We have conducted research and development on *Eucalyptus Urophylla* (Timor Mountain Gum) species and shortlisted 2 superior candidates plus trees from Godhra, India. We have taken multi-locations progeny trials of *Eucalyptus Urophylla* species and commercially released *Eucalyptus Urophylla* clones namely JKSC U283 Turbo which is suitable in our climatic condition with productivity of 50-60 m3/ha/Year in 3 year rotation cycle. Similarly, this clone is having excellent pulping properties like low lignin content, higher bulk density (225 kg/ m3), higher pulp yield (46% bleached yield) and excellent fibre morphology. This clone is highest productive clone presently ruling in India and JKPL has applied variety registration with protection of plant varieties and farmer right authority, New Delhi, India. JKPL is producing clones of JKSC U283 Turbo to the tune of 10 Million clones per annum and planting about 4000 ha with improved package of practices with nutrition management and cultural operations with about 2000 small farmers. These clonal plantations are creating sustainable livelihood opportunities in rural India with higher productivity and helping Industries to meet its increasing quality raw material supplies.

Keywords: Clonal technology, Paper, Eucalyptus, Farmers, Plantations, Pulpwood

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Initial growth in progenies of open pollination of Eucalyptus pellita F. Muell In Selviria-MS

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Eucalyptus pellita is a promising species to expand the areas of planted forests in Brazil, however, productivity germplasm in new environments is still scarce, mainly due to the lack of genetic trials that identify genotypes adapted to some regions of Brazil. Our work aimed to estimate the genetic variation for silvicultural characters, in a progeny test of *E. pellita*. The test was installed in May 2016 in Selvíria-MS. The experimental design was of randomized blocks, single tree plot, 20 replicates, in the spacing of 3.0 m × 1.5 m, 206 treatments (progenies) were used. One year after planting, it was evaluated height (H), breast height diameter (DBH) and survival (S). Estimates of variance components and genetic parameters were obtained by the method of maximum likelihood restricted and best linear unbiased prediction. The trees showed good adaptation in the region with 83% of S and average of H and DBH of 4.28 m and 3.72 cm, respectively. The experimental coefficient of variation was high (> 30%). Despite this, significant differences were detected at 1% significance in deviance analysis. The heritability coefficient, at the mean progeny level, was 0.82 (H) and 0.78 (DBH) resulting in high accuracy: 88%. The coefficient of genetic variation, at progeny level, was high 14.04 (H) and 14.04 (DBH). Thus, the presence of genetic variation and the accuracy found for the characters in the progenies indicate good prospects of gain in selection

Keywords: survival, forestry breeding, genetic variation

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†Speaker

Genetic parameters of Eucalyptus tereticornis Sm. open pollinated progenies in Silviria, Mato Grosso Do Sul, Midwestern, Brazil

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The remarkable expansion of eucalypts plantation area in the last decades comprises almost all of 26 Brazilian states. Due to the country's distinct edaphoclimatic conditions it is imperative the use of a high number of *Eucalyptus* species, which could show different adaption for each region. *Eucalyptus tereticornis* is a promising fast-growing species in the tropics because it is adapted to hot and dry seasons and it is suitable for energy purposes. Thus, this work aimed at verifying adaptation and genetic variation of an open-pollinated progeny trial of E. t*ereticornis* in Midwestern Brazil. The experiment was set up in September, 2017 in Selvíria, Mato Grosso do Sul state. A randomized complete blocks design with 23 replications, in single tree plot design. Eighty-seven treatments (progenies) were used which were provided by the Institute of Research and Forest Studies. Total plant height (ALT) and survival (SOB) were evaluated six months after planting. Estimates of variance components and genetic parameters were obtained by the method of maximum likelihood restricted and best linear unbiased prediction (REML / BLUP). SOB was 95.4% and ALT average was 1.33 m, showing the adaptation of the species to the region. Significant difference at progeny level was obtained at 1% significance, indicating difference among the progenies. Heritability coefficient at the mean progeny level was 0.68 and 82% accuracy and coefficient of genetic variation at progeny level was 7.35%. Although it is an initial evaluation, the results indicated genetic variation for growth character which is expected to increase over time. Therefore, it is important to conduct the test over the years for new assessments of height and other silvicultural characteristics that are crucial to define the use of the species and the best genotypes to be used in conservation and breeding programs of this species " *per se* "or interspecific crosses.

Keywords: eucalypts, genetic improvement, genetic variability

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Genetic variation for diameter at breast height in open-pollinated progenies of Eucalyptus grandis W.Hill ex Maiden IN Selviria, Midwestern Brazil

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Eucalyptus is the most common planted forest genus in Brazilian afforestation programs due to its adaptation to different climate and soil conditions. It is usually used for the production of pulp, paper, charcoal and solid wood, because of its rapid growth. *Eucalyptus grandis* is an important species in Brazil, the species could be use in pure populations or in hybrid combinations. The objective of this study was to evaluate survival and genetic variation for diameter at breast height (DBH) in an open-pollinated progeny trail of E. *grandis*. The trial was set up in February, 2010 in Selvíria, Midwestern Brazil. The experiment was designed in randomized blocks with single tree plot design , 26 replications, at a spacing of 2.0 x 2.5 x 4.0 m. A total of 147 treatments (progenies) and 3 commercial clones, the germplasm belongs to Institute of Research and Forest Studies (IPEF). Seven years after planting, DBH and survival were evaluated. The estimates of variance components and genetic parameters were obtained by the method of maximum likelihood restricted and best linear unbiased prediction. Survival was 68.8%, the DBH average was 14.7 cm and the likelihood ratio test detected significant differences among progenies. The coefficient of genetic variation at the progeny level was 10.2%. The heritability coefficient, at the mean progeny level, was 0.70 (ALT) resulting in high accuracy: 80%. It indicates genetic control for the character. Some progenies had better performance compared to the clones. Thus, the trial showed good genotypes to keep the improvement by pure specie (recurrent selection) or hybridization

Keywords: eucalypts, forest improvement, genetic parameters

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The transpiration water consumption and its influencing factors of E. urophylla × E. grandis plantation in Leizhou Peninsular

