ABSTRACT BOOK

medpine4

4th International Conference on Mediterranean Pines

halepensis

Pinus pinea

Pinus halepensis

Pinus brutia

Pinus nigra

Pinus pinaster

laricio

June 6-10 2011
Avignon - FRANCE

www.colloque.inra.fr/medpine4

INRA • Région PACA • Département VAUCLUSE • AVIGNON • Silva Mediterranea

EDITORIAL

On behalf of the organizing committee and of the Mediterranean Forest Ecology Research group of INRA, it is a great pleasure to welcome you in Avignon and to chair the 4th MEDPINE conference.

Initiated in 1999 in Mt Carmel in Israel, the cycle of MEDPINE conferences have already traveled to Chania in Greece and Bari in Italy. I would like to thank Gidi Ne'eman who initiated the first MEDPINE conference, and Margarita Arianoutsou and Costas Thanos, as well as Vittorio Leone, who chaired the second and third conference respectively. I would like to express my personal thanks to all the members of the International Scientific Committee for their help in shaping MEDPINE 4. I must finally thank all my colleagues of the local Organizing Committee for their dedicated work that made this event possible.

The main objective of the conference is to bring together researchers of all disciplines and studying Mediterranean pines in order to make a state of knowledge, to identify research gaps and make recommendations for sustainable management. The added complexity for all of us is climate change which is likely to be a major concern during the discussions. A special session will be dedicated to this issue on Thursday morning.

MEDPINE 4 is sponsored by the French National Institute for Agricultural Research (INRA), the City of Avignon, the Vaucluse Department, the Provence Alpes Côtes d'Azur Region, Silva Mediterranea from the Food and Agriculture Organization of the United Nations and the industry Fibre Excellence Tarascon.

More than 150 participants from 14 countries are in Avignon to discuss at MEDPINE 4 the ecology, conservation, restoration and management of Mediterranean pines and ecosystems. It is an opportunity to stimulate the multi-disciplinary dialog, strengthen the research community and build transectorial programs.

I hope this meeting will bring fruitful discussions and new partnerships.

Enjoy your stay in Provence.

Eric Rigolot
Chair of the Organizing Committee

Summary

SUMMARY

FIBRE EXCELLENCE

TARASCON

The Fibre Excellence mill, located on the shores of the Rhône in Provence since 1955, produces paper pulp.

Its production methods have evolved over the years : in 1958, it manufactured pulp from alpha sheets originating in North Africa. In 1958, production shifted to softwood pulp, and in 1963 the operation turned exclusively to softwood

To date, Fibre Excellence Tarascon uses fibre from southwestern France, generated by thinning processes that are an integral part of healthy silvicultural practices.

Many mediterranean species are concerned, such as black pine, scots pine and aleppo pine.

With an annual capacity of 260 000 tonnes of pulp, Fibre Excellence Tarascon sells 50 % of its products in France and in Europe, and exports the rest to Asia

Depending on the process used, pulp can be fashioned into many different kinds of paper, including printing and writting papers, papers for food-based and medical uses, packaging, decorating products and disposable products

In order to ensure high product quality, Fibre Excellence Tarascon is ISO 9001 certified and its products are subject to ongoing quality control.

Equally worried about environment and safety, it is also ISO 14 001, OHSAS 18001 et PEFC certified.

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AFAQ
QSE

PEFC
PEFC/10-31-155

Hosting Organisation
INRA, Mediterranean Forest Ecology (URFM),
Avignon, France

Scientific Committee
Eric Rigolot, INRA-URFM, *Avignon, France (Chair)*
Margarita Arianoutsou, *University of Athens, Greece*
Melih Boydak, *University of Istanbul, Turkey*
Philippe Dreyfus, *INRA-URFM, Avignon, France*
Bruno Fady, *INRA-URFM, Avignon, France*
Paulo Fernandes, *UTAD, Vila Real, Portugal*
Roland Huc, *INRA-URFM, Avignon, France*
Abdelhamid Khaldi, *INRGREF, Ariana, Tunisia*
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with the support of Carpe Diem Events

Biographical sketches of keynote speakers

Federico MAGNANI
University of Bologna, DCA, via Fanin 46,
I40127 Bologna, Italy,
federico.magnani@unibo.it

Federico Magnani is Associate Professor in Forest Ecology at the University of Bologna, Italy. He holds a MSc in Forestry from the University of Firenze, Italy, and a PhD in Forest Ecology from the University of Edinburgh, UK. His interest in plant water relations has expanded over the years to the subject of the response of photosynthesis to drought stress, with a specific focus on nonstomatal limitations (mesophyll conductance, biochemical limitations, photoprotection and photodamage) and on Mediterranean pines. Modelling tools have been applied not only to the analysis of physiological processes (in root water transport as well as mesophyll limitation analysis), but also to the scaling of this detailed information to a larger scale, in space and time, with the development of the socalled _Magnani model_ of resource allocation in response to age and the environment. More recently, the expansion of the focus to the global C cycle has led to the hypothesis that the terrestrial C sink could be largely constrained in northern latitudes by N availability through atmospheric N deposition. He is the author of more than 50 scientific papers and book chapters. He is a member of the Italian Academy of Forest Sciences and of the Italian Society of Forest Ecology and Silviculture.

medpine4

Efrat SHEFFER
Hebrew University of Jerusalem, Israel,
efratshe@bgu.ac.il

Efrat Sheffer is currently a graduate student in the PhD program at the Faculty of Agriculture of the Hebrew University of Jerusalem. Her research deals with Mediterranean ecosystem dynamics at different spatial scales, from individual tree growth and colonization to landscape analyses, and at organizational levels ranging from population dynamics to ecosystem processes. She is interested in both natural dynamics as well as anthropogenic impacts on Mediterranean ecosystems. Much of the research is designed to contribute knowledge that will support ecosystem management decisions. Her research combines empirical studies, field surveys, and modelling tools such as theoreticalphysical models, statistical inverse models (using maximum likelihood estimation methods) and spatial models (using GIS tools). Her PhD thesis research has been done in close collaboration with Dr. C.D. Canham, and for this purpose she spends some portion of each year at the Cary Institute of Ecosystem Studies. In the future she would like to continue working on largescale land-scape dynamics, focusing primarily on community dynamics and ecosystem processes in natural and anthropogenic forests. Sound management and conservation are going to require realistic models of the responses of these ecosystems to both deliberate and inadvertent human impacts.

Jon KEELEY
USGS Western Ecological Research Center
and Department of Ecology and Evolutionary
Biology University of California, Los Angeles,
USA, jon_keeley@usgs.gov

Jon Keeley is a research ecologist with the U.S. Geological Survey, stationed at Sequoia National Park in California and is an Adjunct Full Professor in the Department of Ecology and Evolutionary Biology at the University of California, Los Angeles. He has served in Washington, D.C. as director of the ecology program for the National Science Foundation and was professor of biology at Occidental College for 20 years. He has spent sabbatical leaves in all of the Mediterranean climate regions of the world. Dr. Keeley has over 300 publications in national and international scientific journals and books. His research has focused on ecological impacts of wildfires as well as historical changes in fire regimes and their impact on invasive nonnative plants. He has largely focused his work on Mediterranean-type ecosystems including studies of plant life histories, the physiology of seed germination, taxonomy of Arctostaphylos (Ericaceae) and the biochemical pathways of photosynthesis in aquatic plants. In 1985 he was awarded a Guggenheim Fellowship and is a Fellow of the Southern California Academy of Sciences and an Honorary Lifetime Member of the California Botanical Society. He is senior author of a Cambridge University Press book "Fire in Mediterranean Climate Ecosystems: Ecology, Evolution and Management" with coauthors William Bond, Ross Bradstock, Juli Pausas and Philip Rundel, to be published in 2011.

Jose G. BORGES
Forest Research Centre, College of Agriculture, Technical University of Lisbon, Portugal, joseborges@isa.utl.pt

Jose G. Borges holds a PhD from the College of Natural Resources, University of Minnesota, USA and is Associate Professor at the School of Agriculture of the Technical University of Lisbon, Portugal as well as member of its Forest Research Centre. He was member of the European Forest Institute Mediterranean Regional Office (EFIMED) Advisory Group and of the IUFRO Task Force on Information Technology and the Forest Sector. He has participated in research and teaching in several universities in Europe and in North and South America. Teaching and research interests are on the development of stand, forest and landscape level management models, on environmental resources management modelling and on the development of forest resources decision support systems. He has wide experience of participation and coordination of national and international research projects. He is coauthor of 43 international refereed publications and of over 100 other publications. Recent research on Maritime pine forestry has focussed on wildfire risk and damage modelling and on the development of mathematical programming and stochastic approaches to integrate wildfire risk in pine forests management planning.

Bruno FADY
National Institute of Agricultural Research (INRA), Ecology of Mediterranean Forest (URFM), Avignon, France, Bruno.Fady@avignon.inra.fr

Bruno Fady is a French geneticist with an ecology background and a 20-year experience in Mediterranean forest ecosystems. He graduated from the University of Paris "Pierre et Marie Curie" (BSc in Cellular Biology) in 1982 and defended his PhD in Ecology and Genetics at the University of Aix-Marseille in 1990. Since then, he has been interested in many fields related to forest genetics and ecology, from breeding to conservation, and has produced over 50 papers in international journals. Currently, he is studying biodiversity at gene level and the mating system of Mediterranean tree species, and particularly how broad geographic and fine scale genetic and phenotypic patterns are structured in relation to natural ecological factors and human impacts. He is currently senior scientist ("Directeur de Recherche") at the Ecology of Mediterranean Forests research laboratory (INRA URFM) in Avignon, France, leader of the "Population Biology and Evolution" group (16 permanent and temporary researchers, engineers and technicians). Bruno Fady is also active at the cross-roads between science, policy and management. He is strongly involved in the field of conservation of forest genetic resources as a member of the National French Forest Tree Gene Conservation program (CRGF) and as chairman (2005-2009) of the conifers network of the European program for the conservation of forest genetic resources (EUFORGEN), an initiative of the Ministerial conference for the protection of forests in Europe (FOREST EUROPE).

Detailed agenda

Pinus nigra

Pinus pinea

Monday June 6th

14:30   Registration at Petit Louvre (23 rue Saint Agricol, Avignon)

19:00   Welcome Icebreaker at Avignon Town Hall (Place de l'Horloge), on behalf of Avignon Mayor

20:00   Free dinner

Tuesday June 7th

08:00   Registration

08:45   Opening Ceremony

09:10   **Keynote 1: Carbon sequestration in Mediterranean pine ecosystems: interacting effects of water availability, increasing CO_2 and nitrogen**
Frederico MAGNANI
in Chapelle (Main meeting room)

Session 1 – Ecophysiology

Chairs: Costas THANOS and Roland HUC
Located in Chapelle (Main meeting room), Hour: 9:55 – 12:05

9:55   O1-1   **Dynamics and coexistence in the montane-subalpine ecotone: the role of different light-induced strategies**
Aitor AMEZTEGUI, Lluís COLL

10:15   Coffee break (Posters exhibition room, second floor)

10:45   O1-2   **Recent growth reduction in *Pinus halepensis* and *Pinus nigra* forests associated with drought intensification in the eastern Mediterranean**
Dimitrios SARRIS, D. CHRISTODOULAKIS, Ch. KÖRNER, Anastasia CHRISTOPOULOU, Margarita ARIANOUTSOU

11:05   O1-3   **Assessing Aleppo pine (*Pinus halepensis Mill.*) xylem formation by means of periodic microcores sampling**
Frédéric GUIBAL, C. CORONA, M. ALVITRE, Roland HUC, Guillaume SIMIONI

11:25   O1-4   **Paradoxical transpiration patterns of two coexisting tree species submitted to partial rainfall exclusion**
Guillaume SIMIONI, Roland HUC

11:45   O1-5   **Integration of empirical and process-based models for maritime pine in Portugal**
Margarida TOMÉ, Luís FONTES, Luís NUNES, José TOMÉ

12:05   Lunch (Buffet in tne Courtyard)

13:10   **Posters session** (second floor)
Posters related to sessions 1, 2 and 3 will be presented by their authors

14:50   **Keynote 2: Development of novel pine-oak Mediterranean ecosystems: an unintended outcome of conservation and afforestation**
Efrat SHEFFER
in Chapelle (Main meeting room)

Session 2 – Stand Dynamic and Forest Management

Chairs: Margarida TOMÉ and Philippe DREYFUS
Located in Chapelle (Main meeting room) from 15:35 to 18:25, in parallel with Session 3

15:35   O2-1   Combining demography, dispersal, and wind data to model the spread of an invasive Mediterranean pine in New-Zealand mountains
Paul CAPLAT, Ran NATHAN, Yvonne BUCKLEY

15:55   O2-2   Disentangling the effects of land use, shrub cover and climate on the invasion speed of native and introduced pines in grasslands
Nadine BOULANT, Aurélie GARNIER, Thomas CURT and Jacques LEPART

16:15   Coffee break (Posters exhibition room, second floor)

16:45   O2-3   Recent expansion of *Pinus nigra* above treeline in central Apennines, Italy: Man induced or climate controlled dynamics?
Alma PIERMATTEI, Francesco RENZAGLIA, Carlo URBINATI

17:05   O2-4   Even-aged or uneven-aged modelling approach, that is the question: a case for *Pinus brutia*
Sergio DE-MIGUEL, Timo PUKKALA, Nabil ASSAF, José Antonio BONET

17:25   O2-5   Forest dynamics, forest types and forest management of Calabrian black pine in Southern Italy
Orazio CIANCIO, F. IOVINO, G. MENGUZZATO, A. NICOLACI, Susanna NOCENTINI, Davide TRAVAGLINI, A. VELTRI

17:45   O2-6   Growth performance of Turkish Red Pine (*Pinus brutia Ten.*) and its importance for Turkey
Nesat ERKAN

18:05   O2-7   Combining multi-criteria evaluation and geostatistics to predict post-fire regeneration of *Pinus halepensis* at a regional scale a rapid assessment and decision making tool
Kostantino POIRAZIDIS, Konstantina ZOGRAFOU, Panagiotis KORDOPATIS, Dionissios KALIVAS, Margarita ARIANOUTSOU, Dimitrios KAZANIS, Evangelia KORAKAKI

18:25   End of the session

Session 3 – Ecology

Chairs: Catherine FERNANDEZ and Margarita ARIANOUTOU
Located in the Meeting room, third floor, from 15:35 to 18:25, in parallel with Session 2

15:35   O3-1   Fate of secondary metabolites in litter of *Pinus halepensis* Mill.
M. CHOMEL, Virginie BALDY, Anne BOUSQUET-MÉLOU, Y. MONNIER, C. PERNIN, S. DUPOUYET, Catherine FERNANDEZ

15:55   O3-2   Colonization of *Pinus halepensis* in southern Mt. Carmel, Israel: consequences of afforestation, grazing and fire
Yagil OSEM, Arik ROSENFELD, Iyala LAVI

16:15   Coffee break (Posters exhibition room, second floor)

16:45   O3-3   Costs of reproduction in *Pinus halepensis* and their outcomes: an integrative approach
Luis SANTOS DEL BLANCO, José CLIMENT

17:05   O3-4   Does pine canopy facilitate the transition to a mixed forest: the role of the forest structure in dry Mediterranean environments
Orna REISMAN-BERMAN, Shani BEN-YAIR, Oren SHELEF, Shimon RACHMILEVITCH, Bertrand BOEKEN

17:25   O3-5   Plant diversity in natural and artificial Aleppo pine stands in south-eastern Spain
Enrique J. HERNÁNDEZ-TECLES, Jorge DE LAS HERAS, F.R. LOPEZ-SERRANO, Daniel MOYA, Raquel ALFARO-SÁNCHEZ, Javier HEDO, J.L. GONZÁLEZ-JIMÉNEZ

17:45   O3-6   A pine species surviving after volcanic eruptions
Nikos NANOS, José Carlos MIRANDA, Inés GONZÁLEZ DONCEL, Julián GONZALO, José Antonio RODRÍGUEZ MARTÍN, Luis GIL

18:05   O3-7   High seed efficiency among Aleppo pine and maritime pine individuals in Algeria
Fazia KROUCHI, L. BOURI, R. MEHDI, M. REZZIK and Arezki DERRIDJ

18:25   End of the session

19:00   City Tours: Visit of the Popes Palace or visit of the historical part of the city or wines tasting; departure in front of Popes Palace

20:00   Free dinner

Wednesday June 8th

08:30   Keynote 3: Fire ecology and evolutionary biology of Mediterranean pines
Jon KEELEY
in Chapelle (Main meeting room)

Session 4 – Fire Sciences

Chairs: Gidi NE'EMAN and Jean-Charles VALETTE
Located in Chapelle (Main meeting room), Hour: 9:15 – 12:05

09:15   O4-1   Advances in Aleppo pine fire ecology: serotiny and heat insulation
Daniel MOYA, R. SALVATORE, Jorge DE LAS HERAS, Vittorio LEONE, F.R. LÓPEZ SERRANO, L. PULIDO, E. VALERO

09:35   O4-2   Assessment of Aleppo pine stands resistance in recurrent forest fires: the case study of Mt. Penteli, Greece
Margarita ARIANOUTSOU, Giorgos MALLINIS, Eleni MAROUDI and Nikos KOUTSIAS

09:55   O4-3   Post-fire salvage logging increases water stress and reduces seedling growth and nutrient uptake of *Pinus pinaster* in the Sierra Nevada, Spain
Jorge CASTRO, Sara MARAÑÓN-JIMÉNEZ, José Ignacio QUEREJETA, Emilia FERNÁNDEZ-ONDOÑO and Craig D. ALLEN

10:15   Coffee break (Posters exhibition room, second floor)

10:45   O4-4   Modeling the immediate post-fire mortality of maritime pine (*Pinus pinaster*)
Paulo M. FERNANDES, Herminio S. BOTELHO, and Eric RIGOLOT

11:05   O4-5   Stand characteristics and canopy fuel load after thinning in Aleppo pine stands
François PIMONT, Philippe DREYFUS, François DE COLIGNY, Eric RIGOLOT, Jean-Luc DUPUY

11:25   O4-6   Long-term monitoring (1989-2010) of growth and reproductive performance in a postfire-regenerating Aleppo pine population on Mt Parnes (Attica, Greece)
Costas A. THANOS and Evangelia N. DASKALAKOU

11:45   O4-7   Providing silvicultural models to reduce crown fire hazard in *Pinus halepensis* stands
Teresa VALOR-IVARS, Míriam PIQUÉ-NICOLAU, Mario BELTRÁN-BARBA