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As an important strategic tree in the south, the planting area of Eucalyptus plantations in China has reached 4.5 million hectares. The consumption of regional water resources by large area Eucalyptus planting has been widely concerned by the scientific community and the society. In order to correctly understand the transpiration and water consumption patterns of *E. urophylla ×E. grandis* plantations under the climatic conditions of the Leizhou Peninsula, the stem sap flow of *E. urophylla ×E. grandis* was monitored continuously using a thermal diffusive stem flow meter, and the meteorological conditions of the forest were simultaneously measured. The results showed that the average annual precipitation in the Leizhou Peninsula is 1600mm. The dry rainy season is obviously different. The diurnal variation of sap flow throughout the year showed a typical single peak curve. The sap flow of *E. urophylla ×E. grandis* had a great change during the day and accounted for more than 85% of the total flow of the whole day. The mean sap flow density was: 9.88 ml·h-1·cm-2. The nighttime flow curve is flat and weak, and the average sap flow density at night was: 1.79 ml·h-1·cm-2. The flow density and liquid flux under special weather such as typhoon decreased by about 53% compared with normal weather. There was no significant difference in nighttime flow density and recharge between dry season and rainy season. But the contribution rate of nighttime water recharge of dry season was significantly greater than that of the rainy season. In the rainy season, the average value of the peak flow density and liquid flux of *E. urophylla ×E. grandis* was 1.3 times and 1.5 times that of the dry season. The transpiration of eucalyptus forests in Leizhou Peninsula ranged from 0.2 to 3 mm/d. The average daily water consumption single plant in the different ages of *E. urophylla ×E. grandis* varies greatly, with 2.45 L/d at 2 years, 12.95 L/d at 4 years, and 28.03 L/d at 10 years. The main meteorological factors affecting the liquid density of *E. urophylla ×E. grandis* during the day are solar radiation, photosynthetically active radiation, and vapor pressure deficit. Nighttime flow of *E. urophylla ×E. grandis* was produced by the combination of night transpiration and trunk water replenishment. In the process of typhoon, wind speed has become a key factor influencing liquid flow.

Keywords: E. urophylla ×E. grandis, stem sap flow, thermal dissipation probe (TDP), transpiration water consumption

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Biotic stresses - Oral session

New technologies improve the use Cleruchoides noackae (Hymenoptera: Mymaridae) in biocontrol of Thaumastocoris peregrinus (Hemiptera: Thaumastocoridae) in Eucalyptus Plantations

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The bronze bug *Thaumastocoris peregrinus* Carpintero and Dellapé (Hemiptera: Thaumastocoridae), is an exotic sap-sucking insect introduced in Brazil in 2008, causing *important losses in Eucalyptus spp. wood production.* The attacked area by the pest reach 245.000 ha in 2012, but in 2016 the area decreased to 80.000 ha. The main management strategy for *T. peregrinus* is biocontrol using an egg parasitoid *Cleruchoides noackae* Lin and Huber (Hymenoptera: Mymaridae) introduced in Brazil from Australia in 2012. Two mass-rearing protocols for *C. noackae* were developed by Embrapa Florestas and are available for researchers, forestry companies and farmers. Since 2012, *C. noackae* was released in many states from Brazil: Minas Gerais, São Paulo, Espírito Santo, Bahia, Rio Grande do Sul, Mato Grosso do Sul, Paraná, Distrito Federal, Goiás, Tocantins, Piauí and Maranhão. The establishment of *C. noackae* in the field was confirmed for Minas Gerais, São Paulo, Espírito Santo, Bahia, Rio Grande do Sul and Maranhão states. Field and laboratory evaluations showed that *C. noackae* presents a parasitism rate of 50%. The duration of the parasitoid life cycle (egg-adult) is affected by temperature, ranging from 14 (30°C) to 46 days (15°C). The storage of *T. peregrinus* eggs for 15 days at 5°C is viable for the multiplication of *C. noackae* in laboratory, without affecting the reproduction and development of the parasitoid, and the storage period of parasited eggs with six days of development is viable during 7 days at 5°C. The supplies of food containing honey plus pollen increase the parasitism, longevity and survival of *C. noackae.* Thus, as temperature affects *C. noackae* field establishment and parasitism rate the climatic changes will interfere directly on its effectivity as biocontrol agent. Storing eggs and providing food supply are tools which help optimize a mass-rearing of *C. noackae* and provide flexibility for field releases and management of the bronze bug in Brazilian eucalypt plantations.

*Speaker

Keywords: bronze bug, insect pest, bilogical control, temperature, rearing

The use of molecular techniques to understand pest introductions and pest complexes

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Over the last decade the productivity of *Eucalyptus* plantations has been challenged by a rapid increase in invasive pests. This is due to an increasing number of accidental insect introductions, which include gall-forming wasps. Many of these introduced species lack taxonomic descriptions, and detailed information regarding their biology is sparse or unknown. Molecular tools have been valuable in species identification, especially for the delineation of cryptic species. One of the most threatening insect pests to *Eucalyptus* plantation forestry is the gall-forming wasp *Leptocybe invasa.* This wasp is native to Australia, and was first reported outside its native range from Israel in 2000. Since then it has spread globally and was originally thought to represent a single lineage. Application of molecular techniques, however, indicated a second lineage, as well as admixture between the two lineages in some regions. There is increasingly also a number of other native and introduced hymenopterans that are now associated with *Leptocybe* galls in many parts of the world. For example, eight years after the first report of *L. invasa* in South Africa, a second lineage was reported. Subsequent field surveys indicated the presence of a complex of six hymenopterans associated with these *Eucalyptus* galls. This necessitated the development and application of molecular tools such as species specific primers and restriction enzyme profiles to study the distribution and ecology of these wasps on a large scale. Such information is critical for the management of this pest, and illustrates the importance of molecular genetic information to manage an increasingly complex pest community in *Eucalyptus* plantations globally.

Keywords: invasive species, plant galls, plantation forestry, gall, forming complex

*Speaker

Community of parasitoids associated with Gonipterus weevils on Eucalyptus species in Tasmania

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An increasing number of invasive insect pests has been observed in *Eucalyptus* plantations outside Australia. Among these, the eucalyptus weevils *Gonipterus* spp. are major insect pests. Both larvae and adults feed on foliage, causing tree growth reduction and consequent economic losses. An egg parasitoid, *Anaphes nitens* (Girault) (Hym: Mymaridae), is the only biological control agent successfully established and regulating *Gonipterus* spp. in many regions. However, it achieves low parasitism rates in particular areas where *Gonipterus platensis* (Col: Curculionidae) has established, such as in high-altitude eucalypt plantations in the Iberian Peninsula, which have a high economic value. In these cases there is a need to find complementary biological control agents. In 2016 we conducted an exploratory survey in Tasmania, the native region of *G. platensis*, to find parasitoids associated with *Gonipterus* species there, with a view of using these as future biological control agents. We collected *Gonipterus* egg pods from eucalypts growing on road-sides. When both *Gonipterus* larvae and an adult parasitoid emerged from the same egg pod, we used a sister larva to identify the *Gonipterus* species using molecular tools. The distributions of the *Gonipterus* and parasitoid species through the surveyed locations were determined, resulting in a distribution map and list of egg parasitoids found in association with *Gonipterus* species. Studies on *Gonipterus* larvae and their parasitoids should also be conducted to identify other suitable biological control agents that could be released outside of Tasmania against *Gonipterus* pest species.