12:05   Lunch (First Floor)

13:00   Posters session (second floor)
Posters related to session 4 will be presented by their authors

14:40   Bus departure to Luberon short visit (Parking Ferruce)

15:30   Short visit of Mount Luberon
Combining fire hazard mitigation and wildlife habitat improvement in a mixed oak-pine forest
Presentations of Jean-Luc DUPUY, Eric RIGOLOT, Jean-Charles VALETTE (INRA) and Lionel KMIEC (ONF)

19:30   End of the tour

20:00   Free dinner

Thursday June 9th

08:30   Keynote 4: Adaptative management to global change in Mediterranean pine forests
José G. BORGES
in Chapelle (Main meeting room)

Session 5 – Climate change

Chairs: Fazia KROUCHI and Christian PICHOT
Located in Chapelle (Main meeting room), Hour: 9:15 – 12:05

09:15   O5-1   Distribution, interactions and impact of mistletoe in the Mediterranean pine woodlands under a climate change scenario
Ana MELLADO and Regino ZAMORA

09:35   O5-2   Genetic variation in phenotypic plasticity of a Pinus pinaster Atlantic population in a transitional region to Mediterranean conditions
Raúl DE LA MATA POMBO, J. VOLTAS and R. ZAS

09:55   O5-3   Long-term fire history and diversity in Mediterranean mountain of Corsica
Berangère LEYS and Christopher CARCAILLET

10:15   Coffee break (Posters exhibition room, second floor)

10:45   O5-4   Mountain pine at the treeline in the Mediterranean Basin
Caterina PALOMBO, Roberto TOGNETT, Paolo CHERUBINI, Gherardo CHIRICI, Giovanna BATTIPAGLIA, Fabio LOMBARDI, Vittorio GARFI and Marco MARCHETTI

11:05   O5-5   Pollen Dispersal and Movement in Scots Pine (*Pinus sylvestris L.*), its Relations with Climatic Conditions; Concepts of Subpopulation and Population
Melih BOYDAK

11:25   O5-6   Spring precipitation and genotypic variation may be the key to the persistence of *Pinus sylvestris* at the forest-steppe ecotone in the Central Alps
Sarah RICHTER, Barbara MOSER, Tabea KIPFER, Carlos CALDERÓN GUERRERO, Jaboury GHAZOUL, Thomas WOHLGEMUTH

11:45   O5-7   Direct and delayed impact of climate accidents on the architectural development and leaf area of Mediterranean pines
Michel VENNETIER, François GIRARD, Didier CODY, Samira OUARMIM, Christian RIPERT, Yves CARAGLIO, Willy MARTIN, Roland ESTEVE, and Aminata N'DIAYE

12:05   Lunch (First Floor)

13:10   Posters session (First floor)
Posters related to sessions 5 to 8 will be presented by their authors

14:50   Keynote 5: Biogeography of genes and evolutionary history of Mediterranean pines
Bruno FADY
in Chapelle (Main meeting room)

Chairs: Gabriel SCHILLER and François LEFEVRE
Located in Chapelle (Main meeting room) from 15:35 to 18:25, in parallel with Sessions 7 and 8

15:35   O6-1   Genetic improvement of five pine species in Morocco
Hassan SBAY, S.L. EL ALAMI, A. ATTAOUI and M. GHAFOUR

15:55   O6-2   Main results of the *Pinus halepensis – Pinus brutia* French comparative provenance trials
Christian PICHOT, Denis VAUTHIER

16:15   Coffee break (Posters exhibition room, second floor)

16:45   O6-3   Candidate-gene research to understanding the role of genetic diversity in the adaptive response of Mediterranean pines
Giovanni Giuseppe VENDRAMIN, Delphine GRIVET, S. TORRE, F. SEBASTIANI, M. ZABAL-AGUIRRE, Santiago C. GONZALES-MARTINEZ

17:05   O6-4   The further we search, the less we found: low genetic variation in quantitative and molecular traits in Mediterranean stone pine (*Pinus pinea*)
Sven MUTKE, Bruno FADY, Amira BEN MNA, Abdelhamid KHALDI, Mohammed Larbi KHOUJA, Santiago C. GONZALES-MARTINEZ, José CLIMENT, F. SEBASTIANI, S. TORRE, Giovanni Giuseppe VENDRAMIN

17:25   O6-5   Interpreting the ontogenetic delay of shoot development in Mediterranean pines: adaptive trait or phylogenetic constraint?
José CLIMENT, María Regina CHAMBEL, Santiago GONZALES-MARTINEZ, Delphine GRIVET

17:55 O6-6 Genetic variation of **cavitation resistance in *Pinus pinaster*: the first evidence for uniform selection in plants?**
Jean-Baptiste LAMY, Laurent BOUFFIER, Régis BURLETT, Christophe PLOMION, Hervé COCHARD, Sylvain DELZON

18:05 O6-7 Fertility variation and gamete gene pool composition in a black pine (*Pinus nigra Arn.*) clonal seed orchard under changing climatic conditions
Paraskevi ALIZOTI

18:25 Concluding session in Chapelle (Main meeting room)

19:00 End of the Symposium

20:00 Social dinner at Palais Royal Restaurant close to the Popes Palace Theme: Hop on board for a festive trip around the Mediterranean

Session 7 – Pine and Insects Interactions
Session 8 – Conservation

Chairs: Thomas BOIVIN and Philippe CASTAGNONE
Meeting room at the third floor, from 15:35 to 18:25, in parallel with Session 6

15:35 O7-1 Direct molecular detection of the Pine Wood Nematode, *Bursaphelenchus xylophilus*, from *Pinus pinaster* and from its insect vector, *Monochamus galloprovincialis*
Luís FONSECA, Joana M. S. CARDOSO and Isabel ABRANTES

15:55 O7-2 Economic impact of the pine wood nematode *Bursaphelenchus xylophilus*
Valeria REVA, Luís FONSECA, José L. LOUSADA, Isabel ABRANTES and Domingos X. VIEGAS

16:15 Coffee break (Posters exhibition room, second floor)

16:45 O7-3 Pine wilt disease and the pinewood nematode: a threat to Mediterranean pine forests
M.M. MOTA, B. RIBEIRO, I. CARRASQUINHO, P. RIBEIRO, I. EVARISTO, R. COSTA, P. VIEIRA and M.W. VASCONCELOS

17:05 O7-4 The decline of Aleppo pine in semi-arid forests at Djelfa, Algeria
Gahdab CHAKALI

17:25 O7-5 Trade-offs between induced and constitutive resistance in maritime pine: secondary chemistry, effective antiherbivore resistance and environmental modulation
Luis SAMPEDRO, Xoaquin MOREIRA and Rafael ZAS

17:55 O8-1 Natural Stone Pine (*Pinus pinea*) Forest in Kahramanmaras, Problems and Conservation Strategies
Mustafa YILMAZ and Fatih SiVRiKAYA

18:05 O8-2 A synthesis on several years study on Pinus nigra ssp mauretanica in Algeria
Arezki DERRIDJ, D. ABDELLI, D. ADJAOUD, A. ASMANI, Bruno FADY, H. HEDJAM, N. LARBI-AIDROUS, O. ZANNDOUCHE and Fazia KROUCHI

18:25 Concluding session in Chapelle (Main meeting room)

19:00 End of the Symposium

20:00 Social dinner at Palais Royal Restaurant close to the Popes Palace Theme: Hop on board for a festive trip around Mediterranean Basin

Friday June 10th

08:30   Bus departure from by Porte de l'Oule

11:00   **Visit of Fontblanche experimental site** to study carbon and energy exchanges in a mixed oak-pine forest
Presentations of Roland HUC and Guillaume SIMIONI (INRA), Michel VENNETIER (Cemagref), Frédéric GUIBAL (IMEP), Lionel CHEVALIER (Conseil Général des Bouches-du-Rhône), Jérôme ORGEAS (Mayor of Roquefort-la-Bédoule)

13:00   Picnic at Fontblanche

14:30   **Visit of Ceyreste provenance trial** on the *Pinus halepensis* and P. *brutia* complex and arboretum
Presentations of Christian PICHOT (INRA) and Cédric MAZAURIC (ONF)

16:30   Bus departure to Cassis

16:45   **Vineyard visit and wine tasting** at Domaine de Fontblanche - Cassis

18:30   **Visit of the historical parts of the Cassis village and of its harbour**

20:00   Dinner in Cassis city

23:30   Back to Avignon

MONDAY 6th JUNE	TIME	TUESDAY 7th JUNE 6TH - 10TH JUNE 2011			
	08:00 – 8:45	REGISTRATION			
	08:45 – 9:10	OPENING CEREMONY (Chapelle Petit Louvre)			
	9:10 – 9:55	KEYNOTE #1 F. MAGNANI (Chapelle)			
	9:55 – 10:15	1 – Ecophysiology	Oral O1-1 (Chapelle)		
	10:15 – 10:45		COFFEE BREAK (2nd floor)		
	10:45 – 11:05		Oral O1-2 (Chapelle)		
	11:05 – 11:25		Oral O1-3 (Chapelle)		
	11:25 – 11:45		Oral O1-4 (Chapelle)		
	11:45 – 12:05		Oral O1-5 (Chapelle)		
	12:05 – 13:10	LUNCH (Buffet in the Courtyard)			
	13:10 - 14:50	POSTER SESSION A: Ecophysiology, Stand dynics and forest management, Ecology			
REGISTRATION 2:30 – 6:30 PM (Petit Louvre)	14:50 – 15:30	KEYNOTE #2 E. SHEFFER (Chapelle)			
	15:35 – 15:55	2 – Stand dynics and Forest management	Oral O2-1 (Chapelle)	3 – Ecology	Oral O3-1 (1st floor)
	15:55 – 16:15		Oral O2-2 (Chapelle)		Oral O3-2 (1st floor)
	16:15 – 16:45		COFFEE BREAK (2nd floor)		COFFEE BREAK (2nd floor)
	16:45 – 17:05		Oral O2-3 (Chapelle)		Oral O3-3 (1st floor)
	17:05 – 17:25		Oral O2-4 (Chapelle)		Oral O3-4 (1st floor)
Welcome Icebreaker 19:00 on behalf of Avignon Mayor (Town Hall)	17:25 – 17:45		Oral O2-5 (Chapelle)		Oral O3-5 (1st floor)
	17:45 - 18:05		Oral O2-6 (Chapelle)		Oral O3-6 (1st floor)
	18:05 – 18:25		Oral O2-7 (Chapelle)		Oral O3-7 (1st floor)
	18:25 – 19:00				
	19:00 – 20:00	CITY TOUR			
Free dinner	20:00 =>	Free dinner			

TIME	WEDNESDAY 8th JUNE	
08:30 - 9:15	KEYNOTE #3 J. KEELEY (Chapelle)	
9:15 - 9:35	4 – Fire sciences	Oral O4-1 (Chapelle)
9:35 - 9:55		Oral O4-2 (Chapelle)
9:55 - 10:15		Oral O4-3 (Chapelle)
10:15 – 10:45		COFFEE BREAK (2nd floor)
10:45 – 11:05		Oral O4-4 (Chapelle)
11:05 – 11:25		Oral O4-5 (Chapelle)
11:25 – 11:45		Oral O4-6 (Chapelle)
11:45 – 12:05		Oral O4-7 (Chapelle)
12:05 – 13:00	LUNCH (1st floor)	
13:10 - 14:30	POSTER SESSION B: Fire sciences	
14:30	Bus Departure	
15:30 - 20:10	SHORT VISIT LUBERON	
20:15 =>	Free dinner	

pinaster
Pinus nigra Pinus pinea Pinus halepensis

Pinus brutia

TIME	THURSDAY 9th JUNE			
08:30 - 9:15	KEYNOTE #4 J.G. BORGES (Chapelle)			
9:15 - 9:35	5 – Climate change	Oral O5-1 (Chapelle)		
9:35 - 9:55		Oral O5-2 (Chapelle)		
9:55 - 10:15		Oral O5-3 (Chapelle)		
10:15 – 10:45		COFFEE BREAK (2nd floor)		
10:45 – 11:05		Oral O5-4 (Chapelle)		
11:05 – 11:25		Oral O5-5 (Chapelle)		
11:25 – 11:45		Oral O5-6 (Chapelle)		
11:45 – 12:05		Oral O5-7 (Chapelle)		
12:05 – 13:10	LUNCH *(1st floor)*			
13:10 - 14:50	POSTER SESSION C: Climate change, Genetics and breeding, Pine insect interactions, Conservation			
14:50 – 15:30	KEYNOTE #5 B.FADY (Chapelle)			
15:35 – 15:55	6 – Genetics and Breeding	Oral O6-1 (Chapelle)	7 – Pine and insect interactions / 8 - Conservation	Oral O7-1 (1st floor)
15:55 – 16:15		Oral O6-2 (Chapelle)		Oral O7-2 (1st floor)
16:15 – 16:45		COFFEE BREAK (2nd floor)		COFFEE BREAK (2nd floor)
16:45 – 17:05		Oral O6-3 (Chapelle)		Oral O7-3 (1st floor)
17:05 – 17:25		Oral O6-4 (Chapelle)		Oral O7-4 (1st floor)
17:25 – 17:45		Oral O6-5 (Chapelle)		Oral O7-5 (1st floor)
17:45 - 18:05		Oral O6-6 (Chapelle)		Oral O8-1 (1st floor)
18:05 – 18:25		Oral O6-7 (Chapelle)		Oral O8-2 (1st floor)
18:25 – 19:00	Concluding session (Chapelle Petit Louvre)			
19:00 – 20:00				
20:00 =>	SOCIAL DINNER			

TIME	FRIDAY 10th JUNE
08:30	Bus departure Porte de l'Oulle
11:00 - 13:00	EXCURSION DAY, FONTBLANCHE, CEYRESTE Visit of FONTBLANCHE experimental site
13:00 - 14:00	Picnic at Fontblanche
14:00 - 14:10	from Fontblanche to Ceyreste
14:30 - 16:20	Visit of CEYRESTE experimental site
16:20 - 17:00	from Ceyreste to Cassis
17:00 - 18:00	Wineyard visit and wine tasting: Fontblanche - Cassis
18:15 - 19:30	Visit of Cassis village and harbour
19:30 - 21:00	Dinner in Cassis
23:30	Back to Avignon

Oral program

KN 1 Carbon sequestration in Mediterranean pine ecosystems: interacting effects of water availability, increasing CO_2 and nitrogen

Invited Speaker: Frederico MAGNANI[1]

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A short biography of Dr. Frederico Magnani is available at the beginning of this Medpine4 book.

Pine forests make a sizeable contribution to Mediterranean vegetation, and have been considerably expanded over the last centuries through afforestation. Although established with a different purpose, they are now the object of a renewed interest for their C sequestration potential.

Forest growth and C sequestration are generally assumed to be limited by water availability under Mediterranean conditions. We are increasingly aware, however, of the interactions between different limiting factors, since water use efficiency (the ratio between forest gross primary production and C sequestration, on the one hand, and stand evapotranspiration on the other) is affected by factors such as tree age, air temperature and vapour pressure deficit, atmospheric N deposition and N availability, and atmospheric CO_2 concentration. Since all these drivers are expected to change over the next decades, it's important that we gain a better understanding of their interplay in order to predict the future trajectories of Mediterranean pine forests and their C sequestration potential.

Specific reference will be made to results from the long-term experimental site in San Rossore (Pisa, Italy), a *Pinus pinaster* forest where water and C fluxes have been monitored since 1998. Results for maritime pine and co-occurring vegetation at the San Rossore site will be compared with other field and laboratory results for the same species and other Mediterranean pines.

ORAL PROGRAM

Tuesday June 7th • 9:55 – 12:05
Plenary Session
Session 1 – Ecophysiology

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O1-1 Dynamics and coexistence in the montane-subalpine ecotone: the role of different light-induced strategies

Aitor AMEZTEGUI1 and Lluís COLL1

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We evaluated the response (growth and survival) of mountain pine (*Pinus uncinata* Ram.) Scots pine (*Pinus sylvestris* L.) and silver fir (*Abies alba* Mill.) saplings to light availability in a mixed-conifer montane-subalpine ecotone in the Eastern Pyrenees (NE Spain). For each species, 100 living and 50 dead saplings were selected and their size, crown morphology and light availability (percentage of photosynthetic photon flux density (%PPFD)) measured. A wood disk at root collar was then extracted for every sapling and mortality as a function of light was obtained from models relating (1) growth as a function of light and (2) mortality as a function of radial growth. Variation in light availability was found to explain more than 50% of the variation of growth, underlining the importance of light in saplings' performance.
Silver fir showed the highest survival rate (around 90%) at any given irradiance level. Both pines, and especially Scots pine, showed a high mortality risk in deep shade (below 10% PPFD), but their radial growth and their survival rate rapidly increased at higher irradiance levels. Pines and fir seemed to develop opposing strategies to face light deprivation: fir chose a conservative strategy, based on sacrificing height growth, while pines, on the other hand, maintained or even enhanced height growth to escape from shade, but incurring in higher mortality risk.
These two contrasting patterns explained the niche differentiation observed in the analysed forests. Among the three studied species, Scots pine showed the highest plasticity for any architectural or morphological analysed variable, thus showing apparent higher adaptability for other environmental constraints. Since climate change is expected to facilitate the encroachment of montane species into the subalpine belt, evaluating the light-response of these species at the ecotone level constitutes a first step to assess the future dynamics of these singular forests.

Keywords: ecology, subalpine, Pyrenees, mountain pine, silver fir, Scots pine, dynamics, shade tolerance, crown morphology, plasticity

O1-2 Recent growth reduction in *Pinus halepensis* and *Pinus nigra* forests associated with drought intensification in the eastern Mediterranean

*Dimitrios SARRIS[1,3], D. CHRISTODOULAKIS1, Ch. KÖRNER[2],
Anastasia CHRISTOPOULOU[3] and Margarita ARIANOUTSOU[3]*

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In the thermo-Mediterranean vegetation belt of Greece at low elevations and in regions with a negative precipitation trend since late 1970's (i.e. Zakynthos, Skyros, Samos and Crete), growth of *Pinus halepensis* and *P. brutia* trees has declined to unprecedented levels in ca. 200 years. During the driest period on record (1990-1996), pines' annual growth was found to depend on rainfall of 3-4 years before and including the year of tree ring formation (reaching even 5-6 years for some regions). In contrast, during moist periods of the 20th century annual tree growth in the investigated regions was largely controlled by rainfall during a few weeks or months before or in the beginning of the growing season. This suggests that water from deeper ground, accumulated during rainfall of previous years and became increasingly important as drought intensified (also verified by _^{18}O stable isotope analysis). However, a series of dry years may exhaust deeper ground "moisture reserves". In this case, pines may be pushed very close to their survival limits and can even be desiccated, as was documented in the eastern Aegean island of Samos in late summer 2000, even for 80-years old trees.

Mean annual precipitation for the studied area, is projected to decrease in 2090-2099 by almost 30%, compared to the 1980-1999 levels (_1B-SRES, IPCC 2007), reaching 390 mm. These levels of rainfall are far below the threshold of 480 mm that we determined as crucial for the investigated populations of *Pinus* to survive drought by relying on deeper moisture reserves. More recent evidence from late summer of 2007, suggests that the meso-Mediterranean vegetation belt of Greece has also been affected; in northern Peloponnese, severe dryness coincided with *P. halepensis* forest die-back and growth decline. Moreover, at higher elevation in the supra-Mediterranean vegetation belt of southern Peloponnese (Mt. Taygetos), *Pinus nigra* individuals from dry, south facing slopes also experienced a recent growth decline. The repeated findings of *Pinus* sp. growth decline and die-back connected to drought imply that eastern Mediterranean forests on dry sites could already have started to become thinner.

If these trends continue and IPCC's climate projections become a reality, then it is very likely that a retreat in the rear-end (lower altitudinal/latitudinal) range of *Pinus sp.* will occur in the eastern Mediterranean. Accompanied with severe forest fire outbreaks (e.g. summers of 2007 and 2000 for Greece), the desertification risk will probably increase, for such areas during the 21st century.

Keywords: Pinus halepensis, Pinus nigra, drought, climate change

O1-3 Assessing Aleppo pine (*Pinus halepensis* Mill.) xylem formation by means of periodic microcores sampling

Frédéric GUIBAL[1], C. CORONA[1], M. ALVITRE[1], Roland HUC[2] and Guillaume SIMIONI[2]

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Radial stem growth is an outstanding process to understand the biology of the tree. Histological analysis of stem growth based on periodic microcores sampling makes it possible to build up a chronology of cell production throughout the growing season. Xylem formation in *Pinus halepensis* Mill. was measured during three growing seasons (2008-2010) in the Fontblanche (Bouches-du-Rhône, Provence, SE France) Mediterranean forest observatory in which an experimental design (artificial water exclusion and water supply) is being achieved.

Microcores (diameter: 1.5 mm) were collected by means of a mini-puncher (WSL Birmensdorf increment puncher) every second week from April to October/November during three years and the number of cells formed every second week was counted in order to characterize timings of the radial growth at intra-annual scale. The repeated extraction of microcores by the mini-puncher in a spiral pattern, centimetres aprt, minimises the local damages and the compartmentalisation produced by the wound. Three groups of trees were selected: a control group of eight trees, a group of four trees growing in a quadrate in which 27% of the rainfall is excluded, a group of four trees growing in a quadrate in which an excess of 30% of water is supplied. Preliminary analysis at intra-annual scale was made by using the growth data and the *in situ* meteorological data.

Results show a high individual and annual variability according to precipitation and temperature. The onset of cambial activity started in late April-early August; then the rate of cells division remains stable till the end of June-early July before a summer drought during which a weakening of cell division rate occurs. Thereafter, a late summer-early growth recovery occurs depending on precipitation. After two growing seasons of precipitation exclusion, differences are noticeable between excluded pines and control trees.

Keywords: Aleppo pine, Radial growth, Xylem formation

O1-4 Paradoxical transpiration patterns of two coexisting tree species submitted to partial rainfall exclusion

Guillaume SIMIONI[1] and Roland HUC[1]

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As a result of climate change, the Mediterranean region is expected to undergo significant rainfall reduction and temperature increase in future decades. It is therefore essential to assess Mediterranean forest vulnerability to increased water stress. In this regards, mixed forests are particularly interesting to compare the response of coexisting species. This study focuses on water stress and transpiration patterns exhibited by coexisting *Pinus halepensis* and *Quercus ilex*, two species widely distributed in the Mediterranean region, in response to an artificial 30% rainfall exclusion.

Our study took place in the Fontblanche forest, in south-east France, which is a long term experimental site dedicated to study the water and carbon budgets of a mixed pine/oak ecosystem. To assess the effect of 30% rainfall exclusion, we set up gutters covering 30% of the surface of a 25 m x 25 m plot. We set up a control treatment with reversed gutters, again on a 25 m x 25 m plot. This was complemented by a control treatment without gutters in which eight trees of each species were equipped with sap flow sensors. Trees of both species from all treatments were equipped with sap flow sensors corresponding to Granier's constant heating technique. Sap flow was recorded continuously in 2009 and 2010 with a half hourly frequency. Tree water stress was estimated from measurements of predawn and minimum leaf water potentials made on the same trees as the sap flow measurements, at several dates during the dry season.

In the control treatments, water potential measurements showed that water stress typically started in June and was at its highest in August. Significant differences between species were found only at the beginning of the dry season, when water stress started earlier for pines than for oaks. Transpiration temporal patterns were not significantly different between species, even though during the dry season pine transpiration tended to decrease a little earlier than oak's.

Excluding 30% of rainfall caused water stress to start earlier for pines, but had no effect on the water stress experienced by oaks. We therefore expected that 30% rainfall exclusion would cause pine transpiration to decrease earlier in the dry season but would not affect oak transpiration. However, pine transpiration patterns were similar under all treatments while oaks submitted to rainfall exclusion decreased their transpiration earlier than in the control treatments. We discuss the possible mechanisms that could lead to those paradoxical results, with regard to wood hydraulic properties, possible antagonistic environmental effects on stomatal conductance, and growth habits of the two species.

Keywords: ecophysiology, ecology, climate change impacts

ORAL PROGRAM

O1-5 Integration of empirical and process-based models for maritime pine in Portugal

Margarida TOMÉ[1], Luís FONTES[1], Luís NUNES[2] and José TOMÉ[2]

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Forests are very important in Portugal, covering 39% of the land (agriculture occupies 33% and shrubland 21%). From those, the production forest represents 51% (28% maritime pine and 23% eucalyptus) while evergreen oaks represent 36% (23% cork oak and 13% holm oak). Other minor species cover just 12%. Maritime pine is the most important softwood in the country and the only one relevant for wood production (annual wood harvest of softwoods is close to $5 \ 10^6$ m^3). Forest resources in Portugal are mainly driven by forest fires and wood harvest, with some impact also of afforestation and deforestation. The prediction of these drivers in the dynamics of forest resources – namely growing stock, volume growth and carbon stock – is crucial at different spatial scales, from the individual landowners, for forest management purposes, to the industry, for the planning of wood supply, as well as for the definition of forest policies. Optimization of management at local levels plays also an important role for the overall dynamics of the forest resources. Growth and yield models implemented in forest simulators appropriate for different spatial scales have been developed in the country for the most important forest species (maritime pine, eucalyptus and cork oak). The global change environment, namely climate change, gave impetus to an increasing use of process-based models that simulate forest ecosystem dynamics for this purpose. Such models, integrating the main physical, biogeochemical and physiological processes involved in forest growth and development, give a mechanistic description of the interactions between the living plants and their environment and are able to assess the energy balance and the cycling of water, carbon and nutrients within a given ecosystem. In Portugal, the 3PG model, a simple process-based stand model requiring few parameter values and only readily available data as input has been selected as appropriate for the simulation of maritime pine stands. Basal area and underbark volume is the only information for managers provided by the original 3PG model and validation of the output against permanent plot data showed some bias, mainly in volume predictions. This presentation describes a series of functions developed on the basis of existing permanent plot data that were added to the 3PG model in order to improve and enrich the type of output that it provides for management.

Keywords: process-based model, empirical models, 3PG, maritime pine

KN 2 Development of novel pine-oak Mediterranean ecosystems: an unintended outcome of conservation and afforestation

Invited Speaker: Efrat SHEFFER[1]

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A short biography of Dr. Efrat Sheffer is available at the beginning of this Medpine4 book.

Mediterranean landscapes typically form a patch mosaic, with different community structures intermingled in complex patterns. Species of pines (*Pinus*) and oaks (*Quercus*) are common dominants in many of the patch types, either alone or in mixed pine-oak communities.
Pines are known for their strong dispersal and colonization potential (pioneer species), while oaks are characterized by slow development and resilience (late successional species). In Israel, for example, Aleppo pine has begun to spread into oak-dominated maquis that has been restored through intensive conservation efforts. On the other hand, oaks have begun to form understories beneath the canopies of pine forests that have been planted throughout the Mediterranean region of the country. New plant communities are therefore emerging as a result of species exchange, with ecosystem structure and function that may differ in many ways from those envisioned as the original goals of the conservation and afforestation programs.

We will present a framework for the analysis of landscape interactions of Mediterranean pine and oak communities, and how these processes may create novel communities. Our approach uses spatially-explicit models that focus on the processes that both promote and resist successful colonization of one patch type by species that typically dominate in other patch types.
We illustrate the approach with results of a study of the reciprocal dynamics of colonization of natural maquis communities by pines dispersing from plantations of *Pinus halepensis*, and the development of oak maquis understory within planted pine forests in Israel.
Specifically, we investigated how pine and oak colonization are controlled by:
1) the spatial configuration of the landscape and its effect on propagule arrival, and
2) local environmental conditions acting as resistance factors that limit recruitment of colonizing individuals.
We will compare our models with reports of other pine-oak communities throughout the Mediterranean Basin, and suggest how such models can be used to predict the evolution of the landscape mosaic in Mediterranean environments

Tuesday June 7th • 15:35 – 18:25
Parallel Session
Session 2 – Stand Dynamic and Forest anagement

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O2-1 Combining demography, dispersal, and wind data to model the spread of an invasive Mediterranean pine in New-Zealand mountains

Paul CAPLAT[1], Ran NATHAN[2] and Yvonne BUCKLEY[1]

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Amongst the world's invasive plant species, those of the genus *Pinus* are widespread and conspicuous. In many parts of the world pine trees were planted for production purposes or erosion control, and are now spreading well outside the plantations, threatening biodiversity, ecosystem function, and landscape values. In New Zealand, this phenomenon has been observed for several decades, and the total area affected by conifers is estimated at 150,000 ha. Yet, little is known about the relative importance of mechanistic drivers of spread, particularly when long distance dispersal (LDD) events occur, as they affect spread significantly while being difficult to measure.

A wide array of methods exists that assess LDD, or spread, but no analytical method exists to date that combines mechanistic dispersal in a spread model. Here we integrate two models of mechanistic wind dispersal and plant spread to determine the relative effects of dispersal and demographic traits and wind statistics on the spread of an invasive pine.

We focus on Mount-Barker (South Island, New Zealand), where the wind-dispersed Corsican pine (*Pinus nigra* ssp. *laricio*), planted around 1910 has since spread to neighbouring grasslands and scrublands. Our models are parameterised using data collected *in situ* and tested using independent data on historical spread. We carry out a full sensitivity and elasticity analysis of spread rate to demographic, seed trait and wind variables.

We show how this method allows to test
(1) the effect of location and wind direction on the spread of Corsican pine, and
(2) the relative importance of demographic and dispersal variables for spread rate. Predicted spread rates and direction match strikingly with historical spread. Seed terminal velocity has the greatest potential influence on spread rate and three wind properties -turbulence coefficient, mean horizontal wind speed and standard deviation of vertical wind speed- are also important.

Fecundity has marginal importance for spread rate, but juvenile survival and establishment are consistently important. This coupled empirical/theoretical framework enables prediction of plant spread rate and direction using fundamental dispersal and demographic parameters. It also identifies the traits and environmental conditions which facilitate spread – allowing us to discuss the invasive potential of Corsican pine compared with other pine species, and potential management options.

Keywords: Integro-difference equation; invasion biology; long distance dispersal ; matrix model; mechanistic model; *Pinus nigra*; plant traits; population biology; WALD; terminal velocity

O2-2 Disentangling the effects of land use, shrub cover and climate on the invasion speed of native and introduced pines in grasslands

Nadine BOULANT[1], Aurélie GARNIER[2], <u>Thomas CURT</u>[3] and Jacques LEPART[1]

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To determine how changes in land use, climate and shrub cover affect the invasion dynamics of native (*Pinus sylvestris* L.) and introduced (*Pinus nigra* Arn. subsp. *nigra*) pines in grasslands. To analyse how these factors interact and affect seedling recruitment, a bottleneck in the lifecycle of many trees. Such information is required to manage the dynamics of these species. We used both published and unpublished demographic and dispersal data to assess population growth and invasion speed of invading pines. A demographic and spatially explicit model, which included density dependence and stochastic in dispersal, demography and environment, was run for different scenarios of sheep grazing pressure (nil, extensive or intensive), shrub cover (0, 10 or 20%) and drought frequency (past-to-present or future). For each scenario, population growth rate, invasion speed and elasticity of invasion speed to each demographic and dispersal parameter were computed.

Grazing was the main factor for limiting invasion speed. Shrub cover reduced tree spread under nil or extensive grazing pressure, but increased it under intensive grazing pressure. Although dry years led to nil seedling establishment rates, an increase in their frequency had surprisingly few effects on pine invasion speed. This last result remained unchanged when very dry years, inducing seedling, but also sapling mortality was introduced. In most environmental conditions, population growth rate and invasion speed were higher for the introduced than for the native pine. Elasticity analysis highlighted the importance of demographic parameters on invasion speed, notably adult and sapling survival.
Tree invasion speed may rely at least as much on human activities, like sheep grazing, tree cutting and non-native trees introduction, as on changes in climate factors. Therefore, human activities need to be explicitly taken into account in the prediction and management of tree dynamics.

Keywords: pine invasion, spatially explicit modelling, grazing, drought

ORAL PROGRAM

O2-3 Recent expansion of *Pinus nigra* above treeline in central Apennines, Italy: Man induced or climate controlled dynamics?

Alma PIERMATTEI[1] , Francesco RENZAGLIA[1] and Carlo URBINATI[1]

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The synergic effects of natural and anthropogenic disturbances throughout the last millennia have lowered the altitude of Apennines treelines, usually formed by coppiced beech forests. In these previously grazed ecotones the onset of ecological succession processes are usually attributed to pasture management changes and/or abandonment.

In limestone soils at the higher mountains of Central Apennines, above current treeline, we have found numerous dispersed individuals of black pine (*Pinus nigra* Arn. *austriaca*), a pioneer species used at lower elevation for slope protection plantations. It is the only tree species present today above 1,600 m asl in these previously grazed grasslands, but pollen analysis from nearby bogs recorded the presence of pines during the anathermic period after the Würmian glaciation.

In two treeline sites of the central Apennines, located 150 km apart, we tested the role of climate change as a possible driving force of the pine upward expansion. More than 250 specimens were GPS mapped, several site and dendrological parameters were individually recorded. These included elevation, aspect, type of microhabitat (rock, debris, grassland, etc..), habitus (tree or shrub form), social status (single or in cluster), basal stem diameter, tree height, height of crown insertion point, crown shape, height of stem internodes, years of needle persistence and tree age (increment cores extracted close to ground level). Tree-ring width and intra annual density fluctuations (IADF) frequency were measured in most samples. Time series of radial and height annual growth were also correlated to monthly temperature and precipitation series from local meteorological stations.

The treeline elevation and the slope aspect are different at the two sites but pines are found mainly at higher altitudes up to 2,000 m asl. Seed dispersal is mainly wind controlled and through a stepwise process can reach long distance sites. Favourable habitats are either bare-rocky sites or dry grasslands. Highest germination frequencies are synchronous (1997-2001) and their distributions have similar trends in both sites.

Mean tree-ring width chronologies are stationary with a major peak in 2003. IADF frequency is relatively low until the year 2000 but increases rapidly and peaks also in 2003, one of the warmest and driest year of the last centuries. Black pines at high elevation show good adaptation to severe drought conditions but are also very sensitive to minor precipitation in late summer.

The different pasture use at the two sites and the results of this analysis contribute to limit the role of anthropogenic factors as the main drivers of the pine expansion and enhancing that of climate change. Finally, further expansion, growth and reproduction of these pine cohorts could also raise questions about structure, function and management of a newly formed treeline.

Keywords: *Pinus nigra*, treeline, climate change, tree rings, IADF

O2-4 Even-aged or uneven-aged modelling approach, that is the question: a case for *Pinus brutia*

Sergio DE-MIGUEL[1], Timo PUKKALA[1], Nabil ASSAF[2] and José Antonio BONET[3]

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Pinus brutia Ten. occurs in the Eastern Mediterranean region and is the most widespread conifer species in Middle East. It is ecologically important and produces wood for several purposes (Gezer 1985; Fischer et al. 2008). Despite this, there is a lack of knowledge concerning brutia pine stand dynamics. The past forest management has led to diverse stand structures that cannot be easily classified as even-aged or uneven-aged. Most stands are between these stand types, and they may be called as "semi-even-aged". This is, in fact, a very common characteristic throughout the Mediterranean countries, at least when dealing with conifer forests. Nevertheless, most models fitted for *Pinus* species have assumed the stands to be either even-aged using even-aged modelling approach, or uneven-aged using uneven-aged modelling approach.

The set of equations required for even-aged forestry consists of site index, diameter increment, height, and mortality models. On the other hand, the set of equations required for uneven-aged forestry consists of ingrowth, diameter increment, height, and mortality models (Vanclay 1994). Stand age and dominant height are not used as a predictor in the model set for uneven-aged stands.

Few studies, if any, have analysed which modelling approach is better for the Mediterranean semi-even-aged stands. The growth and yield modelling studies on *P. brutia* have mostly applied an even-aged approach (de-Miguel et al. 2010, Shater et al. 2011) or have provided a partial set of models for uneven-aged stands (Palahí et al. 2008). In Lebanon, where *P. brutia* is the most widespread conifer, the forests are neither strictly even-aged nor uneven-aged. This particularity makes a straightforward application of one of the approaches questionable.

To seek the best model set for *P. brutia* in Lebanon, a study was carried out using measurements from fifty sample plots placed so as to capture the whole range of variation in site quality, stand age and stand density. Growth models were fitted using either uneven-aged or even-aged modelling approach. Afterwards, the sample was split into two sub-samples of twenty five plots according to the standard deviation and skewness of the diameter distribution. A 10-year individual-tree diameter increment model, a height-diameter model and one single self-thinning model were fitted for the entire sample and the sub-samples.