Keywords: Biological Control Agent, Anaphes, Insect pests, Interactions, Parasitism

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Multiscale remote sensing of plant pathogens: Detecting and monitoring myrtle rust

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Australia's natural and managed landscapes, dominated by the plant family Myrtaceae, are under threat from a devastating, invasive disease called myrtle rust (*Austropuccinia psidii)*. Already, the lemon myrtle (*Backhouse citriodora*) essential oil industry has suffered yield losses up to 70 percent per year. Due to recurring infections, natural populations of several highly susceptible native plant species seem likely to go extinct. Reports of susceptibility within the eucalypts are escalating the problem as it suggests the potential of myrtle rust to affect the forestry industry in Australia, both native and plantation. Currently, detecting and monitoring disease outbreaks is only possible by eye. This method can be resource intensive and sometimes unreliable. Fungicides can only be applied once clear disease symptoms are visible, which is wasteful, ineffective and resulting in high costs. However, optical remote sensing techniques are well known for objective and reliable automated diagnosis of plant diseases. Combined with advanced data analysis techniques, sustainable and targeted pest management systems can be developed. This study aims at establishing a proof-of-concept for monitoring and detection of myrtle must. At the *Eucalyptus 2018* in Montpellier, we would like to present results of our recently published results (http://doi.org/10.1111/ppa.12830) where we could discriminate healthy and infected lemon myrtle trees with an accuracy of 95% based on their leaf spectral characteristics. In detail, we would like to present (i) the results of our study published in *Plant Pathology*; (ii) a self-designed myrtle rust-specific vegetation index and introduce an approach to validate this index with multispectral aerial imagery. Finally, we would like to iii) provide an outlook on upcoming projects, especially on spectral data we collected for other pathosystem.

Keywords: hyperspectral field spectrometry, multispectral remote sensing, Myrtaceae, plant disease management, precision agriculture

*Speaker

Biological control of Australian-origin eucalypt plantation pests requires international collaboration

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Australian-origin pests of eucalypts have been moving around the world since 1873. Since the 1990's, the invasion of new eucalypt pests has increased almost exponentially with rapid subsequent invasion of these pests into new countries and across continents. Traditional approaches to classical biological control, where individual countries or regions funded natural enemy searches and carried out the required specificity testing and released the agents, were effective when rates of invasion were low and with slow subsequent movement between countries and continents. These approaches are less able to cope with multiple new pests arriving in rapid succession. A more collaborative and coordinated approach to biological control of these pests was thus required, where funds and expertise can be more cost-efficiently pooled and shared to develop effective biological control for eucalypt plantation pests. The Biological Control of Insect Pests Alliance (BiCEP) was developed by industry and researchers worldwide to attempt to solve this problem. BiCEP carries out collaborative research in Australia and overseas on biological control of the key invasive pests prioritised by its industry partners. Approaches used in this collaboration include conventional surveys for endemic natural enemies in Australia, genetic characterisation of these agents and climate matching with invaded countries. Key outcomes from current research and future directions will be presented.

Keywords: Eucalyptus, pests, biological control, Australia, forest health, pest management

*Speaker

State-of-the-art and research strategy for tree protection in commercial Eucalyptus forestry in Uruguay

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Eucalyptus plantations cover around 800000 ha in Uruguay, mostly with monospecific or clonal stands, 90% of which are under FSC and/or PEFC certification. Exports of *Eucalyptus* derived products reached 1500 million US dollars in 2017. More than half of the sanitary problems currently affecting *Eucalyptus* species have entered the country after 1995. Being a country of 3.3 million inhabitants in 176215 km2 makes it necessary to come up with collaborative strategies to keep pace with the constant introduction of new sanitary issues. We describe the current phytosanitary status of *Eucalyptus* tree plantations in Uruguay and discuss the strategy followed to allocate research efforts. At present, the most frequent sanitary problems of *Eucalyptus* trees include 12 insects and 14 pathogens. The strategic agenda regarding pest management is discussed in two interinstitutional spaces: The CECOPE and the GIPF. The CECOPE is a commission seated at the Ministry of Livestock Agriculture and Fisheries, where the political agenda in tree health is agreed with representatives from the private sector and the academia. The GIPF gathers forest scientists from different institutions to discuss the scientific approaches and funding strategies to follow. Research focuses on biological control and tree breeding as the primary management strategies for insect pests and diseases, respectively.

Keywords: phytosanitary problems, biological control, tree breeding, inter institutional collaboration

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A Genome-Wide Association Study in Eucalyptus grandis reveals genomic regions and positional candidate genes for the insect pest, Leptocybe invasa

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The galling insect, *Leptocybe invasa,* causes significant losses in plantations of various *Eucalyptus* species and hybrids, threatening its economic viability. We applied a Genome-Wide Association Study (GWAS) to identify single nucleotide polymorphism (SNP) markers associated with resistance/susceptibility to *L. invasa.* A total of 563 insect-challenged *E. grandis* trees, from 61 half-sib families, were genotyped using the EUChip60K SNP chip and we identified 15,445 SNP markers that were informative in the test population. Multi-Locus Mixed Model (MLMM) analysis identified 31 SNP markers putatively associated with resistance/susceptibility to *L. invasa* based on four discreet classes of insect damage scores. MLMM analysis identified four associated genomic regions on chromosomes 3, 7 and 8 jointly explaining 17.6% of the total phenotypic variation. SNP analysis of a validation population of 494 *E. grandis* trees confirmed seven SNP markers that were also detected in the initial association analysis. Transcriptome profiles of resistant and susceptible genotypes from an independent experiment identified several positional candidate genes in associated genomic loci including NB-ARC and TIR-NBS-LRR genes. Our results suggest that *Leptocybe* tolerance in *E. grandis* may be influenced by a few large effect loci segregating in our test and validation populations. In ongoing work, we are interested in *E. grandis* terpene profiles associated with resistance against the insect pest and aim to identify SNP associations with such terpenes.