The two modelling approaches were evaluated statistically and graphically, and their accuracy in the simulation of stand dynamics was analysed (e.g. bias, mean square error, partitioning of the root mean square deviation) (Gauch et al. 2003). Such a systematic analysis enabled us to propose the best modelling approach and recommend equations for simulating the dynamics of the semi-even-aged *Pinus brutia* stands of Lebanon on an individual-tree basis.

The results revealed that, if one single modelling approach has to be chosen, the models for uneven-aged forests enable more accurate predictions of wood production. The uneven-aged approach was almost as good as the even-aged one when predicting stand dynamics of the most even-aged plots. Despite the even-aged modelling approach uses more information (age and dominant height are used), it provides poorer predictions in simulation. The errors are very high when the even-aged approach is applied to uneven-aged stands.

This paper sheds light on the applicability of different modelling approaches and might be useful for raising new interesting research questions for other species and areas within the Mediterranean region.

O2-5 Forest dynamics, forest types and forest management of Calabrian black pine in Southern Italy

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In Italy, the Calabrian black pine forests (*Pinus nigra* Arn. ssp. *laricio Poiret* var. *Calabrica Delamare*) have a natural range extending from Calabria to Sicily. In Calabria the most important and well-known Calabrian pine forests grow on the Sila Plateau, where they characterize the forest landscape from 900 up to 1,600 m asl, and in large part are included within the Sila National Park. The conservation of these pine forests is relevant not only for cultural and historical reasons but also for environmental and socio economic needs. In the Sila Plateau the forest landscape consist of a mosaic of forest patches where pure Calabrian pine stands alternate with mixed pine - beech stands and beech stands including patches of pine. The former prevail both in the northern east and southern area in relation to their management history, which depends on land ownership, as well as the economic and social changes that have taken place in the area. Even-aged and uneven-aged pine stands alternates between forests with widespread and vigorous natural regeneration of beech under the canopy of the older pine stands as a consequence of the forest management and ecological site conditions. Even-aged Calabrian pine forest are the result of forest fires or clear cutting which was applied in the past over large areas. Since 1950 forest management is based on three silvicultural systems: felling of individual, sparse trees; strip and patch clear cutting; and a particular form of selection cutting called «small group selection system», which is applied by private owners on the basis of century long experience and tradition, which creates forest stands with structural characteristics very similar to those observed in old-growth Calabrian pine forests. This study focuses on Calabrian pine forests of natural origin in the Sila Plateau with the following objectives:
1) discriminate in the selected study areas between pure pine forest (even-aged and uneven-aged stands) and mixed forest of pine and beech;
2) describe the structure and dynamics of the different forest types and their relationship with forest management; and
3) define forest management strategies for Calabrian pine in Southern Italy.
Forest type maps have been produced from remote sensing data with very high spatial resolution collected over representative study areas of the forest landscape; the classification's accuracy has been assessed by field observation. Field measurements have been carried out in experimental study areas to describe stand structure and forest dynamics of each forest type. The results are finally discussed in relation to management history and forest ownership providing sustainable forest management guidelines aimed at conserving the landscape of the Sila Plateau

Keywords: Stand dynamics and forest management; Conservation

O2-6 Growth Performance of Turkish Red Pine (*Pinus brutia* Ten.) And Its Importance For Turkey

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Turkish Red Pine (TRP) (*Pinus brutia* Ten.) is an important species for Turkish forestry. It covers an area of 5,4 million hectares, the largest distribution of a single forest tree species in Turkey. Substantial wood production comes from Turkish Red Pine forest.

More natural forest areas are allocated to non-wood forest uses as a result of increasing and differentiating of people expectations from forests. But sustainability of wood production is still vital issue in meeting the national demand.

So far, overwhelming part of wood production has been obtained from the natural forests in Turkey. To reduce the pressure of wood production on the natural forest, plantations with fast growing species should be used to meet the national demand for wood.

In this paper the growth performance of TRP in natural forests and plantations were examined. For this purpose, the result of two yield studies done for natural forests and plantations of this species were evaluated. Cost benefit analyses were carried out and Net Present Value, Output/ Input Ratio and Internal Rate of Return were calculated as economic criteria in a sampled area to see the economic aspect of TRP plantations using PLANTEK (software prepared for economic analyses of plantations). As a result it was concluded that TRP could be a candidate for meeting the national demand for wood, especially for industrial purposes, beside the other exotic fast grooving species. Additionally cost - benefit analyses showed that private sector can invest feasibly in TRP plantations.

Keywords: *Pinus brutia*, fast growing species, industrial plantation, economic analyses.

ORAL PROGRAM

O2-7 Combining multi-criteria evaluation and geostatistics to predict post-fire regeneration of *Pinus halepensis* at a regional scale – a rapid assessment and decision making tool

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Fire is long ago considered as a natural phenomenon in Mediterranean climate ecosystems, which in the course of their evolution have developed specific adaptation mechanisms. However, this natural cycle is very commonly interrupted both by repeated man-related fires in the same area and through subsequent changes in land use.

During 2007, in Ilia Prefecture, Peloponnese, a severe fire burned 22,678 ha of Aleppo pine (*Pinus halepensis* Mill.) forests. Responding to the public demand for an effective post-fire restoration strategy, a GIS-based decision making model was developed, at a regional scale, in order to predict natural *P. halepensis* regeneration, and identify forest areas where natural recovery will be limited and hence human intervention is rather required.

The methodology followed constitutes of three stages. Initially, field records were collected on eighty four plots (total area 20,518 ha), two years after the fire, regarding the number of pine seedlings as well as a number of other environmental factors that are known to affect natural regeneration of *Pinus halepensis*. Secondly, two parallel spatial models were developed to predict the natural regeneration based on:

(a) spatial interpolation of field data for the entire burned area, using geostatistical algorithms

(b) hierarchical multi-criteria analysis of selected factors using Fuzzy functions. Finally, the two models were combined according to Bayesian statistics.

The final model of natural regeneration probability includes ten categories. Areas that belong to categories:

1-5 (low - very low regeneration) will need human intervention in order for Aleppo pine forests to be satisfactory restored;

5-9 (moderate regeneration) must be protected in order to maintain the existent regeneration;

9-10 (excellent regeneration) specific silviculture measures can be considered when necessary.

Keywords: Aleppo pine, regeneration, fire, multi-criteria analysis, geostatistics, restoration

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O3-1 Fate of secondary metabolites in litter of *Pinus halepensis* Mill.

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In the French Mediterranean region since the early twentieth century, the rural depopulation promotes strong reforestation with pioneer and expansionist species, such as Aleppo pine (*Pinus halepensis* Mill.). Owing to its richness in secondary metabolites, Aleppo pine may play an important role in plant succession through several processes, such as needles decomposition. The decomposition of litter, a key process connecting ecosystem structure and function, is governed by different biotic and abiotic factors. Among these factors, secondary metabolites are known to affect the activity or presence of detritivorous organisms (mesofauna) and decomposers (bacteria and fungi).

In this context, it's important to determine the impact of Aleppo pine on the Mediterranean forest ecosystem functioning along the secondary succession. We propose to study, during decomposition, the dynamics of secondary metabolites contained in Aleppo pine litter from pine forests with different stages of maturity and consequences on decomposition process and decomposers communities.
Our results show, during decomposition, a succession of invertebrates and microbial communities that are determined by changes in the composition of litter secondary metabolites. Microbial communities have different metabolic capacity during decomposition process. Communities that are in the litter after two and a half years are more able to decompose more recalcitrant compounds like polymeric substances, and carboxylic acids like phenolic compounds.

Terpenoids are resistant to the decomposition and started to slightly decrease after one year of decomposition. On the opposite, we observe a drastic decrease of phenolic compounds after six months of decomposition, except in young forests where decrease of the principal phenolic compounds appeared after one year of decomposition. Moreover, we observed a higher content of total phenolic compounds in the litter of young pines, especially certain compounds known to be allelopathic (e.g. gallic acid or p-coumaric). The abundance of decomposers is therefore lower in these litters, resulting in slower decomposition compared to other stages.

Keywords: Ecology, *Pinus halepensis* Mill., decomposition, mesofauna, microorganisms, secondary metabolites

O3-2 Colonization of *Pinus halepensis* in southern Mt. Carmel, Israel: consequences of afforestation, grazing and fire

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The expansion of *P. halepensis* from plantations into natural sites of high conservation value is becoming a frequent occurrence across the Mediterranean zone of Israel. This phenomenon has become a central source of debate among natural conservationists, foresters and other landscape managers. We studied how colonization of *Pinus halepensis* in a natural Mediterranean shrubland is related to afforestation, cattle grazing and fire. This study is a part of a long-term program for adaptive management in a multifunctional nature park in Israel.

The study was conducted in a Mediterranean garrigue (shrubland) located in Ramat Hanadiv Nature Park, southern Mt. Carmel region, Israel. The study area (ca. 350 ha) was divided into cells (100 _ 100 m) categorized according to distance from planted pines, grazing (grazed since 1990 versus. ungrazed), fire (burned in 1980 vs. unburned), and vegetation structure (garrigue, dense garrigue, dense woodland). The location of colonizing pines, 3 m. or more in height, was determined using aerial photographs. Density of colonizing pines decreased linearly within 300 m from planted pines with a long tail that extended out to ca 1,000 m. Over 90% of the colonizing pines were located within a distance of 300 m (56% of the park area) from planted pines. Colonization was about two times greater under grazing than without grazing. The effects of fire and of the interaction fire _ grazing were found insignificant. A separate analysis revealed that colonization was about two times larger in patches of sparse woody cover than in those of dense cover. In conclusion, pine colonization was mainly determined by the proximity to seed sources. Additionally, pine colonization was enhanced by cattle grazing probably through reduction of the natural vegetation cover.

The results of this study serve as a benchmark for a management plan accompanied by a long term monitoring program with regard to pine colonization in Ramat Hanadiv Nature Park.

Keywords: Stand dynamics and forest management; Ecology; Aleppo pine; Invasion

O3-3 Costs of reproduction in *Pinus halepensis* and their outcomes: an integrative approach

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The mechanisms of species adaptation to their environment can be seen as a complex net of interrelations between processes, where conflicting relationships exist. The costs of reproduction are defined in relative terms, as the relative impact of reproduction in other life history traits or in survival. In order to maximize its fitness, any organism should, by definition, maximize the number of offspring reaching reproduction at the next generation. It follows then that the estimation of costs of reproduction provides valuable information about the whole process of adaptation. *Pinus halepensis* (Aleppo pine) is an ecologically important species in the Mediterranean, growing in poor dry soils and acting as a pioneer after disturbances. At the same time out of its natural range it is considered a virulent invasive species. In both cases, reproductive issues are keystones for understanding the species' performance. Despite the estimation of costs of reproduction in trees is challenging, the Aleppo pine has some advantages as precocious and intense reproduction, non-masting fruiting habit and the permanence of the cones in the crown after seed release (Ne'eman et al., 2004). In the literature of costs of reproduction, four approaches have been defined to seek for empirical evidence of costs of reproduction in plants: phenotypic correlations, experimental manipulations, genetic correlations and correlated responses to selection (Reznick, 1985). In our work, we used three out of the four approaches in range-wide *Pinus halepensis* populations in 16 year-old provenance and provenance-progeny common garden experiments, and discussed their biological implications. Phenotypic correlations between reproductive and growth-related traits revealed, both at the population or metapopulation level, a non linear pattern with maximum reproduction at medium sizes indicative of constraining relationships between reproduction and growth. Also a wide genetic variability of this relationship was detected. As a second approach, a set of trees was subjected to experimental cone removal in order to estimate somatic costs of reproduction. Preliminary analyses indicated a light but significant effect of cone removal upon relative girth growth, which was dependent on the tree size. Finally, (negative) genetic correlations between reproduction and growth and additive genetic variation for reproductive allocation were calculated. These two parameters reflect the real genetic basis of reproduction and its costs and inform about the evolutionary response to selection in natural habitats. All these approaches indicated a general significant trade-off between growth and reproduction in this species and the potential for fast micro-evolution. These findings in association with local climatic information and disturbance regimes will help understanding the distinct geographic patterns of phenotypic variation and the processes of local adaptation.

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ORAL PROGRAM

O3-4 Does pine canopy facilitate the transition to a mixed forest: the role of the forest structure in dry Mediterranean environments?

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In the planted Pine forests of Israel, the spontaneous regeneration of native broadleaved woodland species marks a possible change in forest dynamics and forest type towards a mixed forest ecosystem. Currently, *Quercus calliprinos* dominates the understory in some of the Pine forests, in others *Q. calliprinos* did not establish at all, and in some sites a true mixed forest is developing. A fundamental question in understanding the possible transitions from Pine forest to a mixed forest is how the Pine forest affects the spontaneous regeneration of broadleaved species. A companion question in the era of global warming is if Pine forest canopy shade, may ameliorate the conditions for regeneration and establishment of broadleaved species, or alternatively; the combined effect of shade and droughts may inhibit broadleaved establishment. We studied the effect of *Pinus halepensis* canopy on the establishment of Common Oak (*Quercus calliprinos*) from acorns. Our main research questions are:

1. Is Pine forest canopy shade beneficial to the establishment of *Q. calliprinos* population in the presence of Mediterranean droughts? and

2. What is the effect of Pine canopy shade on the development and the physiological performance of young *Q. calliprinos*?

We created a canopy openness gradient by forming gaps in the Pine forest (Masua, 400 mm rainfall); each gap surrounded by sparse or dense forest, on North and South facing slopes. *Quercus calliprinos* acorns were planted in plots placed along the openness gradient, i.e. gap, gap-margin, sparse and dense forest, and in plots shaded with nets of 50%, 70% and 90% shade.

Our results show that both treatments, aspect and shade, had a significant effect on seedling establishment, with higher survival rates on the Northern aspect and in moderate shade, whether cast by Pine canopy or by shade-nets. In contrast, seedling development was much more vigorous in forest gaps, where *Q. calliprinos* seedlings were subjected to full sun. Under the Pine forest canopy and in gap margins, development was poor, even more than in the artificial shade treatments. Seedling establishment in a drought year followed a similar pattern, with a lower rate of establishment, but with a stronger positive effect of the North aspect and shade.

Photosynthesis evaluated by estimating electron transport rates, showed the highest rates in plants growing under artificial shade and in gaps and the lowest transport rates in plants growing under the forest canopy or heavy shading (90%). However, stress measured by photochemical efficiency (Fv/Fm), was the highest in gap plants. Results show a complex relationship between Pine canopy and the establishment of *Q. calliprinos*. On one hand, forest canopy shade has a positive effect on seedling survival by the mitigation of drought effects; on the other, light is required for further plant development.

Therefore we conclude that a trade-off exists between *Q. calliprinos* establishment and its development in Pine-forests. Implications for forest management by gap formation - will be discussed.

Keywords: Ecology, Stand dynamics and forest management, Climate change impacts

O3-5 Plant diversity in natural and artificial Aleppo pine stands in south-eastern Spain

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In arid and semiarid Mediterranean areas, Aleppo pine (*Pinus halepensis* Mill.) is one of the dominant tree species and is widely used in restoration programmes. The Mediterranean Basin is a fire-prone area in which the stand reestablishment should require intervention due to the failure of natural regeneration. Reforestations are a common tool to improve soil and water conservation, carbon sequestration and biodiversity. In the 20th century, several areas of eastern Spain have been reforested but the forest management in the medium and long term has not been carried out (e.g. monitoring to check objectives, silvicultural treatments).

Our study area is located close to Calasparra (Murcia) in south-eastern Spain. It is a Mediterranean semiarid area (less than 300 mm per year) with very low productivity. Several reforestations of Aleppo pine stands have been carried out in this area. We selected two origins (natural and artificial) and three ages (young, medium and old) to check the plant diversity and mature degree of these Aleppo pine stands.

Trees, shrub and herbaceous canopy cover were recorded in late spring 2010. Several plots were located and line-intercept sampling was carried out. Four transects were set in each plot and the cover values for all species were obtained following the linear intercepting method. We calculated four diversity indexes: floristic richness (S), total vegetation cover (V), Shannon diversity index (H) and life-form rate (R). They were compared including the influential factors origin and age.

Results showed significant differences for Shannon index in different stand ages. Young stands showed the highest H, medium stands the lowest H and older showed intermediate values. In the opposite way, V values were found to be lower in medium stands but higher in young stands. H was significantly and positively correlated to S, meanwhile it was negatively to V. The life-form rates pointed to higher percentages of phanerophytes in older stands in spite of chamaephytes and therophytes which were most common in young stands. We found no significant differences between reforested and natural stands according to H and S values.

We checked that younger stands (either natural or artificial) showed higher diversity due to lower competence in the first years when invader and annual herbs were present. In the medium and long-term the dominant species increased coverage displacing them. Plant diversity is a dynamic value that should be measured at different stand ages in order to evaluate the effectiveness of restorations or natural regeneration.

Keywords: Aleppo pine, plant diversity, restoration, species richness

O3-6 A pine species surviving after volcanic eruptions

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Among the pines species able to resprout from adventitious buds, the Canary Islands pine (_Pinus canariensis_ C. Sm.) is a unique representative in the old world. Resprouting enables individuals of this species to recover after natural disturbances such as forest fires and -as we will show in this presentation- volcanic eruptions, that reduce their aerial biomass and cause severe mechanical damage on the trunk.
This study aims to
1) acquire some basic knowledge about the nature and the extend of the damage produced by the pyroclastic discharge of volcanic eruptions to the Canary Islands pine populations,
2) describe the recovery process from the tree-trunk wounds developed after an eruption and
3) to discuss on the phenotypic traits favouring fitness of pines to volcano prone habitats.
In May of 2010 we selected three pine individuals located close to La Palma _s "Hoyo Negro", a crater generated after the last freatomagmatic eruption of 1949. Pines were felled and their trunk was cut into small slices. These trees were measured for their age and dendrometrical traits. On a sample of fifty six trunk slices we quantified the proportional damage generated by the pyroclast discharge as well as the post-eruptive tree-ring width development. Two individuals (P1 and P2) were over 120 and 76 years-old and can, conclusively, be considered to have survived the eruption; the third pine (P3), however, was found to be under 61 years old (meta-eruptive pine). The survivor pines were affected at a percentage of 8.7% (P1) and 28.8% (P2) of their total trunk surface (damages were observed exclusively in the direction facing the crater). Individual P2 was found to have healed completely; on the contrary P1 is still seen to be damaged at a 4.1% of its trunk surface.
These results suggest that individuals of the Canary Islands pine have a remarkable ability to heal the wounds generated by pyroclastic flows even when located close to the crater were the eruptive potential is typically higher (P2, for instance, was the nearest pine to the crater, located 45 m away from the border). Old photographs, taken a few days after the eruption show, furthermore, that pines close to the crater were branchless. Based on these results we suggest that fitness of Canary Islands pine to this volcano prone habitat is greatly enhanced by both its wound-healing ability and the capacity to resprout after a pyroclastic flow removes the tree-crown. The role of volcanoes as a selective agent in the evolution of resprouting is considered crucial for this pine species.

ORAL PROGRAM

O3-7 High seed efficiency among Aleppo pine and maritime pine individuals in Algeria

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Cone-seed contents of Aleppo pine and maritime pine were sorted to the following categories: filled seeds, empty seeds and rudimentary structures.

Cones of maritime pine were sampled in the coastal range of El-Kala region within a forest dominated by *Quercus suber* at the boundary frontiers with Tunisia (2,7 km from the sea coast and elevation of 310 m).

Cones of Aleppo pine were collected in three geographic sites corresponding to different ecological conditions: El-Kala, Tikjda and Senalba-Chergui (Djelfa).

At El-Kala, the species constitutes a localised patch on coastal dunes at a distance of 600 m from the sea coast and an elevation of 10 m. At Tikjda, 55 km to the inland, Aleppo pine is represented by scattered individuals within a mixed forest of *Quercus ilex* and *Cedrus atlantica*, at an elevation which does not exceed 1,500 m, but occupies larger areas at lower elevations on the southern side of the mountain. At Senalba-Chergui, distant by 235 km from the sea coast, Aleppo pine constitutes a large forest as a dominant tree between 1,200 and 1,450 m of elevation.

On cones of Aleppo, most of seeds identified as normal-sized revealed to be filled (i.e. 81.92 out of 91.66 normal-sized seeds per cone are filled).

In the average, there are 12.92 rudimentary structures per cone corresponding to 12.54% of the whole cone-seed contents (range per tree: 2.41 - 53.88%) and 9.75 empty seeds per cone corresponding to 10.15% of the whole cone-seed contents (range per tree: 1.85 - 24.21%).

Empty seeds (assumed to result from selfing) and rudimentary structures (assumed to result from inadequate or insufficient pollination) accounted together, for only 22.68% of the cone-seed contents resulting in seed efficiency (ratio "number of filled seeds / the total number of seeds per cone") reaching a high of 77.32%.

Mean values per tree, for the mentioned parameters, indicate that, in either site, we may register low amounts of seed efficiency on some few individuals as a consequence of their reproductive statute during a given reproductive session.

On cones of maritime pine, we recorded 100.66 filled seed/cone out of 122.60 normal-sized one; 9.07 rudimentary structures (representing 7.27% of the cone-seed contents); and 22.04 empty seeds (corresponding to 17.51% of the cone-seed contents). Seed efficiency reached a high of 75.22%.

Ranges per tree are as following: 1.84 - 51.20% for the amount of rudimentary structures; 4.95 - 46.55% for that of empty seeds and 29 - 92% for seed efficiency.

Aleppo pine as well as maritime pine, which are both obligate seeders, displayed similar reproductive strategies with high values of seed efficiency at the stage of mature cone in agreement with their dynamics of stand occupancy.

In its actual extending area within the cork oak forest, maritime pine, displays good seed efficiency in combination with a good dynamics of field recruitment in burned spaces or low density ones as indicated by the cohorts of saplings of different size. A good dynamic of recruitment is also observed among the understorey species such as *Erica arborea, Erica scoparia, Cistus salvifolius, Juniperus oxycedrus,* etc., whereas establishment of cork oak seedlings is deficient. Frequent fires in such site may shift the actual landscape physiognomy, where cork oak is a dominant element in the overstorey, into a forest cover where maritime pine should become the dominant element in the overstorey.

Data on seed efficiency on Aleppo pine indicates its good viability both on localised patches and on large areas. This is in agreement with its chorological statute in Algeria where it occupies very large areas.

Wednesday June 8th • 8:30 – 9:10
Plenary Session
Keynote 3

KN 3 Fire ecology and evolutionary biology of Mediterranean pines

Invited Speaker: Jon KEELEY[1]

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A short biography of Dr. Jon Keeley is available at the beginning of this Medpine4 book.

Pines and angiosperms share a similar history in timing of origin and major species radiations. Faced with intense competition from the rapidly radiating angiosperms, pines and other gymnosperms were at a decided disadvantage in warm and mesic conditions but have been successful in stressful environments.

During the Cretaceous Period the genus *Pinus* underwent a major split into the haploxylon and diploxylon subgenera. Many of the former taxa have subsequently radiated into climatically stressful habitats such as deserts or subalpine environments, whereas most of the diploxylon taxa are tied to fire-prone habitats.

Contemporary Mediterranean Basin species, originated under various climates although selective factors such as seasonal drought and fire prone conditions, have likely prevailed throughout the evolutionary history of many species. Pines in fire prone environments have three very different life history responses to fire.

On highly productive sites where there exists the potential to outgrow the flames from fires spreading through surface fuels, pines have been selected for traits that enhance persistence under frequent low intensity surface fires. On less productive sites where fires inevitably become crown fires a very different suite of traits have evolved. A third category of pines persist in fire-prone landscapes by metapopulation dynamics that cause populations to wax and wane with periodic high intensity fires.

These three life histories require very different land management strategies that seek to both minimize fire danger to human populations and sustain this resource.

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O4-1 Advances in Aleppo pine fire ecology: serotiny and heat insulation

Daniel MOYA[1], R. SALVATORE[2], Jorge DE LAS HERAS[1], Vittorio LEONE[2], F.R. LÓPEZ-SERRANO[1], L. PULIDO[1] and E. VALERO[3]

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Mediterranean Basin is a fire-prone area and the plant communities have therefore developed adaptive traits. Aleppo pine (*Pinus halepensis* Mill.) is a widespread conifer common in the Mediterranean Basin, mainly in low altitudinal and xeric areas. It is an obligate seeder species showing a dual life strategy, usually colonizing unburned areas by releasing seeds enclosed in non serotinous cones or promptly starting recover after disturbance (fire or severe drought) through seeds released from serotinous cones. Serotiny is described as the closure of cones to store seeds but concentrating the seed delayed release and dispersion after fire occurrence. We proved that is a very complex adaptive trait increasing fire resilience. We sampled several cones from two autochthonous provenances of southern Italy, in the main area where species is native. They were separated by cone age and colour, but also by differences in the temperature necessary for cone opening which allowed distinguishing serotinous from non serotonious strobila. We investigated on macro and microscopic characteristics for both cone types to check morphological differences. In addition, the protection of wood scales to seeds against temperature increase was evaluated. We applied different heating levels (in a muffle furnace) to simulate crown-fire scenarios, following the inner thermal raise of cones. We also checked differences in seeds developed in both cone types: seeds were manually extracted, counted, weighted and separated according the cone type. We recorded the seed size, embryo diameter and the nutritive tissue thickness, but also analysed them by using both, a scanning electron microscopy and an energy dispersive X-ray spectroscopy. In addition, the seeds were heated simulating surface-fire scenarios. The germination percentages and enzymatic activity values were evaluated for both types.

Anatomical differences seem related to differences in thermal insulation comparing serotinous and non-serotinous cones. Our results confirm that serotinous cones are more compact, rigid and consistent than non-serotinous cones, so exhibiting a higher insulation degree. Seeds exhibited too anatomic and morphological differences according to cone type and provenance. Bigger seeds were found in wetter provenances and developed in non-serotinous cones. They had some characters related to a more efficient germination in absence of fire but it implied lower heat protection as expected. Serotiny is confirmed as an efficacious adaptive trait in *Pinus halepensis*, significantly influencing the ability to cope with recurrent fires. The characteristics obtained are coherent with the lower insulation, seed protection and the ease opening and also with the higher biological quality but lower heat resistance of the seeds enclosed in non-serotinous cones. Advances in knowledge of serotiny can improve post-fire management protocols and promote restoration tools improving serotiny in fire-prone areas with high events recurrence.

Keywords: Pinus halepensis, Resilience, Fire ecology, Restoration, Post-fire germination

O4-2 Assessment of Aleppo pine stands resistance in recurrent forest fires: The case study of Mt. Penteli, Greece

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Forest fires, an integral part of Mediterranean ecosystems, affect the composition, structure and dynamics of natural ecosystems. The particular fire regime found across Mediterranean Basin is primarily driven by climate, characterized by extensive dry and warm summers as well as by human presence and activities. However, as a result of the spectacular increase in the number of fire events observed in recent decades, recurrent fires over the same landscape as well as intensification of human activities, resilience of Mediterranean ecosystems is set under threat.

Pinus halepensis (Aleppo pine) forests found across the west part of the Mediterranean Basin have long been considered to be wildfires. They can be burned and subsequently regenerate without being degraded under certain conditions. However, under decreased fire return interval and hence low pine seed availability, Aleppo pine forests are loosing their structure being thus in danger to be transformed in shrublands. In addition, fire-affected Aleppo pine stands found within or near the Wildland-Urban-Interface (WUI) are in danger from the expansion of residential areas. Within this context there is a need for spatially explicit data in order to map and monitor spatio-temporal processes and changes in Aleppo pine ecosystems resulting from wildland fires.

The aim of this study is to map and interpret Land Use/Land Cover (LULC) transformations observed in Mt Penteli, Greece with special emphasis on the abundance of pine forests. The majority of the Mt Penteli (max altitude 1,200m) situated north-east of Athens city, was covered by the first half of the 20th century by Aleppo pine forests. During the 20th century several fire events and human activities led to significant changes in the vegetation cover and the LULC of the mountain.

Spatio-temporal maps were produced over a period of 62 years (1945-1960-1996-2007) based on historical panchromatic aerial photographs and natural colour orthophotographs. To determine multi-temporal changes multi-date post-classification comparison was adopted upon the creation of transition matrices. To quantify landscape patterns and analyse landscape dynamics, landscape metrics were calculated both at landscape level and for Aleppo pine class. Finally, diachronic fire scar mapping at Mt. Penteli was conducted from analogue Forest Services maps and satellite imagery. Spatio-temporal changes were linked to Mt. Penteli's fire regime in order to assess Aleppo pine resistance in recurrent forest fires.

Keywords: spatiotemporal changes, Landuse cover, *Pinus halepensis*

O4-3 Post-fire salvage logging increases water stress and reduces seedling growth and nutrient uptake of *Pinus pinaster* in the Sierra Nevada, Spain

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Intense debate surrounds the effects of post-fire salvage logging versus non-intervention policies on forest regeneration, but scant support is available from experimental studies. We experimentally analyse the effect of three post-fire management treatments on the growth and performance of seedlings of a serotinous pine (*Pinus pinaster*) in the Sierra Nevada of Spain, a Mediterranean mountain range. Treatments were applied seven months after the September 2005 fire and differ in the degree of intervention, ranging from "no intervention" (NI, all trees left standing) to "partial cut plus lopping" (PCL, felling most of the trees, cutting the main branches, and leaving all the biomass *in situ* without mastication), and "salvage logging" (SL, felling and removing the logs, and masticating the woody debris). After three years, a random sample of naturally regenerating young pines was harvested (above-ground biomass) and analysed for growth, biomass, nutrient content, and leaf _^{13}C. Total above-ground pine seedling biomass was similar among treatments, although it tended to be higher in PCL (marginal significance). However, biomass accumulated during the second and third growing season (years 2007 and 2008) was higher in PCL or NI treatments, and the lowest in SL. Leaf nutrient concentrations in the second and third growing seasons were overall similar among treatments, and even lower in SL. As a consequence, accumulated nutrient pools were overall higher in PCL treatment and lower in SL. Pines from SL showed the highest leaf _^{13}C values, suggesting more severe water stress in this treatment. The results support that salvage logging has a negative effect on pine growth and performance, and that this effect magnifies with time in relation to treatments were burnt logs and branches are left in situ. This is likely associated with the amelioration of microsite conditions under the burnt logs and branches by increasing soil moisture and nutrient availability through wood decomposition.

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Keywords: Facilitation, nurse structures, *Pinus pinaster* regeneration, post-fire restoration, salvage harvesting

ORAL PROGRAM

O4-4 Modelling the immediate post-fire mortality of maritime pine (*Pinus pinaster*)

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The prediction of fire-induced tree mortality is crucial to assess the ecological impacts of disturbance by fire and is an important component of prescribed burning planning. Two-year post-fire tree mortality data was available from previous studies conducted in Portugal and France on the fire ecology of maritime pine. Such experimental data, plus data from wildfire events, was analysed with the goal of modelling both tree- and stand-level mortality from common tree attributes and fire severity descriptors. The individual tree data base included 2,145 trees with diameter at breast height (dbh) and height varying in the ranges of 1-29 cm and 1.6-19.0 m, respectively.

Three-variable logistic regression models were built for the probability of tree mortality using as independent variables dbh, burn season (dormant or growing) and, as alternative descriptors of crown injury, the ratio of crown scorch height to tree height (RSH), crown scorch volume, or green crown length; the three models perform similarly and all have excellent discrimination ability, with areas under the ROC curve of 0.95 or 0.94.

Classification tree modelling showed that individual mortality resulting from dormant season burning was almost absent when RSH < 0.90 and dbh ≥ 6 cm. However, under this RSH partition, growing season fires killed 70% of all trees with dbh < 13 cm. RSH dominated the mortality explanation (64.4%), followed by dbh (25.1%) and burn season (10.5%). Stand-level mortality was expressed as the percentage of basal area killed and was modelled from data from 118 fires, where flame length ranged between 0.3 and 4.3 m. Regression tree modelling based on fire severity classification and stand type (planted or naturally-regenerated) explained 75% of the percentage basal area killed, with the upward component of fire severity accounting for 86% of the explained variation. Stand-level mortality was primarily driven by weather-related variables, the results suggesting marked non-linear effects. The models reflect only the direct, immediate impact of fire, hence are not applicable when delayed secondary mortality occurs due to biotic agents.

Keywords: Pinus pinaster, tree mortality, fire effects, fire ecology, prescribed burning

O4-5 Stand characteristics and canopy fuel load after thinning in Aleppo pine stands

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Characterization of fuel is required for fire risk assessment. Aleppo pine is a major Mediterranean fire-prone ecosystem, which fuel characteristics have seldom been studied. In addition, prescriptions about distances between crowns on fuel-breaks imply intensive thinning which is difficult to evaluate (number and diameter class of stems to maintain, final fuel load, etc). In the present study, we describe and use a model for Aleppo pine fuel that considers management. This model is integrated to the Fuel Manager, which is a software devoted to fuel modelling, fuel build-up and fire effect assessment. This software is included in Capsis (http://www.inra.fr/capsis), a platform designed to host forestry models, either growth and yield or forest dynamics models including regeneration and mortality processes.

Aleppo pine stands were modelled from stand characteristics (age, dominant height, number of stem per hectare) or dbh inventory. Individual tree diameter, height, crown base height were simulated with a statistical approach. A 3D stand was generated, thinned and visualized. The fuel characteristics (needles and small twigs amount and distribution) of individual trees were derived from allometric relationships with dbh.

Using a French National Inventory, 558 plots were simulated. From these simulations, canopy fuel load was modelled as a function of stand synthetic parameters (canopy cover (C_{ini} in %), dominant height ($hdom_{ini}$)).

$$Load_{ini}(kg/m^2) = (0.0081 + 0.0094 hdom_{ini})e^{0.025 C_{ini}} \qquad R^2 = 0.95$$

Several scenarios of thinning were also simulated, with a target distance between crown d varying from 1 to 10 m.

Several relationships were then assessed, in order to provide accurate estimates of number of stem per ha (Nha) or fine fuel load after treatment (using Gha_{ini}, the initial basal in m^2/ha):

$$Nha = 80.6 \frac{Nha_{ini}^{0.415}}{(2+d)^{1.35}} \quad (R^2 = 0.91)$$

$$Load = 0.035 Nha(d, Nha_{ini})\left(1.08 \frac{Gha_{ini}}{Nha_{ini}} + 0.003\right) + 0.017 \quad (R^2 = 0.97)$$

The present study provides managers a useful application of stand modelling, allowing estimating fuel characteristics of Aleppo pine stands according to thinning intensity.

Keywords: Fuel Modelling, Stand Dynamics, FUEL MANAGER, CAPSIS, Fire Sciences

O4-6 Long-term monitoring (1989-2010) of growth and reproductive performance in a postfire-regenerating Aleppo pine population on Mt Parnes (Attica, Greece)

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The early, post-fire regeneration of a 45-yr-old *Pinus halepensis* (Aleppo pine) forest in Mt Parnes, entirely burned in July 1989, has been continuously monitored for 21 years (1990- 2010) in regard to pine seedling establishment and survival as well as plant growth and reproduction. Measurements were carried out (at least once yearly - at the end of the growth season) in four experimental plots (established early in 1990, at various slopes and exposures, Thanos et al. 1996) on randomly selected, tagged individuals (fifty saplings per site) and on additional larger samples of pine saplings. Detailed height dynamics for four growth periods (Sep 93 – Jul 97) followed sigmoid curves for each yearly growth season (Thanos et al. 2002).
The overall dynamics of the annual growth increment are considerably slower in comparison with all available bibliographic data, due to the very poor soil conditions in Mt Parnes. Although pine height dynamics followed initially (for the first 15 years) an impressive linear regression curve, this curve has eventually turned into a power function one for the entire 21-yr period of study ($Y = 4.1437\ X^{1.2829}$, $R^2 = 0.9974$; average annual increment 9.8 cm). On an individual sapling basis, height variability both among- and within-site has been considerably marked. Mortality of saplings after the initial establishment period (1990-1993) was rather negligible and this has led the negative exponential curve of survival to level off at a value ca. 15% of the initially (end of spring 1990) established pine seedlings.

The transition of the pine sapling population from the vegetative growth phase into the reproductive one also followed significantly slower dynamics (compared to other cases reported in the literature); best fit curve is sigmoid, starting at year 4 after fire (0.1% of pines with cones) and approaching 40% at year 21; reproductive individuals are significantly taller (on average) than those remaining at the vegetative phase. Finally, yearly data on cone abortion rate, cones per plant (including temporal variability on an individual basis), cone size and mass and germinable seeds per cone are presented and analyzed.