Keywords: Genome, Wide Association Study, Linkage Disequilibrium, Single Nucleotide Polymorphism, Quantitative Trait Locus, Multi Locus Mixed Model

*Speaker

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Sustainable management of the eucalyptus weevil Gonipterus platensis – state of the art IPM tools and strategies

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Native to Australasia, weevils of the genus *Gonipterus* (Col., Curculionidae) feed on eucalyptus young leaves, buds and shoots causing reduced tree growth and mortality. *Gonipterus platensis* is the main coleopteran defoliator of eucalyptus worldwide, being also present in Spain and Portugal, where eucalyptus plantations jointly occupy about 1.4Mha. In Portugal, economic losses caused by the eucalyptus weevil attained 648.M Euros over a period of 20 years, in spite of biological control being exerted by the egg parasitoid *Anaphes nitens* (Hym., Mymaridae). Yet, in cooler regions the parasitoid proves inefficient, so that the potential use of other *Anaphes* species is under study. Chemical control, mostly resorting to a chitin synthesis inhibitor has been applied, yet results were inconsistent and environmental impacts can occur. Aiming at the sustainable management of *G. platensis* an integrated approach appears indispensable, although a diversified range of tools is required, namely: i) Population monitoring based on sampling, coupled with teledetection to assess defoliation rates and inform decision making on treatment applications; ii) Genetic selection of eucalyptus clones showing reduced susceptibility to the weevil; iii) Release/augmentation of biological control agents, in combination with biotechnological strategies; iv) Biotechnological control, based on the use of semiochemicals - both volatile organic compounds (VOCs) released by the host trees as well as pheromones emitted by the weevils, having attractant, deterrent or repellant effects on conspecifics and/or natural enemies. In general, research conducted to develop the proposed tools yielded promising results and is in progress. The strategies envisaged to be implemented in eucalyptus plantations include push–pull techniques, use of trap crops, attraction of natural enemies, weevil repellency and/or oviposition deterrence.

Keywords: eucalyptus snout beetle, IPM, biotechnological control, semiochemicals

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Defoliation assessment in Eucalyptus globulus plantations through the use of multispectral cameras mounted on a UAV

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Eucalyptus globulus plantations are threatened by a defoliator weevil, *Gonipterus platensis*, which is responsible for the loss of high volumes of timber, especially in Portugal and the north of Spain. Assessing defoliation levels is crucial for predicting wood loss and undertaking pest control and forest management decisions. Harnessing the advantage of remote sensing tools to acquire high resolution images, the aim of this study was to assess defoliation using vegetation indexes built from NIR (*Near Infrared*) and RE (*Red Edge*) multispectral cameras mounted on a fixed-wing *UAV (Unmanned Aerial Vehicle)*. For this purpose, an experimental network was set up across 4 study areas in Portugal and Spain with plots of differing damage intensity. Defoliation level within each plot was measured using a 7-level scale. Coinciding with different attack periods and in parallel with the damage inventory, several flights with both cameras were conducted, which resulted in 13 vegetation indexes being calculated in each of the zones. By means of *GLM (General Linear Model)* statistical analysis, the values of the vegetation indexes were then compared with the field measurements to identify those that best describe the variability of the defoliation. We found significant differences in some of the values of the vegetation indexes to estimate the different levels of defoliation when compared to the field data, especially when these levels are high. The indexes based on the red edge band showed the greatest sensitivity. In conclusion, multispectral cameras mounted on *UAV*s proved to be useful to monitor Eucalyptus defoliation, and can serve as a support tool for the monitoring and control of *Gonipterus platensis*.

Keywords: Gonipterus platensis, Near Infrared (NIR), Red Edge (RE) vegetation indexes, damage inventory

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The plant endophytic microbiome and biosecurity: Hidden threats to global Eucalyptus forest health

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The emergence of new pathogens that threaten plant health has shown a marked increase during the course of the last two decades. The movement of plant material, especially live plants, is broadly recognized as one of the most important pathways for the introduction of these new pathogens. Plant quarantine systems that aim to address this pathway of introduction rely on visual inspection for disease symptoms or damage, screening for known pests or pathogens, or in some cases treatment of material prior to importation. None of these systems consider the fact that the endophytic microbiome associated with healthy above ground plant parts might harbor potential harmful microbes. This is because many plant pathogens have an extended asymptomatic infection stage, which can extend for many years. Furthermore, some plant pathogens including those of *Eucalyptus* are common asymptomatic endophytes in plants other than those on which they cause disease. We argue that the current phytosanitory approaches are out of touch with the knowledge of endophytes. Importantly, also that these communities should receive more focused attention as a pathway that is relevant to biosecurity. Research during the course of the past 25 yaers on the endophytic microbiome of *Eucalyptus* provides a solid foundation to better understand an important cryptic threat to *Eucalyptus* forestry globally.

Keywords: Forest health, biosecurity, microbiome, endophyte, invasive forest pathogens

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Potential of Anaphes inexpectatus as a biological control agent of the Eucalyptus snout beetle, Gonipterus platensis

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The Australian weevil *Gonipterus platensis* (Marelli) (Coleoptera: Curculionidae), commonly known as the Eucalyptus snout beetle, is one of the main pests of eucalypts. Because this is a non-native insect, classical biological control with natural enemies from its region of origin should be a viable control strategy. The introduction of the Australian parasitoid *Anaphes nitens* (Girault) (Hymenoptera: Mymaridae) has been the main method to control the pest worldwide. However, this natural enemy is not completely effective in reducing *G. platensis* populations and does not avoid the occurrence of damage in several regions. Given the insufficient efficacy of *A. nitens*, other Australian natural enemies that could be used in a classical biological control programme have been evaluated. From a set of eight natural enemies identified in Tasmania, we selected the egg parasitoid *Anaphes inexpectatus* Huber and Prinsloo (Hymenoptera: Mymaridae) for further studies. Laboratory studies comparing the biology of *A. inexpectatus* and *A. nitens* at different temperatures, a competition study between these two species, and a risk analysis for the introduction of *A. inexpectatus* in the Iberian Peninsula were carried out. Overall results suggest that *A. inexpectatus* might complement parasitism by *A. nitens* under field conditions without non-target effects on native fauna.