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Keywords: *Pinus halepensis*, postfire growth and reproduction, height dynamics, cone bearing, seed germination

O4-7 Providing silvicultural models to reduce crown fire hazard in *Pinus halepensis* stands

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In the Mediterranean basin the likelihood and impact of wildfires might increase in the near future due to climate, environmental and social changes leading to drier periods, higher fuel loads and more ignition sources. In Catalonia (north-eastern Spain), close to the 90% of fires do not exceed 10 ha, but the remaining percentage is the responsible of near de 95% of the total area burned per year. In a context of global change, active crown fires pose a significant and growing threat to forest managers, who need tools for fuel management.

Using an expert opinion approach we have developed a key based on the main structural and silvicultural variables that play a significant role in crown fires. The key has been designed to rank pre-fire stand conditions for the initiation of crown fires in *Pinus halepensis* stands in Catalonia. The key has led to a total of fifty eight types of forest structures, ranked as:
A (high vulnerability to the initiation of active crown fire),
B (moderate) and
C (low).

In addition, silvicultural models have been developed in order to reduce crown fire hazard taking into account the defined forest structures. The models use, a part of most common forest stand variables, variables as the percentage of surface fuel cover, presence of ladder fuels, height to live crown and percentage of forest cover. We discussed the effectiveness of treatments such as thinning from below, pruning and understory removal to reduce canopy bulk density, increase live to crown base and reduce surface fuel load for each rank.

Keywords: Pinus halepensis, crown fire hazard, expert approach, forest structures, silvicultural models

Thursday June 9th • 8:30 – 9:10
Plenary Session
Keynote 4

KN 4 Adaptative management to global change in Mediterranean pine forests

Invited Speaker: José G. BORGES[1]

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A short biography of Dr. José Borges is available at the beginning of this Medpine4 book.

The aim of this talk is to present and discuss models and tools that may be used by the public administration, non-industrial forest owners, industry and non-governmental organizations for enhanced adaptive Maritime pine forest management planning.

Methods and tools that will be discussed in order to address the complexity of Mediterranean pine forests adaptive management planning encompass
(1) risk models,
(2) damage models,
(3) fire spread models,
(4) fuel and stand growth and yield models,
(5) stand-level management scheduling models,
(6) forested landscape management models and
(7) information and decision systems as technological support platforms.
A new approach to adaptive pine forest management planning by developing, testing and combining methods and tools (1) to (7) will be discussed.

Recent research results will be presented. Emphasis will be on demonstrating:
(1) the use of risk and damage models to generate change scenarios,
(2) the use of process-based models to project vegetation in climate change scenarios,
(3) the use of stochastic dynamic programming to design optimal adaptive management policies under change scenarios,
(4) the use of mixed integer and stochastic programming to address adaptive management planning at various spatial scales.

Keywords: risk model, wildfires, mortality model, forest management, stochastic programming

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O5-1 Distribution, interactions and impact of mistletoe in the Mediterranean pine woodlands under a climate change scenario

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Changes on climate will affect growth and survival of *Pinus* species (Reich & Oleksyn 2008), mostly in populations situated in the edges of their distribution. However, little is known about the effect of climate warming on *Pinus* distributions through the variation of biotic factors such as parasite-host interactions. In Mediterranean mountains *Pinus nigra* and *Pinus sylvestris* are commonly infected by a parasitic plant, the specialist Pine mistletoe (*Viscum album* spp. *austriacum*).

The effects of Pine mistletoe can be magnified under a climate change scenario, favouring its spread and increasing water stress of hosts. We hypothesize that under a scenario of climate warming Pine mistletoe will expand its altitudinal distribution range since a warmer climate positively affects its establishment and survival success, while host species (*P. nigra* and *P. sylvestris*) will become more prone to infection (Dobbertin & Rigling 2006). The study was conducted in Sierra de Baza Natural Park (37°42´N 2°86´W), a Mediterranean mountain range in south-eastern Spain, during November 2010 to December 2011. The study site represents the southernmost limit of the European distribution of *V. album* spp. *austriacum* and *P. sylvestris*. We measured Pine mistletoe infection prevalence and determined its demographic structure at eleven altitudes. We also recorded Pine mistletoe germination and establishment success along the altitudinal gradient through a seeding experiment. HOBO data loggers were used to record temperature of the near environment of sowed seeds on pine branches.

Results show decreasing mistletoe prevalence with increasing altitude and older mistletoe populations at higher altitudes. From an applied point of view, the results obtained are valuable to improve integrative management of forest pests, promoting the diversity of ecological interactions and forest conservation in climatic adverse environments.

References:
Dobbertin M. & Rigling A. (2006). Pine mistletoe (Viscum album spp. austriacum) contributes to Scots pine (Pinus sylvestris) mortality in the Rhône valley of Switzerland. Forest Pathology 36: 309-322.
Reich P. B. & Oleksyn J. (2008). Climate warming will reduce growth and survival of Scots pine except in the far north. Ecology Letters 11: 588-597.

Keywords: Ecology, Climate Change, Conservation

Thursday June 9th • 8:30 – 9:10
Plenary Session
Keynote 4

O5-2 Genetic variation in phenotypic plasticity of a *Pinus pinaster* Atlantic population in a transitional region to Mediterranean conditions

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Pinus pinaster is found in the Iberian Peninsula under a wide range of climatic conditions, from the harsh Mediterranean conditions in the Southeast to the favourable Atlantic influence in the Northwest. Mediterranean and Atlantic climates encounter each other in Galicia (NW Spain), where *P. pinaster* is a main forest species. Here, two different environmental regions can be clearly differentiated, the coastal and the interior area. Both regions differ mainly in summer drought intensity and intra-annual temperature oscillation. Trying to account for the large climatic differences between regions, two breeding and deployment areas are currently delimited. A breeding program was started in the Coastal area, where plus trees were selected and established in clonal seed orchards. The analysis of the plasticity patterns of the coastal-selected material across these two regions and the identification of the environmental variables that define these patterns is highly desirable, not only to check the suitability of the breeding areas but also to improve our knowledge about how the breeding material will respond to the predicted climate change.

Here, we analyse the genetic variation in phenotypic plasticity of the breeding coastal population of maritime pine across the transition region between the Atlantic and Mediterranean conditions in NW Spain. We characterized the Genotype by Environment interaction patterns of 116 open pollinated families of superior trees selected within the Coastal region and planted in sixteen locations covering a wide range of environments, from clearly Atlantic climates to Mediterranean-like interior areas. Total height three and seven years after plantation was used for the analyses. In particular, stability analyses were performed using mixed models, grouping of environments with similar genotypic performance was conducted with the CINTERACTION procedure, and familiar sensitivities to explicit environmental factors were characterized using factorial regression.

The results show intra-specific variation in phenotypic plasticity among the studied families. The previous delimitation of the two breeding areas appears to be pointless, since crossover interactions were detected both within and between breeding areas. It was not possible to regionalize Galicia into other geographic areas of stable genotypic performance. Additionally, no single environmental parameter alone could explain the observed interaction patterns. However, the thermal regime and, especially, the frost frequencies were found to partly underlie the array of observed phenotypic responses to changing environmental conditions. These results suggest a relevant role of climate warming on the success of the Coastal breeding material when transferred to inland areas. Selecting for genotypic stability appears as a conservative strategy to reduce the transfer risk and also to pull together all breeding activities into a single deployment area.

Keywords: Genetics and breeding, genotype x environment interaction, crossover interaction, stability, maritime pine

O5-3 Long-term fire history and diversity in Mediterranean mountain of Corsica

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Question: Relationships between vegetation, climate and disturbance are likely to be altered in the near future as a result of changes in both climate and human impacts on ecosystems. Studies on the variability of multi-millennial fire regimes are needed to understand plant responses in a changing environment in term of biodiversity (testing here the intermediate disturbance hypothesis [Connell 1978]) and dynamics.

Methods: We present high-resolution charcoal records from lacustrine cores from a small lake located in a coniferous Mediterranean forest. Sedimentary plant macroremains are used as local vegetation proxy. Fire frequency is reconstructed by decomposing the high-resolution sedimentary charcoal series.
Location: Creno lake (1,310 m), a *Pinus nigra laricio* dominated ecosystem, Corsica, France

Results: Frequent fire events and presence of *Pinus nigra laricio* was recorded since 10,000 years ago at least. Two distinct periods of fire regime were detected based on fire intervals; the mean fire intervals (MFI) were longer (299 ± 303) between c. 9,000 and 3,800 years ago. The MFI was shorter after 3800 BP and we observed a peak of fire frequency at 2,900 cal (125 ± 103). The plant assemblages show one clear switch of composition and abundance. Between c. 9,000 and 3,800 years ago, the vegetation was composed of *Pinus nigra laricio, Betula* sp., and *Fagus silvatica*. During the last 4,000 years, the abundance of these species increased and, we observed the local stochastic development of *Abies alba* in the assemblages. Statistical analyses show that *Pinus laricio* was the specie characterizing this ecosystem all over the last 10,000 years. Two different ecological trajectories are evidenced, first characterized by Pinus nigra laricio and Ericaceae whatever the MFI and, second, by *Fagus silvatica* and *Betula* sp. with low MFI.

Conclusion: Changes in fuel quality (species) likely explain the fire frequency transition. Our results indicate that the vegetation are linked to fire intervals in the mountain Mediterranean forest of Corsica since 10,000 years at least.

Keywords: Paleoecology, ecosystem, pine forest, Mediterranean, fire frequency

O5-4 Mountain pine at the treeline in the Mediterranean Basin

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Actually, the Mediterranean Basin is affect by important changes in climate and land-use. The greatest impact of global warming is expected to occur on ecosystems at high altitudes, where plant growth is mainly limited by temperature; as well the abandonment of marginal areas, land-cover change and grazing cessation have transformed the landscape patterns deeply. The end of traditional human practices in alpine ecosystems and the increase of tree productivity and survival at high elevation, because of warming temperature, have led to a negative impact on the spatial distribution of rare or endemic species. These changes occur also along the Italian peninsula, on the Apennines chain and, in particular, on the Majella Massif. This mountain represents one of the lower border of the subalpine/alpine ecocline at continental level, where the treeline ecotone is dominated by mountain pine (*Pinus mugo Turra* ssp *mugo*), unlike the typical Apennines treeline with a compact frame of beech forests. The mountain pine forms populations mainly on the Alps treeline, while in the Apennines only in Abruzzo, where the widest stands are in the Majella massif [habitat 4070 * bushes of *Pinus mugo* and *Rhododendron hirsutum* (*Mugo-Rhododendretum hirsuti*)].
In order to examine the relative roles of climate warming, land abandonment and natural disturbance in influencing the population dynamics of mountain pine tree lines in the Majella National Park, Italy, we conducted analysis of the distribution of mountain pine stands based on:
1) orthophoto video interpretation from 1954;
2) historical research on the grazing practice within the study area;
3) dendroclimatological analysis.
The distribution map of the mountain pine was created by visual interpretation of the 2007 orthophoto and manual delineation in a GIS environment, and then modified on the basis of the 1999, 1991 and 1954 orthophotos in order to obtain the historical mountain pine distribution maps. Each polygon was classified according to crown cover classes: I < 40%; 40% < II <80% and III > 80%. All the maps were overlayed with the DEM in order to extract the average, minimum and maximum altitude of mountain pine at the different investigated dates. By various documentary archives, supplemented by interviews with local authorities, we reconstruct the grazing history from the 1880s. The canopy cover versus time provides a proxy indicator for reconstructing forest cover change, whereas the number of sheep versus time allows an indirect assessment of grazing rate changes. Two sampling site was selected for dendrochronological analysis, where two transects were established along an altitudinal gradient (from 2,000 m to 2,200 a.s.l.); within each transect of 3,000 m^2, three plots (30 x 20 m) were sampled at a distance of 10 m from each other. Cores of *P. mugo* trees were extracted and rings counted and measured. Raw and standard ring-width chronologies were generated and correlated with temperature and precipitation, from the nearest montane meteorological station, by Pearson's correlation. On the Majella massif, the mountain pine forest extends over an area of 1,403 ha. The altitudinal distribution of the forest ranges from 1,438 to 2,503 m asl; during the last 52 years, the mountain pine forest has expanded 52 m upwards and 154 m downwards; the forest cover has increased during the past 50 years with a mean annual increment of 13.7 ha. Significant and positive correlations were found between the *P. mugo* growth and spring maximum temperature and summer rainfall. This implies that *P. mugo* dendrochronology is a suitable proxy for trends in warmer springs or wetter summers, had they occurred. However, the comparison between historic photographs and

age structure indicates that areas that are now covered by closed mountain pine forest were almost vegetationless in the first half of the 20th century. Large areas of the Majella plateau (at the tree line), once grazed, are today covered by an upward-expanding mountain pine forest. The pattern of *P. mugo* expansion has changed fundamentally during the last 50 years, involving bare lands, simultaneously with land-use abandonment, then, the tree line upward migration since the middle of the 20th century should be explained by the abandonment of alpine pastoralism. Further analysis warrants investigating the expansion and colonization of mountain pine downhill, in crop systems and beech forest.

O5-5 Pollen Dispersal and Movement in Scots Pine (*Pinus sylvestris* L.), Its Relations with Climatic Conditions; Concepts of Subpopulation and Population

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The aim of this research was to study the effects of climatic conditions on pollen dispersal, to find out the relations between onset of pollen shedding and temperature sums (degree days), and to evaluate the subpopulation and population (provenance; seed stand) concepts in Scots pine (*Pinus sylvestris* L.) stands in Eski_ehir - Çatacık - Turkey.
The seasonal and diurnal course of pollen dispersal were recorded by two pollen samplers which were mounted on two anthesis masts at a height of most common occurrence of female flowers in the Scotch pine stands (1550 m asl). A meteorological tower was constructed about one meter above the height of the trees. Data on temperature and relative humidity were collected by means of a thermograph and hygrograph mounted on the meteorological tower, and precipitation was measured by a rain gage. Phonological observations concerning anthesis and gynesis were made once a day at five points between elevations of 1,250 – 1,650 meters with vertical intervals of a hundred meter. Pollens on pollen bands catched by the recording pollen meters were counted by means of a microscope. Temperature sums at the time of onset and ending of pollen dispersal were calculated by using 5°C threshold value.

Seasonal pollen catch values of Scots pine were 1,065; 1,385 and 3,648 pollens per mm^2 in the years 1970, 1971 and 1972, respectively. Considering six days of maximum pollen dispersal, more than 90 percent of total catch were recorded in day time. Temperature was found to be more limiting factor on pollen shedding than the relative humidity. Maximum pollen dispersal occurred at one of the warmest hours of one of the warmest day during the pollen shedding period. Diurnal cycle of pollen dispersal might also be controlled, genetically including external factors. Pollen catch values decline rapidly as the distance from the pollen samplers, in other words from the female flowers, increase.

The results revealed that in the years 1971 and 1972 15.0% and 14.5% of annual temperature sums were required for the onset of anthesis, respectively. These results fairly agreed with the findings in Finland and other European countries. Considering pollen movement within the stands, subpopulation and population (provenance, seed stand) concepts were discussed. Furthermore minimum and maximum area of a seed stand in natural Scots pine forests were evaluated from the viewpoint of genetic and practice. The study is a part of the author's doctoral thesis and/or produced from it which were published in Turkey, but not submitted to an international meeting or published in an international journal.

Keywords: Scots pine, Pollen dispersal, Climate, Temperature sum, Subpopulation, Population, Genetics and breeding, Ecology

O5-6 Spring precipitation and genotypic variation may be the key to the persistence of *Pinus sylvestris* at the forest-steppe ecotone in the Central Alps

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Increased summer drought will exacerbate the regeneration of many tree species at their lower latitudinal and altitudinal distribution limits. In the Central Alps, where forests play an important role in the protection against natural hazards, increased drought may threaten the persistence of *Pinus sylvestris* forests at the forest-steppe ecotone. Management options include the introduction of more southern provenances or more drought resistant species.

We compared the performance of *P. sylvestris* seedlings from the Rhone valley, Switzerland, to that of P. sylvestris and closely related *P. nigra* from a more southern seed source in the Penyagolosa Mountains, Spain, under combinations of increased soil temperature (ambient, +2.5°C, +5.0°C) and three precipitation regimes simulated in a common garden experiment with mobile rainshelters.

Seedling performance was much more affected by low summer precipitation than increased soil temperatures. Under conditions of high spring and low summer precipitation, the number of autochthonous *P. sylvestris* seedlings reached twice the number of seedlings under conditions of low spring and summer precipitation. This difference was due to higher emergence rate but not increased survival. Soil heating of 5°C led to earlier seedling emergence, which slightly increased seedling survival during summer drought compared to temperatures of +2.5°C.

Under low summer precipitation, two times more seedlings of the southern *P. sylvestris* provenance were present at the end of the growing season than the autochtonous provenance, due to higher rates of seedling emergence and lower mortality in summer. Independent of spring precipitation, *P. sylvestris* provenances allocated similar amounts of biomass to roots when grown under low summer precipitation. But, under high summer precipitation, the southern seedlings had higher root-shoot ratio under indicating lower phenotypic plasticity.

Similar performance of southern *P. sylvestris* and *P. nigra* suggests that the introduction of new species should not be a priority for forest management at the Central Alpine forest-steppe ecotone.

Low plasticity of southern *P. sylvestris* provenances may limit their competitive ability in Central Alpine stands of *P. sylvestris* in years with average precipitation. By contrast, high variability in the response of autochthonous seedlings to summer drought indicates high genotypic variation and the potential for adaptation to changing environmental conditions.

Keywords: phenotypic plasticity, climate change, species provenance

O5-7 Direct and delayed impact of climate accidents on the architectural development and leaf area of Mediterranean pines

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Context of the study: Many past and present research deals with the influence of climate on the secondary growth of Mediterranean pines (tree-ring, long-term evolution of productivity). Conversely, very few can be found in scientific literature on the interannual variations of primary growth and tree architectural development, and their evolution with climate change.

Goals: We tried to quantify the influence of climate and climatic accidents (scorching heat, drought, snow) on the primary production and architectural development of five pine species growing in Mediterranean regions: *Pinus halepensis, P. pinea, P. pinaster, P. nigra and P. silvestris.* Measured parameters include branch length growth, number of annual flushes for polycyclic species, branch ramification rate, the size of needles and number of needles per year, the production of male and female flowers and the rate of successful fructification. The study also aimed at assessing the direct and delayed effects of climatic accidents on the leaf area, to be related to observed crown transparency.