Keywords: Classical biological control, Natural enemy, Parasitoid, Ecological risk assessment

*Speaker

Resurgence of Gonipterus platensis in Eucalyptus plantations in South and Southeast regions of Brazil

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The Eucalyptus snout beetle (ESB) *Gonipterus platensis* (Coleoptera: Curculionidae) is one of the most widespread eucalypt pest in the world. In Brazil this pest was detected in 1955 in South Brazil and has been spread to Southeast in last 50 years. The ESB has been considered under control due the parasitism by its egg parasitoid *Anaphes nitens* (Hymenoptera: Mymaridae) in five Brazilian States. In December 2012 a new outbreak was recorded in South region of Sao Paulo State, causing intense defoliation in clonal plantations. Early evaluations have demonstrated a reduced parasitism rate in this region (30-60%). Nowadays, ESB has spread for new areas in Sao Paulo State and in Parana State, affecting more than 20,000 ha of Eucalyptus plantations in 2016 and reducing the MAI in 10.2 to 42.8 m3/ha/year, according *Eucalyptus* clone and age. Ongoing studies have showed the reduced *A. nitens* effectiveness may be related with the occurrence of some endosymbionts (*Rickettsia*, *Serratia* and *Yersinia*) in the parasitoid, affecting parasitoid reproduction. Other possible cause is the occurrence of a parasite mite in egg clusters (genus *Pyemotes*), affecting viability of *G. platensis* eggs, including parasitized eggs. New management strategies have been proposed, including introduction of new *Anaphes* species (*A. tasmaniae* and *A. inexpectatus*) for eggs, bioinseticides application, with *Beauveria bassiana, Metarhizium anisopliae* and *Bt* var. *tenebrionis* for larvae, use of entomopathogenic nematodes to control pupae in soil and predatory bugs (*Podisus nigrispinus*) to control adults

Keywords: Eucalyptus snout beetle, biological control, IPM, forest pest, parasitoid

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Biotic stresses - Lightening talks

Evaluating the performance of new Eucalyptus globulus genotypes using an experimental trial approach

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Eucalyptus globulus plantations are one of the main sources of pulpwood in Southern Europe. Spain and Portugal supply approximately 25 million m3 per year of eucalypt wood for the pulp and paper industry. In order to identify high productivity genotypes adapted to different environmental conditions, we established a program to evaluate new genotypes performance, rapidly and at low cost. This study established an experimental plot network to evaluate the performance of *E. globulus* plant materials genetically improved by Eucalypt European companies (clones and seeds) under different soil and climatic conditions. Five experimental trials (3-6 ha each) with a replicated block design that included 11-14 genotypes in each were established in northwest Spain from 2014 to 2018. Tree growth and impact of *Mycosphaerella* sp. and *Gonipterus platensis* where quantified by classical methods (forest inventory and canopy scoring) and through the use of remote sensing. There were significant differences in survival rate, and productivity between genotypes and trials, showing strong genotype-environment interaction. A specific genotype was the most productive at all trial sites. There were significant differences in biotic damage between genotypes. Only one genotype was resistant to *Mycosphaerella*. The information derived from this pioneer trial in Europe can provide relevant information to select the best genotypes in terms of growth and resistance to diseases according to site characteristics for the forest industry.

Keywords: Eucalyptus globulus, genotype performance, clone selection, production, biotic damages

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Behavior of different Eucalyptus species, hybrid and provenances to natural infestation of Leptocybe invasa

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The pest occurrence in forest plantations is increasing over time and has negative impacts on wood production. This occurrence is influenced by genotype and environmental conditions, so climate changes can interfere in pest occurrence maps. In 2008, the exotic pest *Leptocybe invasa* (Hym: Eulophidae), known as blue gum chalcid, has been introduced in Brazil causing damage in many regions of the country. The objective of this work was to evaluate the progenies behavior of *Eucalyptus grandis* (Anhembi and Itatinga provenances), *E. urophylla* (Anhembi and CSIRO), *E. camaldulensis* (Selvíria) and *E. urophylla* x *E. grandis* (Anhembi and Itatinga) exposed to natural infestation of *L. invasa* in two seasons of the year (winter and summer). The severity of attack on seedlings was evaluated, this way: healthy (absence of pest attack); only signs of oviposition and gall formation. A difference in the two evaluations was observed with higher pest incidence in summer than winter. *E. urophylla* was the least attacked, where 90% of the seedlings were healthy, whereas *E. grandis* showed the highest number of seedlings with galls (30%). The hybrid *E. urophylla* x *E. grandis*, showed intermediate results between the two species. It's possible to note some differences in susceptibility between *E. urophylla* provenances, Anhembi provenance presented 90% of healthy plants, whereas CSIRO presented only 51%. For the other species, the differences in provenances were not so expressive. *E. camaldulensis* was the species that surprised, once it was expected to present the highest incidence of galls, but it had a high incidence of oviposition (60%) and small incidence of galls ($< 10\%$), probably due to the studied provenance or pest preference for other species. The progenies presented significant differences in relation to *L. invasa*, showing that the genetic control is possible with the selection of tolerant material, considering not only the species but their provenance/origin and progeny.

Keywords: Eucalyptus, exotic pest, forest breeding, forest protection

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Ecophysiological Disorder of Eucalyptus (EDE): development of a predictive model for disease management in Brazil

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During 2010 and 2015, Eucalyptus plantations of south Bahia state (BR) was highly impacted by the disease called Ecophysiological Disorder of Eucalyptus (EDE). EDE is a disorder with a complex etiology, originated by the combination of biotic and abiotic disturbances. In order to understand the specific causes of its occurrence, a business intelligence software from SAP (Predictive Analytics©) was used to analyze large datasets and predict behaviors. The databases of climate, soil, genetic material, site quality and forestry activities used totaled 735 million entries. From 350 variables analyzed, the 13 most significant were selected. The model presented 85.18% of predictive power (KI), 98.28% of prediction confidence (KR) and 87.93% of classification rate. Environmental variables were the main factors that explained the occurrence of EDE. The outputs of the model allowed the elaboration of a risk map of EDE. According to the risk levels, the deployment of eucalyptus clones considered the level of resistance and the risk of occurrence of EDE. The use of this information, as well as other improvements in forest management for high risk areas, were sufficient to recover wood productivity projections, becoming the first application of the bigdata analysis technology to solve a forestry problem in Brazil.

Keywords: bigdata, predictive analytics, abiotic stress

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Austropuccinia psidii has sex on Myrtaceae, increases genotypic diversity in invaded ecosystems and potentially threatens Eucalyptus forestry

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Different strains of *Austropuccinia psidii*, the cause of a rust disease of *Eucalyptus* and other Myrtaceae, have invaded new areas and infected hosts that were naïve to this pathogen. There was evidence that this rust on *Eucalyptus* spread by its clonal spore stage and that recombination was uncommon, even in areas in which it was native. However, we were able to show that basidiospores (the gametic spores) of *A. psidii* infected species of Myrtaceae and recombination was part of the life cycle. A knowledge gap for investigation was whether recombination occurred in natural ecosystems. We used microsatellite markers to test whether recombination and infection by basidiospores had occurred in invasive populations from New Zealand and South Africa. Several signs of recombination included presence of the sexual stage (teliospores), genotypic diversity within a strain, and many possible recombinant multilocus genotypes within a population. The Index of Association for populations from New Zealand and South Africa supported that microsatellite markers were not linked and these populations were recombinant. Our findings show that teliospores and basidiospores play a role in the life cycle and spread of disease. They also raise questions relevant to *Eucalyptus* forestry such as whether different strains of *A. psidii* can outcross and overcome disease resistance.

Keywords: disease resistance, myrtle rust, population biology, recombination

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†Speaker

Monitoring exotic pests and their natural enemies with a Trap Network design based on Climatic Zoning for Eucalyptus in Brazil

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Integrated Pest Management (IPM) is a silvicultural tool for the detection, monitoring and control of insects to maintain the forest productivity. Suzano Pulp and Paper has silvicultural operations in more than 550,000 ha of *Eucalyptus* plantations under subtropical, tropical and equatorial climatic conditions, and the Red gum lerp psyllid (PSC - *Glycaspis brimblecombei*) and Bronze bug (PVB - *Thaumastocoris peregrinus*) are the most important exotic pests. A network, "RAPID", of 476 yellow sticky traps (YST) were distributed across the forest plantations, stratifying by climatic zones, to provide an infrastructure for fast and efficient detection of pests and their natural enemies. Every 30 days the YST are replaced and the insects of interest and their natural enemies quantified, totaling more than 5,000 traps in 2017. PVB was observed between June and December in the northern region of Brazil with peak occurrence coinciding with high soil water deficit in November. PVB was also observed in low frequency and population in tropical and subtropical regions, which may be associated with the simultaneous detection of its parasitoid *Cleruchoides noackae*. PSC was counted in at least one YST throughout the year and in all climatic zones, except for the wetter months (February and April) in the north of the country, when rainfall accumulation was greater than 800 mm. Similarly, *Psyllaephagus bliteus*, PSC's parasitoid, was observed in all regions contributing to the natural biological control of this pest. Both pests increased their populations in the driest months and their natural enemies directly influence the population dynamics. When used in a systematic and organized way, YST is attractive and effective for pest detection, even when in low population, generating operational alerts for pest control.

Keywords: Bronze bug, Red gum lerp psyllid, climatic variability

*Speaker

Application of DNA markers in breeding for resistance to Teratosphaeria in E. globulus

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Teratosphaeria leaf disease (TLD) is an important pathogen of *E. globulus* plantations in Australia and the incidence of TLD is increasing, particularly in plantations due to uniform age and reduced genetic diversity. Resistance to the disease is under moderate to strong genetic control; however, resistance is expected to be controlled by many genes making breeding using phenotypic selection a slow and arduous task.

We used a candidate gene-based association studies approach to discover molecular markers controlling TLD resistance. An *in-house* genotyping method was used to genotype large numbers of markers. We observed several markers associated with TLD resistance. Genomic selection models were used to predict disease resistance using unrelated populations. High predictive ability i.e. ability to predict disease phenotype using just the genotype data was observed when all the markers were used in the prediction model.

These results indicate that markers from this study can be used to predict resistant genotypes at seedling stage. Markers identified in this study can be combined with markers developed for other commercial traits such as wood quality and growth to select lines that contain favorable alleles of different traits.

Keywords: Genomic selection, Marker, assisted selection, predictive ability, association studies, disease resistance

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Biotic stresses - Poster session

The occurrence rule and control technology of Dappula tertia Templeton, a pest of Eucalyptus

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Dappula tertia Templeton (1847) is a severe pest of *Eucalyptus* plants. This pest is mainly distributed in India, Australia and Solomon islands. In China, it is mainly distributed in Guangxi, Guangdong, Hainan, Fujian, Hunan, Hubei, Jiangxi and Zhejiang. *D. tertia* larvae consume a large amount of leaves, branches and barks, and therefore adversely affect the growth of *Eucalyptus* trees. In this study, we investigated the biological and ecological characteristics of *D. tertia*, as well as the control tactics of this pest. The main results were:.1)*D. tertia* had one generation per year in Guangxiand overwinters as pupae. The adults began to appear in the middle February and reach the peak in the middle and the late March. The oviposition peak of adults was observed in the late March and the early April. Each female laid 1,500 to 2,000 eggs, which hatched in _˜ 20 days. The larvae began to appear in the late March, and reached a peak in the middle and the late April. The most serious damage of *D. tertia* larvae appeared in June and July. The first hatching larvae climb out of the bag, the dropped with the help of silks. They produced a bag with the fragments of leaves. After the middle September, they began to pupate. In general, the larvae were most active at 8:00_˜1100 and 1700_˜1900. The larvae period was very long, which had 5 instars. The head width of different instars follows the growth regularity of larvae head width that was described by Dyar. Adults fed on honey and dew solution, and their longevity was ranging from 10 to 15 days. The adults were sexual dimorphism. The male moths length 1725 mm and wingedand the female adults length 1625mm, with light yellow, and were apterous. 2)The spatial distribution of *D. tertia* in forests was measured to belong to an aggregated distribution pattern.3)The feeding preference of *D. tertia* to 3 *Eucalyptus* species was tested by the leaf-dish method. *D. tertia* larvae consumed more leaves of *E. urophylla* than that of *E. robusta* and *E. Protruding*. The larval preferences in response to different ages of *Eucalyptus* leaves were also observed.4)Four pesticides were evaluated for their effect on *D. tertia* control. 5)Other control methods, including manually removing of the pouch, cutting off the infested branches, and focusing on burning or crushing also showed potential for *D. tertia* management.

Keywords: Eucalyptus sp.Dappula tertia Templotonoccurrence rule, control method

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Eucalyptus species and logs age effect on development of Phoracantha recurva (Coleoptera, Cerambycidae).