Material and methods: The study area includes eight sites distributed from the coast to the hinterland, between 100 and 1,300 m of elevation. 2,100 branches from 105 trees were sampled from 2004 to 2010 and architectural development was retrospectively measured from morphological markers over a period of 15 to 25 years according to species. The sampling design considered separately for each tree various parts of the crown (top, middle and base), orientation (north and south), and took into account branch hierarchy (primary or secondary axis) and vigour. A weekly follow-up of phenology and architectural development was performed from 2008 to 2010 and is still ongoing on one of the sites to measure precisely their evolution and understand better their relations with climate. A simplified model of pine branch architectural development was calibrated to simulate the impact of various climatic accidents on pine leaf area. The observed variations of the architectural parameters were integrated into a more complex model of full tree development, and compared to ring width.

Results: Models of architectural parameters versus climate relationships were calibrated with the monthly or seasonal data of rain and temperature and their extremes. For a given year, architectural parameters were often mainly influenced by the climate of the previous year, and for less than 50% by the climate of the current year. Their medium-term evolution was clearly influenced by recent climate changes, particularly repeated droughts and increasing temperatures. For branch length growth, we were able to disentangle the respective weight of climatic accidents and of the normal evolution with age.

With the exception of *Pinus silvestris* at high elevation in the hinterland (Mont Ventoux), 2003 scorching heat and repeated droughts from 2003 to 2007 considerably reduced the primary production for all species and on all sites: weak branch length growth, abnormally short needles and low number of needle per shoot, low polycyclism, ramification and fruiting rates. This reduction began in 1998 for most of these parameters in the low and sometimes middle parts of the crowns, and on weak branches. For the most Mediterranean species (*Pinus halepensis* and *P. pinea*), these parameters recovered gradually from 2008 to 2010 in the top crown, but they remained low in the middle and base of the crown and, for the other species, in the whole crown. The weakness of trees in the 2003 to 2007 period was highlighted by the impossibility for twigs to develop normally when they carried cones: the dominant axes, on

which the female flowers are formed, often aborted behind cones or gave up their dominance to side twigs.

Phenology follow-up showed that, at low or intermediate elevation, climate warming led to a time shift and disturbance in the architectural development: male flower appearing in the middle of winter, continuous growth of shoots over two successive years. These disorders led to high rates of twig abortion caused by frost and fungus.

Simulations with architectural development models allowed calculating the resilience of leaf area according to the intensity and duration of climate accidents. Following the 2003-2007 drought, the deficit of active twigs (carrying needles) and of leaf area amounted respectively to 60% and 75% for *Pinus halepensis* compared to the values simulated with an average climate. Because of the 2 to 3-year persistence of needles and of the time necessary for restoring a normal ramification rate, this deficit is only slowly absorbed: it remained close to 30% and 40% respectively two years after the end of the drought and may need four years to disappear if no new accident occurs.

The long lasting reduction of potential tree LAI after a climatic accident, due to a simplified architecture and small needle size, may contribute to carbon shortage and starvation, and therefore to delayed forest die back.

Thursday June 9th • 14:50 – 15:30
Plenary Session
Keynote 5

KN 5 Biogeography of genes and evolutionary history of Mediterranean pines

Invited Speaker: Bruno FADY[1]

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A short biography of Dr. Bruno Fady is available at the beginning of this Medpine4 book.

Mediterranean pines share common biological attributes such as a wind-pollinated and mostly outcrossed mating system which promotes long distance gene flow. However, they are found at almost all altitudinal levels around the Mediterranean Basin, from sea level under hot and dry bioclimates to high elevation mountains under wet and cold bioclimates. Their distributions range from widespread to regional and narrowly distributed, from dense populations to scattered individuals. They have been extensively used by human civilizations for millennia.

Because of these contrasted ecological, demographic, historical and geographical traits, and despite their common biological attributes, pines of the Mediterranean Basin display complex biogeographical patterns at gene level that can help retrace their Quaternary evolutionary history.

Using examples from the literature on selected species, I will show which are the main factors responsible for within and among population patterns of neutral genetic diversity in Mediterranean pines. Although individual species often represent unique case studies that make generalizations risky, understanding why and where ''hot-spots'' and ''cold-spots'' of genetic diversity are located may prove useful for profiling areas of high conservation value and high potential for breeding or assisted migration under climate change.

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O6-1 Genetic improvement of five pine species in Morocco

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Research on genetics and breeding of pine species is increasingly being seen as essential in many countries. The establishment of breeding programs is not only interested in economic criteria but also in sustainable development and conservation of genetic diversity. To face insufficient wood production, Morocco has already set an important reforestation program. Pine species have been the subject of increasingly intensive breeding efforts.
The first goal was to evaluate genetic variation, due to the geographical origin, in growth traits and drought tolerance. Indeed, several field trials were set up mainly for five species (*Pinus pinaster, P. halepensis, P. brutia, P. canariensis and P. pinea*).
The results showed significant differences between species, provenances and progenies. They are in accordance with what may be expected from knowledge of the drought severity of the environment and the natural distribution of species. Recommendations on the use of certain genetically superior seed sources for reforestation are made.

Keywords: Pine, genetics, breeding, growth, drought, provenances, progenies, Morocco

O6-2 Main results of the Pinus halepensis – Pinus brutia French comparative provenance trials

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Pinus halepensis Mill. and *Pinus brutia* Ten. play a major role in low elevation Mediterranean forests, covering 7 millions ha around the Mediterranean Basin (250,000 in France). Due to their good adaptation to water stress and their ability to rapidly colonize abandoned lands from agriculture or burned areas, these species not only constitute ecologically valuable natural stands but also permit afforestation in dry conditions for production or protection purposes.

In order to estimate the adaptive diversity of these species several multi-site trials (common gardens) were established in the last 35 years by national or international research projects. In France, a two-site comparative trial with twelve *P. halepensis*, twelve *P. brutia* and three *P. eldarica* provenances was planted in south-eastern France in 1976 (Ceyreste), and 1978 (Vitrolles) within the international FAO network (FAO/SCM/CRFM/4bis, Bariteau 1992). Both sites are located in the thermo-Mediterranean coastal environment and exhibit a strong water stress. In order to evaluate *P. brutia* variability in less stressful conditions (deeper soils or higher elevation) a five-site provenance test was planted in 1996 and 1997 within the MPC European project and the FORADAPT INCO project, with eighteen *P. brutia* and five *P. halepensis* provenances. Survival and growth were recorded over years for the two sets of trials. Stem and branch features were also characterised in the 'old' 2-site FAO trial.

In the 'old' trial, the highest mortality rates were observed for some *P. halepensis* provenances from Greece, Italy and Morocco. Provenances from France, Spain and northeastern Greece exhibited high survival rates, but no clear geographic pattern was observed. The highest survival was observed for some *P. brutia* provenances specially those originating from eastern Taurus (Kisildag and Baspinar). At Vitrolles on compact limestone (drier conditions) the best growing provenances belong to *P. halepensis* and provenances originating from high elevation stands exhibited a low growth. At Ceyreste, on sandstone, most of *P. brutia* provenances grew faster than *P. halepensis* provenances. A clear species x site interaction was observed confirming the different ecological optima of the two species.

However provenance ranking within species remains almost stable. In the 'new' 5-site trial, results confirm the better adaptation of *P. brutia* to frost. The very high susceptibility to frost of the Moroccan *P. halepensis* provenance (one of the controls) illustrates the risk of introducing exotic Aleppo pine material in Southern France. In 1956 and 1985, planted stands with Algerian and Italian seed sources were thus seriously damaged by frost (Tabeaud and Simon, 1993). French P. halepensis provenances grow faster than P. brutia provenances which confirm the highest juvenile growth of *P. halepensis*. When becoming older, *P. brutia* trees are expected to grow faster and best provenances should overpass *P. halepensis* as observed at Ceyreste plantation.

Analysis of growth variability among *P. brutia* provenances indicates good performances of material originating from middle altitude eastern Taurus mountain, such as "Mersin Findikpinari" or from north-western part of *P. brutia* natural area. Provenances from eastern Taurus would also exhibit a high survival rate and a good stem straightness. *P. brutia* is undoubtedly a good alternative species for afforestation in southern France, at middle elevation (400-700 m) which generally corresponds to the upper limit of *P. halepensis* and the lower limit of *Pinus nigra*.

These results are of main interest for the knowledge of adaptation to various ecological environments within the global change context, and contribute to the ongoing international synthesis of all the Aleppo-brutia provenance trials.

Keywords: *Pinus halepensis, Pinus brutia,* genetic resource, adaptation, common garden, provenance, survival, growth, France

O6-3 Candidate-gene research to understanding the role of genetic diversity in the adaptive response of Mediterranean pines

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Combining coalescence modelling, neutrality tests and environmental correlations, demographic history and non-neutral patterns of evolution in candidate genes related to drought stress and secondary compounds were investigated in two closely-related Mediterranean conifers, *Pinus pinaster* Ait. and *Pinus halepensis* Mill. Amplicons covering candidate genes were sequenced in a sample from the full range of these two species. Higher levels of nucleotide diversity in candidate genes for drought response were present in *P. pinaster* than in *P. halepensis*, despite its narrower range in the Mediterranean.

Differences across species were also reflected in the haplotype distribution for each tree species, with *P. pinaster* showing many different haplotypes at similar frequencies and *P. halepensis* showing fewer haplotypes with only one that is common or even fixed. The low levels of nucleotide diversity in Aleppo pine are more noticeable in its western distribution where most genes were fixed or almost fixed for particular haplotypes, a probable consequence of long-range colonization of the Western Mediterranean from ancient Aleppo pine populations in the easternmost edge of its current distribution and a more acute impact of the Ice Ages in this range of the species.

Molecular analyses also revealed intense and relatively recent bottlenecks in Aleppo pine as well as a time of split between North-African and Iberian populations of the species well predating the Last Glacial Maximum albeit not as old as the one estimated for maritime pine. In contrast, maritime pine seems to harbour large amounts of diversity for these genes due to a more stable demography; in addition, because of its more mesic distribution, higher environmental heterogeneity would have resulted in contrasted selective pressures that may have increased general levels of diversity at candidate genes.

Using a wide range of neutrality tests, we found some of the candidate genes studied to evolve in non-neutral patterns. Interestingly, two of them showed statistical correlation with temperature variables, in particular with extremely high or low temperatures, and may constitute valuable tools for monitoring adaptive genetic diversity in these two Mediterranean pines. Our study shows that the use of complementary approaches can help capturing different aspects of the evolutionary processes that govern molecular variation at both intra- and inter-specific levels

Keywords: adaptive evolution, neutrality tests, environmental associations, candidate genes, Mediterranean pines

4th International Conference on Mediterranean Pines

ORAL PROGRAM

O6-4 The further we search, the less we found: low genetic variation in quantitative and molecular traits in Mediterranean stone pine (*Pinus pinea*)

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Genetic variation is generally considered a prerequisite for adaptation to new environmental conditions. The finding of widely distributed, obligatory sexually reproducing species that are genetically impoverished is a priori surprising. Mediterranean Stone pine (*Pinus pinea* L.) represents such a case. This native species widely used for reforestation in the Mediterranean for soil protection, ecosystem restoration and both for pine nut and timber production, is characterised by a near absence of genetic variation at both phenotypic traits and molecular markers.

In the early nineties, experimental plots were established in several countries bordering the Mediterranean Sea for studying the distribution of genetic variability between provenances in adaptative traits as survival, vegetative and reproductive phase change, phenology and growth. Here we report the results of the first fifteen years at eleven trial sites in France, Spain and Tunisia, as well as the results of analyses with nuclear molecular markers.

The survival, ontogeny and growth patterns were quite similar among provenances but differed among sites. On the other hand, the phenotypic plasticity of the species produced strong spatial autocorrelations of the response variables, both between and within sites, which masked greatly the variation between provenances. After nearest-neighbours adjustments that captured the spatial patterns, the significance of the geographic genetic variation increased considerably. Comparison of the adjusted average heights of each provenance showed a common trend between sites, with a more vigorous growth in plants from colder inland provenances, coinciding with an earlier spring shoot phenology and a stronger tendency to polycyclism.

Previous results from chloroplast molecular markers revealed that the same haplotype was fixed in nearly all populations investigated, except for some populations at the edges of the distribution (central Spain and Lebanon). New nuclear molecular markers (microsatellites and gene sequences) showed a similar pattern of low genetic variation, for example level of nucleotide diversity of one order of magnitude lower than in other conifer species. On the other hand, significant genetic differentiation was found among westernmost and easternmost stone pine origins, with central Spanish and Lebanese populations showing markedly differentiated nuclear polymorphisms. This extreme situation is probably the result of a combination of factors that have acted in the same direction. The possible role of these factors in reducing genetic diversity in this species as well as aspects related to its demographic expansion will be presented and discussed.

Keywords: Conservation genetics, diversity depletion, Pinus pinea

O6-5 Interpreting the ontogenetic delay of shoot development in Mediterranean pines: adaptive trait or phylogenetic constraint?

José CLIMENT[1], María Regina CHAMBEL[1], Santiago GONZALES-MARTINEZ[1] and Delphine GRIVET[1]

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Juvenile developmental rates are relevant life history traits in plants. Pines show an especially marked vegetative (heteroblastic) phase change during early developmental stages, shifting from a shoot with primary needles and free growth to a shoot with secondary needles and cyclic preformed growth. In previous works we have confirmed - within the subgenus Pinus - a marked divergence in heteroblastic phase change between Mediterranean (Subsection Pinaster) and Eurasian pines (Subsection Pinus) that share neighbouring habitats along the Mediterranean Basin. A high genetic variation between populations and high additive variance within populations has been shown in Maritime pine (_Pinus pinaster_). These facts, together with a significant relationship between the heteroblastic stage of the plants and their field survivorship in some species, as well as marked morpho-physiological differences between primary and secondary needles suggest a relevant adaptive value of the timing of heteroblastic change, at least in some Mediterranean pines.

However, we still do not know to which extent interspecific differences in this trait might be due to a phylogenetic constraint or to relatively recent adaptation. On the other hand, the fact that one of the species with a more exaggerated ontogenetic delay, the Canary Islands pine (_Pinus canariensis_), has also the rare ability of resprouting in adult stage, could suggest that both traits are evolutionarily linked. To test these hypotheses, we performed a nursery common garden experiment with thirty species covering all subsections of subgenus Pinus (Dyploxylon) and a smaller sample of subgenus Strobus (Haploxylon). We used the ratio of secondary needle dry mass to total foliar dry mass, reflecting the degree of heteroblastic change, as a quantitative ontogenetic index.

Results confirmed the rarity of ontogenetic delay in the genus: within subsection Pinaster, _Pinus canariensis_, _P. halepensis_, _P. pinea_ and _P. roxburghii_ (the Himalaya's chir pine) shared this character, but not their close relatives _Pinus pinaster_ and _P. brutia._ No other species of subgenus Pinus showed such a marked delay. The apparent delay in some Haploxylon pines (_P. cembroides and P. lambertiana_) cannot be separated from their extremely low growth rates. On the other hand, with the exception of the Canary Islands pine, all sprouter species assayed (_P. merkusii P. rigida. P. oocarpa_ and _P. leyophylla_) showed normal or fast heteroblastic development rates, which seems to discard an evolutionary correlation between resprouting ability and delayed shoot ontogeny in pines.

We discuss the relevancy of these findings (i.e. patterns of trait evolution) in the light of new ongoing research on Mediterranean pines molecular phylogeny of DNA sequence data and the correlations with other life history traits of the species (i.e. patterns of correlated evolution).

**Keywords:** Correlated evolution, Heteroblasty, Ontogeny, Phylogeny, Resprouting

O6-6 Genetic variation of cavitation resistance in *Pinus pinaster*: the first evidence for uniform selection in plants?

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Cavitation resistance to water stress-induced embolism determines plant survival during drought. This adaptive trait has been described as highly variable in a wide range of tree species, but little is known about the extent of genetic and phenotypic variability within species. This information is essential to our understanding of the evolutionary forces that have shaped this trait, and for evaluation of its inclusion in breeding programs.

We assessed cavitation resistance (P_{50}), growth and carbon isotope composition in six *Pinus pinaster* populations in a provenance and progeny trial. We estimated the heritability of cavitation resistance and compared the distribution of neutral markers (F_{ST}) and quantitative genetic differentiation (Q_{ST}), for retrospective identification of the evolutionary forces acting on these traits.

By contrast to growth and carbon isotope composition, no population differentiation was found for cavitation resistance. Heritability was higher than for the other traits, with a low additive genetic variance ($h^2_{ns} = 0.43 \pm 0.18$, $CV_A = 4.4\%$).

Q_{ST} was significantly lower than F_{ST}, indicating uniform selection for P_{50}, rather than genetic drift. Putative mechanisms underlying $Q_{ST} < F_{ST}$ are discussed.

Keywords: heritability, Q_{ST}/F_{ST} comparison, carbon isotope composition, cavitation resistance, drought tolerance, stabilizing selection, canalization, diversifying selection.

ORAL PROGRAM

O6-7 Fertility variation and gamete gene pool composition in a black pine (*Pinus nigra* Arn.) clonal seed orchard under changing climatic conditions

Paraskevi ALIZOTI[1]

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Pinus nigra Arn. (black pine) is an important and prominent high elevation pine species that grows naturally in Greece, with a distribution range extending from the northern border of the country down to the southern part of the Peloponnesos peninsula, and the islands of the Aegean Sea. Due to the species high ecological value and wood production the species is used extensively for reforestation purposes in the country. The need for improved genetic material is covered by a network of black pine first generation clonal seed orchards. The main objective of a seed orchard is the production of genetically improved seed assuming that the criteria for panmictic equilibrium are fulfilled.

Change of climatic conditions may be proved a crucial factor resulting in flowering asynchrony and discrepancies in gamete gene pool composition among the clones of a seed orchard and thus affecting significantly the quality and quantity of the seed crop. Fertility variation and clonal gamete contribution were studied in successive years in a *Pinus nigra* Arn. clonal seed orchard. Sixty plus trees that were selected from five geographic areas representing the distribution of the species in Northern Greece were then used to establish the clonal seed orchard. Each clone was represented by sixteen to nineteen ramets that were planted following a honeycomb experimental design, so that kinship could be avoided. The effective number of clones during the time of the study was $N_c = 57$, while the relative effective number of clones was $N_r = 0.95$. The number of female and male flowers, the size of the male strobili and the number of conelet scales of the female strobili were recorded, while flowering phenology was considered in order to evaluate the clonal gamete contribution during the two years of the study.