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The woodborer, *Phoracantha recurva,* was detected in Tunisia in 1999. Its population has increased at the expense of that of its congener *P. semipunctata* detected in 1962. The present work presents the effect of *Eucalyptus* species on development of *P. recurva* through field and laboratory experiments. In the field, logs of three *Eucalyptus* species, *E. camaldulensis*, *E. gomphocephala* and *E. astringens* were exposed in Mai, June and July 2013. Two months later, logs were brought and stored until adult emergence. In the laboratory egg masses of *P. recurva* were stapled on the bark of three lots of *E. camaldulensis* logs aged of 30 days, 7 days and logs cut the same day of experiment (0 day) and on logs of *E. astringens* aged of 7 days. Fifteen days later, egg masses were retrieved to determine the hatching percentage. Every three days, emerging adults have been collected and sorted by sex. The size of the right elytra of each adult was measured. After adult emergence, all logs were debarked to determine the survival of young and aged larvae, by counting larval galleries, percentage of emergence and offspring productivity. In the field as well as in the laboratory rearing, adult emergence from *E. camaldulensis* and *E. gomphocephla* logs began in the same year of the experiment (2013), whereas, from *E. astringens* logs, all adults emerged the next year (2014). On *E. camaldulensis*, more young larvae reached the sapwood of logs aged of 30 days than those aged of 7 and 0 days. Percentage of larvae reaching aged stage was higher on logs aged of 30 and 7 days which were more productive of adults. Comparing *E. camaldulensis* to *E. astringens*, and despite the same percentage of young larvae that penetrate the bark, the first one was more productive of adults. Emerging adults from *E. camaldulensis*, have the longer elytra than those from the *E. astringens*.
It appears that *E. astringens*, is less adequate for the development of *P. recurva* and fresh logs are more adequate for this development.

Keywords: Phoracantha recurva, Eucalyptus, host suitability, logs age, larvae survival, development.

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An online mitochondrial DNA sequence database to support pest management research in Eucalyptus and Pinus plantations

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Insect pests threaten the sustainability of *Eucalyptus* and *Pinus* plantations worldwide. The accurate and rapid identification of such insect pests is, however, often a challenge and this has implications for management and quarantine decisions. Accurate identification is frequently delayed or not possible due to the shortage of taxonomists and the shortcomings of morphological comparisons for identifying cryptic lineages. Common sequence barcoding methods can assist to overcome these challenges, but such databases are often poorly curated and incomplete with respect to organisms of interest to a specific sector, such as forest plantations. For these reasons we developed the forest insect mitochondrial (FIMT) online database to serve as a tool for rapid identification of insects associated with *Eucalyptus* and *Pinus* trees. The database contains sequence data produced from insect pests and their biological control agents using two mitochondrial DNA regions, namely Cytochrome Oxidase I (COI) and Cytochrome b (CYBB). The sequences in the database are curated and linked to metadata about hosts and distribution, which can be linked to a sequence from an unknown specimen. The increasing global spread of invasive insect pests associated with *Eucalyptus* and *Pinus* requires international collaboration on surveys in the native and non-native areas, including sharing of information on the identification of insect pests and their possible biological control agents. The FIMT database can support these efforts through accurate identification and linking sources of information.

Keywords: invasive species, molecular database, species identification

*Speaker

The role of Hymenoptera associated with Leptocybe invasa (Eulophidae: Hymenoptera) galls in South Africa

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The wasp *Leptocybe invasa* is native to Australia and induces galls on *Eucalyptus* trees. Since 2000, it has been detected outside its native range, with two genetically distinct lineages (lineage A and B). Lineage A has been reported worldwide, whereas lineage B has a more limited distribution in Asia and Africa. Since the release of the parasitoid wasp, *Selitrichodes neseri*, in South Africa, three other hymenopteran species were noticed emerging from *L. invasa* galls. These include *Quadrastichus mendeli,* which is a parasitoid of *L. invasa*, *Megastigmus zebrinus* and *M. pretorianensis*. The role of the latter two species is yet unknown. The objective of this study was to determine the nature of the interactions between the different gall-associated hymenopterans. *Leptocybe invasa* galls were dissected and interactions within a single gall cavity were observed. For each interaction, DNA was extracted from the individual wasps. Species-specific primers and restriction enzymes were used to identify larvae through comparison with identified adult specimens. The results indicated that *S. neseri* was capable of feeding on both lineages of *L. invasa,* while *M. zebrinus* fed on *S. neseri* and *L. invasa* (Lineage A). *Megastigmus pretorianensis* was found coinhabiting galls containing *L. invasa*, but parasitism of *L. invasa* could not be confirmed. These data will form the basis for further observations and experiments to characterize the ecology of this unique community in South Africa.

Keywords: Eucalyptus, Leptocybe invasa, Selitrichodes neseri, gall wasp, gall community

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†Speaker

Botryosphaeriaceae from Eucalyptus plantations in YunNan Province, China

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The fungus family Botryosphaeriaceae includes pathogens of a wide range of woody plants worldwide. In 2014, field surveys were conducted in YunNan Province showed that *Eucalyptus* plantations were threatened by diseases and that stem canker and die-back caused by Botryosphaeriaceae were amongst the more serious problems. The aims of this study were to identify the Botryosphaeriaceae isolated from diseased branches and shoots in the YunNan Province. This was achieved using multigene phylogenetic analyses based on DNA sequence data for the internal transcribed spacer regions and intervening 5.8S nrRNA gene, partial translation elongation factor 1 alpha, β-tubulin, DNA-directed RNA polymerase II subunit, the nuclear ribosomal large subunit and the nuclear ribosomal small subunit as well as by comparing morphological characteristics. Pathogenicity of these species was also tested on *E. urophylla* $\times$ *E. grandis* and *E. globulus* seedlings. A total of 166 Botryosphaeriaceae isolates were selected for study. The results showed that 11 species resided in the genera *Botryosphaeria* (52 isolates), *Lasiodiplodia* (2 isolates) and *Neofusicoccum* (112 isolates). These species included *B. fusispora*, *B. wangensis*, *L. pseudotheobromae*, *N. kwambonambiense*, *N. parvum*, one novel species of *Botryosphaeria* and five novel species of *Neofusicoccum*. Pathogenicity tests showed that all 11 species were pathogenic to the tested *Eucalyptus* plants and that one *L. pseudotheobroame* isolate was most virulent. Overall, the results revealed that there is a high level of Botryosphaeriaceae diversity on *Eucalyptus* plantations in YunNan Province and that some of these are likely to affect tree health in the future.

Keywords: Botryosphaeria, Lasiodiplodia, Neofusicoccum, Pathogenicity, Plant pathogen

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Characterization of the mating type (MAT) loci in Calonectria species pathogenic to Eucalyptus

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The genus *Calonectria* includes many important pathogens that cause or are associated with important plant diseases including those of *Eucalyptus*. Understanding the reproductive biology of *Calonectria* species will better inform our ability to contain their spread and effect their management. Pursuing this objective, we identified and characterized for the first time, the structure of the mating type locus in a collection of *Calonectria* species. This was achieved by sequencing the genome of a strain of *Calonectria hongkongensis* that is self-fertile and resides in the Sphaero-Naviculate Group of species and two strains of *Ca. pauciramosa* known to be self-sterile and reside in the Prolate Group of species. The results confirmed that *Ca. hongkongensis* is homothallic having all the mating type genes (*MAT1-1-1*, *MAT1-1-2* and *MAT1-2-1*) in the MAT locus. *Calonectria pauciramosa* was confirmed as heterothallic with strains having either the *MAT1-1* idiomorph or *MAT1-2* idiomorph. The *APN2* (DNA lyase) and *SLA2* (cytoskeleton assembly control protein) genes were found to flank the *MAT* locus in all cases. Furthermore, the *MAT 1-1* locus of *C. pauciramosa* included a *MAT1-1-3* gene, which was not found in *Ca. hongkongensis*. Overall, the results of this study have provided substantial insights into the mating biology of selected *Calonectria* spp. and it will now be possible to expand this understanding to all species in the genus that infect *Eucalyptus*.

Keywords: Mating type, Sexual reproduction, Idiomorph

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Calonectria species from soils in Fujian Eucalyptus plantations revealed as highly diverse and putatively important pathogens

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To meet the growing demand for wood and pulp products, *Eucalyptus* plantations have been rapidly developed in China during the course of the past two decades. These plantations have encountered serious disease and pest problems such as blight caused by *Calonectria* species in the FuJian Province of Southeast China. In this study, surveys were conducted in five regions of FuJian Province and soil samples were collected in *Eucalyptus* plantations. As a basis for comparison, soil samples were collected from natural forests of *Cunninghamia lanceolata* and *Phyllostachys heterocycle* adjacent to the *Eucalyptus* plantations. A total of 101 *Calonectria* isolates were baited from soil and these were identified based on DNA sequence comparisons for the β-tubulin (*tub2*), calmodulin (*cmdA*), histone H3 (*his3*) and translation elongation factor 1-alpha (*tef1*) gene regions as well as using comparisons of morphological characters. Twelve *Calonectria* species were identified, including four known taxa (*Calonectria arbusta*, *Ca. pentaseptata*, *Ca. pseudocolhounii* and *Ca. pseudoturangicola*) and eight novel species. The novel species are in the process of being formally described. *Calonecctria. arbusta* was the most prevalent species, representing 47 % of all the isolates and it was found in all five regions surveyed. Pathogenicity tests showed that all 12 *Calonectria* species were pathogenic to three *Eucalyptus* clones and that *Ca. arbusta* and two undescribed species were most virulent. Overall, the results showed that *Calonectria* species are common in Fujian soils and that they are likely to challenge *Eucalyptus* plantation forestry in China in the future.

Keywords: Calonectria leaf blight, Forest pathogens, Phylogeny, Taxonomy

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The molecular mechanism of Buzura Suppressaria nucleopolyhedrovirus host range control

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Buzura suppressaria (Bs) is a serious eucalyptus pest in south of China, and causes grave economic losses every year. *Buzura suppressaria* nucleopolyhedrovirus (BsNPV) is an attractive biocontrol candidate to promote. But its' popularization and application are greatly restricted, because Bs can't be maintained in lab artificially. So it is expected that it can expand its host range specifically to solve these issues. Since *Bombyx mori* is a model species and its nucleopolyhedrovirus (BmNPV) is one of the most thoroughly researched baculovirus, recombinant virus was bred artificially based on BsNPV and BmNPV. The morphology of recombinant virus and parental virus were observated, it was found that shapes of viruses was similar between recombinant and parental virus, but the size was different, recombinant virus came from Bs was significantly smaller than which came from Bm. In addition, the virulence of recombinant virus was larger than parental virus'. Then genomes of BsNPV, BmNPV and the 3rd generation of recombinant virus were sequenced respectively. Characteristics of recombinant virus were similar with BsNPV, including GC content, size of genome, quantities and types of SSR, characteristic of homologous repeated sequences (HRS), quantities and order of genes, but was quite different from BmNPV. The genome of BmNPV and recombinant virus were sequenced with 3 repeats using high-throughput sequencing technology. Repeats of BmNPV were similar, but repeats of recombinant virus had more differences in quantities of genes, quantities and types of SSR and characteristic of HRS. There 57 genes in BsNPV had difference in at least one repeat of recombinant virus, and 29 genes in 57 were different between BsNPV and 3 repeats of recombinant virus. These genes were considered to be host range related genes. To confirm if every gene is related to host range, we would verify each gene using specific bacmid in further research.

Keywords: Buzura Suppressaria, nucleopolyhedrovirus, host range, recombinant virus, Bombyx mori

*Speaker

Leaf spots in Eucalyptus benthamii in southern Brazil

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Forest plantations are subject to biotic and abiotic stresses that cause damage and can affect growth and productivity. Among the diseases that occur in *Eucalyptus* plantations in Brazil, leaf spots caused by several types of fungal colonizers are of particular importance. The objective of this study was to identify and evaluate the intensity of fungal leaf spots in *Eucalyptus benthamii* progeny tests. The study included 91 progenies located in Porto União, Santa Catarina State, southern Brazil. The analysis of the diseased material was conducted using both direct and indirect methods of isolation. Incidence and severity were evaluated at 16 and 27 months of age, with incidence quantified as the number of trees with spots and severity evaluated based on a scale ranging from 0 to 4 (0 - without spots, 4 - more than 2/3 of the tree canopy with defoliation). The incidence of leaf spot was total in the evaluated individuals. Symptoms such as lesions and defoliation in the lower part of the crown have been verified up to 2/3 of the crown. The average severity of leaf spots in the first assessment was 2.4, and the second was 3.4, demonstrating a progression of the disease as the trees age. Isolates revealed the presence of *Calonectria* sp. (= *Cylindrocladium* sp.) with 47% frequency in the first assessment and 64.2% in the second. *Pestalotiopsis* sp. was also detected with a frequency of 35.3% in the first assessment and 28.1% in the second. The results indicate that *Calonectria* sp. is the main pathogen causing leaf spots in *E. benthamii*, which may have an impact on the species' productivity.

Keywords: biotic stress, leaf disease, Eucalyptus, fungus

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