The black pine clones differed significantly for their maleness and femaleness index, the parental balance, the size of the male strobili and the number of conelet scales. The pronounced variability in climatic conditions over the two years of the study affected significantly the individual clone gamete contribution to the seed crop, as the effective number of parents was reduced significantly during the xerothermic year. Clonal fertility variation, variation in male strobili dimensions and pollen production as well as flowering asynchrony had a significant impact to the final gene distribution in the seed orchard. The impacts of fertility variation and unequal parental contribution need to be considered when management actions are planned, as they can affect significantly the genetic diversity of the seed crop. The impact of changing climatic conditions though may be detrimental for the quantity, quality and genetic diversity of the produced seed.

Keywords: Breeding, Climate Change, parental balance, gamete gene pool, panmixia, genetic diversity of seed crop.

Thursday June 9th • 15:35 – 17:55
Parallel Session
Session 7 – Pine and Insects Interactions

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O7-1 Direct molecular detection of the Pine Wood Nematode, *Bursaphelenchus xylophilus*, from *Pinus pinaster* and from its insect vector, *Monochamus galloprovincialis*

Luís FONSECA[1], Joana M. S. CARDOSO[1] and Isabel ABRANTES[1]

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The Pine Wood Nematode (PWN) *Bursaphelenchus xylophilus*, the causal agent of the Pine Wilt Disease (PWD), is placed on the A1 list of quarantine pests by the European and Mediterranean Plant Protection Organization (EPPO). Trees of the genus *Pinus* are the main hosts for these nematodes and the transmission of the nematode from one tree to another is carried out by insects (Coleoptera-Cerambycidae), mainly belonging to the genus *Monochamus*. The nematodes, migrating through resin canals and feeding on parenchyma cells, cause the development of cavitation and embolism of tracheids, denaturation and necrosis of parenchyma and cambial cells, leading to cell destruction, cessation of oleoresin exudation, reduction of transpiration and photosynthesis and death of infected trees in a few months.

The detection of this nematode on pine trees, wood products and/or in its insect vector is fundamental to define aspects of its control and management, to implement quarantine regulations and to prevent the spread of the disease. In most cases, the identification of PWN is based on morphological or molecular markers after nematodes extraction from wood samples or from the insect vector, involving several time consuming steps and requiring a high level of expertise on *Bursaphelenchus* taxonomy. Furthermore, the use of morphological characters offers some limitations due to intra-specific variability and morphological similarity with other species of the genus *Bursaphelenchus*.

The main goal of this research was to develop a simple and reliable method to identify and differentiate *B. xylophilus*, from other species, directly from *P. pinaster* samples and from *M. galloprovincialis*. The detection of PWN was performed by PCR based assay with a species specific set of primers from PWN satellite DNA, using total DNA extracted directly from pine wood samples and the vector. This method, involving two amplification steps, allows the rapid and direct detection of a single nematode present in *P. pinaster* wood and bark samples and in its insect vector without the need of nematode extraction, representing a new tool for the diagnosis of PWN.

Keywords: direct detection; diseases; Monochamus galloprovincialis; Pine Wood Nematode; *Pinus pinaster*

O7-2 Economic impact of the pine wood nematode *Bursaphelenchus xylophilus*

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The Pine Wood Nematode (PWN), *Bursaphelenchus xylophilus*, the causal agent of Pine Wilt Disease (PWD) is a quarantine organism in the European Union, and was placed on the A1 list of quarantine pests by European and Mediterranean Plant Protection Organization (EPPO). This nematode is considered a native species from North America, where it is distributed throughout Canada and USA. At the beginning of the 20th century, the PWN has been carried to Japan and it has spread into China, Korea and Taiwan. In 1999, the PWN was reported for the first time in Portugal (and in Europe) associated with dead trees of maritime pine, *Pinus pinaster*. In 2009, it was also detected in Madeira Island and Spain. The PWN constitutes a serious problem for the worldwide forest economy leading to the annual loss of pine timber. Imposed restrictions on import of a raw softwood cause export value decreasing and disturbance of forest industry, based on use of pinewood as a raw material. However, the negative impact of the PWN is not limited to the above mentioned economic consequences. After tree invasion, nematodes begin to migrate, feed and reproduce within the resin canals causing development of cavitation and leading to a reduction or cessation of oleoresin flow in the infected trees. Thus, the problem of the PWD states another important economic aspect, such as the use of PWN infected wood as a raw material by woodworking industries (for example, pellets production).

The objective of this research is to understand how anatomic changes of PWN infected wood and biochemical incidences of tree defence reaction affect the gross calorific value (GCV), flammability and chemical composition of wood. In order to evaluate technological aptitude of PWN infected wood biomass, a comparative analysis of GCV of infected wood samples, with different values of PWN / 100 g, and non-infected wood samples was performed using a Parr 6300 automatic isoperibol calorimeter. The flammability as a function of the stage of PWN infection of wood was determined by cone calorimeter. Comparative analysis of chemical composition of infected and non-infected wood was also performed.

This interdisciplinary study stresses important technological and economic aspects, namely suitability of use of PWN infected wood by woodworking industries, and interrelationship between economic criteria and disease control activities.

Keywords: Diseases, stand dynamics and forest management, pine wood nematode, heating value, chemical composition, flammability

ORAL PROGRAM

O7-3 Pine wilt disease and the pinewood nematode: a threat to Mediterranean pine forests

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Bursaphelenchus xylophilus, the pinewood nematode (PWN), is the causal agent of pine wilt disease (PWD). It was detected for the first time in Europe in 1999, in declining maritime pine (*Pinus pinaster*) in Portugal. The PWN has been detected in new pine (*P. pinaster*) forest areas in the centre of the country, in 2008, despite efforts developed by the national forestry and quarantine authorities to control the nematode and its insect vector (*Monochamus galloprovincialis*). The nematode has also recently been reported to be present in Spain, again in *P. pinaster*.
Circulation of non-treated wood and wood products, i.e. human action, is certainly responsible for the worldwide spread of the nematode. The nematode constitutes a threat to the rest of Europe, and namely to Mediterranean pine forests, if proper measures are not taken by European governments. Species such as *P. pinaster, P. nigra* and in particular *P. sylvestris* are considered highly susceptible to PWN.
In this presentation, some of the strategies currently under way in Portugal to find a solution for the PWN will be discussed. These include, among others, the identification of naturally resistant *P. pinaster* trees, the identification of quantitative trait loci (QTLs) for PWN resistance, identification of resistance genes using 454 pirosequencing and suppressive subtraction hybridization, and genetic transformation of *P. pinaster.*

Keywords: Bursaphelenchus xylophilus, *Pinus*, Portugal

O7-4 The decline of Aleppo pine in semi-arid forests at Djelfa, Algeria

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In the natural forests of Senalba Chergui, the decline of Aleppo pine is related to the activity of the pine shoot beetle, _Tomicus destruens_. Among the assumptions concerning the nature of the causal bond, the drought episodes during the last decades partly explain the passage from endemic to epidemic of this insect pest, whose attacks worsen the sanitary condition of the pines with limited capacities of reaction.

Due to its ecology this xylophagous beetle could proliferate in the natural pine forests and increase its natural range. During three last decades, _Tomicus destruens_ has been detected in the pine forests of the semi-arid belt, being associated with high forestry impacts and mortality. Within the sanitary management of these regions, the volume of wood taken from 1988 to 2004 in the Senalba Chergui area was approximately 40,000m^3, in an area of 20,000 ha. The precocious felling of young pines due to the insect's attack is causing significant economic losses. Important shifts in population trends have occurred during the last years. The activity and attacks of the pine shoot beetle are more intense under favourable climatic conditions.

At the tree scale, the study of the distribution of the attacks showed a great variability between trees. The females preferentially seek the northern slope of the main forest and the southern face of the host tree to construct the maternal gallery. Among the considered variables, the slope and the tree's age assume a significant role in the beetle's host choice and attack strategy. Insects select in priority trees located on northern slopes, according to their age and the physical characteristics, such as diameter and bark thickness.

In this paper I present a synthesis and discuss the most important environmental and morphological variables of the trees which condition and regulate population dynamics of _Tomicus destruens_ in Aleppo pine forests in semi-arid locations in Algeria.

Keywords: Semi-arid, Aleppo pine, forest decline, Scolitids, Algeria

O7-5 Trade-offs between induced and constitutive resistance in maritime pine: secondary chemistry, effective antiherbivore resistance and environmental modulation

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We know that plant genotypes can express preformed defensive phenotypes called "constitutive defences", however the defensive function is a plastic trait, and plants can increase the investments in defences when receiving a signal of attack by herbivores or pathogens. This newly formed or mobilized defences to the site of attack are called induced defences. Plant defence theory predicts that, as secondary metabolism is costly for the plant, presenting effective constitutive defence levels and the ability of expressing efficient inducible defences by a plant are two resource related attributes that are not likely to be maximized at the time. Induced defences have been considered a "cheaper" strategy than constitutive defences since the cost is realized only when required. Moreover genotypes constitutively well-defended are expected to gain little by boosting their defences after damage to be protected against subsequent attacks. Conversely, genotypes with low constitutive defences are likely to be under the pressure of being able to express effective inducible responses. A negative, non spurious, correlation between constitutive and inducible defences illustrates this classical trade-off. It has been many times suggested in the literature and some times reported for angiosperms, but, rarely not yet, in conifers.

The aim of this paper is to explore the existence of this trade-off in the pine tree *Pinus pinaster*. We grew pinions from thirty four open pollinated mother trees from the coastal population of *P. pinaster* at Galicia (NW Spain) in a greenhouse under two nutrient availabilities: complete fertilization and phosphorus deficient conditions. We triggered induced defensive responses in half of the pine seedlings with 22 mM MJ, and twenty days after induction we harvested the pines for analysing secondary chemistry (Sampedro *et al.*, 2011). In an independent experiment, we grew half-sib seedlings belonging to eighteen families from the same population, and we performed a bioassay exposing a part of the stem to experimental attack by the pine weevil *Hylobius abietis*, a phloem herbivore, and after 48 hours we harvest the pines for measuring the debarked area consumed by the weevil in the experimental section (Sampedro *et al.*, 2010). We explored the existence of trade-offs by regressing the difference in mean resistance levels between experimentally MJ induced individuals and control individuals from a given family (induced - control), against the family means of control treatment. The first variable indicates the potential to express induced resistance in each family, and the second one the actual level of constitutive resistance. In order to avoid the common mathematical problems leading to spurious correlations when comparing a difference against one of the terms, we explored all correlations not to be spurious with a MonteCarlo confirmatory analysis. We found strong negative genetic correlations between induced and constitutive levels in total polyphenolics in the needles ($R^2 = 0.48$), diterpene content in the stem ($R^2 = 0.72$), and also for the damage by the weevil on constitutive and induced genotypes ($R^2 = 0.71$). All relationships were significant at $P < 0.001$, however MonteCarlo only confirmed as non-spurious those negative genetic correlations observed under phosphorus limitation, while those under complete fertilization appeared to be likely spurious. The genetic entries from our population appeared distributed within range of strategies from families with reduced expression of constitutive defences which showed the possibility of dramatically increase their defences after induction signals, and families with strong expression of constitutive defences which are poorly capable of increase their defences after attack. These negative genetic correlations between the constitutive and

inducible defences, at the physiological and functional level, constitute strong experimental evidences that this evolutionary trade-off between induced and constitutive defences exists in this pine trees. Phosphorus availability and trade-offs between defensive strategies, and between chemical defences and growth potential recently found for this species can play a role for understanding the evolution of this pine species.

Keywords: Pinus pinaster, trade-offs, induced defences, Hylobius abietis, resistance, herbivory

medpine4

Thursday June 9th • 15:35 – 17:55
Parallel Session
Session 8 – Conservation

Note: Abstracts are arranged according to the sessions and in the sequence in which they are delivered; the name of the speaker is underlined.

O8-1 Natural Stone Pine (*Pinus pinea*) Forest in Kahramanmaraş, Problems and Conservation Strategies

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One of the natural populations of *Pinus* pine occurs in Kahramanmaraş-Önsen, Turkey. The altitude of the distribution is relatively high, from 600 m to 1,000 m. Although the average annual rainfall and average temperature is 731.3 mm and 16.7°C in the region, the site productivity of the forest is very low. Old dominant trees in the forest ares about 11 m in height, 52.2 cm in diameter and 79.7 in age (Yılmaz et al., 2010).

The main rock of the site is quartzite (Korkmaz, 2001). The content of the soil is 56.5% sand, 32.4% clay, and 11.1% dust (Akgül and Bilgin, 1991). Quartzite rocks constitute sandy poor soils (Kantarcı, 2000). Since the mainrock is close to the surface and the depth of the soil about 40-50 cm in the forest, *P. pinea* trees can't develop deep roots and some trees have been damaged from the snow load during the winter. In the large gaps of the forest, natural good quality seedlings are also seen.

In recent decades, the plantation of *P. pinea* is increasing dramatically in Marmara, Aegean, and Mediterranean part of Turkey for its nuts and due to its better fire-resistance ability than *P. brutia* (OGM, 2006). Therefore, conservation of the natural gene resources of the species is very important. Around this natural forest, *P. pinea* plantations should be established only with the local seed sources. A comprehensive program and a detailed research are needed to conserve and sustain this unique gene resource at higher elevation.

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Keywords: Stone pine, *Pinus pinea*, Gene Resources, Conservation

O8-2 A synthesis on several years study on *Pinus nigra* ssp *mauretanica* in Algeria

Arezki DERRIDJ[1], D. ABDELLI[1], D. ADJAOUD[1], A. ASMANI[1], Bruno FADY[2], H. HEDJAM[1], N. LARBI-AIDROUS[1], O. ZANNDOUCHE[3] and Faiza KROUCHI[1,2]

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Pinus nigra ssp mauretanica in Algeria is found on the southern side of the Djurdjura Mountain where it occupies three stands of unequal importance regarding the number of individuals: Tigounatine, Taouielt and Tikjda distant from each other by 1.2 to 1.5 km.

At Tigounatine, there are 445 individuals (including saplings) according to records of June 2007. At Taouielt, there are around twenty individuals and at Tikjda there are eleven individuals of which four burned one following fire of 2000.

Several studies are devoted to this taxon mainly in its major stand (i.e.Tigounatine), including soil description, floristic composition, vegetation physiognomy, reproduction (number of seeds per cone, in vitro germination of pollen and seeds); pollen, cone and needle morphology; needle anatomy; records of individuals, their size measurements and their cartography; genetic variation and causes of needle discoloration.

Sorting of normal-sized seeds into empty and filled seeds followed by their records, over several years, allowed analysis of the cone seeding rates.

Germination of seeds on Petri dishes provided data on germination rate and dynamics. *In vitro* germination of pollen provided data on its viability through germination rate and pollen tube length.

Measurement of pollen size (i.e. size of pollen grain and its ballonets on distal and profile view) on samples from Turkey, Spain and France allowed comparison between some subspecies of the collective species *Pinus nigra* Arnold.

Cones from Algeria, France, Spain and Morocco were compared for cone size (length, width and weight) and seed contents.

Data on needle morphology (i.e. needle length, width and thickness, number of stomatal rows on its abaxial and adaxial side) and anatomy was compared to that provided by literature for the same taxon.

A genetic study of the biggest trees using chloroplast microsatellites (cpSSR), provides a first insight into the genetic statute of this very narrow ranged taxon.

Causes of partial needle discoloration are under investigation.

Data on soil characteristics, floristic composition, vegetation physiognomy and seedling mycorhization are available from other sources.

Regarding the conservation statute of this taxon in Algeria, its inclusion in the limits of a national park, does not constitute a guarantee of its long-term conservation in the face of hazards represented mainly by frequent fires in the surrounding perimeters.

Keywords: *Pinus nigra* ssp mauretanica, Algeria, Djurdjura, morphology, dendrometry, cartography, genetic variation, reproduction, conservation.

Posters
Chapter

Pinus nigra

Pinus pinea

Tuesday June 7th • 13:10 – 14:50

Posters related to **Ecophysiology, Stand Dynamic and Forest Management** and **Ecology** will be presented by their authors (underlined names)

Ecophysiology

P1-01 Influence of drought in the canopy transpiration of Pinus canariensis living at the upper limit of its distribution in Tenerife
Patricia BRITO, J. KUCERA, D. MORALES and Maria Mª Soledad JIMENEZ

P1-02 Physiological performance of Pinus canariensis trees at the timberline in Tenerife
Patricia BRITO, J.R. LORENZO, D. MORALES and Maria Mª Soledad JIMENEZ

P1-03 Drought effect on xylem vulnerability to cavitation and hydraulic traits in *Pinus halepensis* Mill.
Amira BEN MNA1 and Roland HUC

P1-04 Towards understanding the mechanisms and magnitude of fertilizer responses in thinned, mid rotation Pinus radiata stands in a Mediterranean climate:
Components for potential incorporation in decision support tools
Ben DU TOIT, Phillip M. FISCHER and Vavariro CHIKUMBU

P1-05 Monitoring drought effects on Scots pine (Pinus sylvestris) and forest resilience
Laurent BORGNIET, Ali THABEET, Thomas CURT, Christophe BOUILLON,and Michel VENNETIER

P1-06 Why do large, nitrogen rich Pinus halepensis Mill. seedlings better resist stressful transplanting conditions? A physiological analysis
Bárbara CUESTA, Pedro VILLAR-SALVADOR, Jaime PUÉRTOLAS, Douglas F. JACOBS, José M. REY BENAYAS and Juan PEÑUELAS RUBIRA

P1-07 NOTG: a 3D mechanistic model to study fine scale water and carbon budgets of multi-specific, heterogeneous ecosystems
Guillaume SIMIONI, Guillaume MARIE, Jacques GIGNOUX, Xavier LE ROUX, and Roland HUC

P1-08 Seasonal changes in the physiological status of regeneration under two structural typologies and a natural light gradient in mixed *Pinus pinea – Quercus ilex* stands in Spain
Carolina MAYORAL, Maria de la O. SÁNCHEZ GONZÁLEZ, Rafael CALAMA, Guillermo MADRIGAL CASANUEVA and Marta PARDOS MINGUEZ

P1-09 Response of mature Scots pines to drought stress: comparing various foliar and stem wood indicators
Matthias DOBBERTIN, Britta EILMANN, Peter BLEULER, Elisabeth GRAF PANNATIER, Werner LANDOLT, Arnaud GIUGGIOLA and Andreas RIGLING

Stand Dynamic and Forest Management

P2-01   Application of the 3PG forest growth model to stands of *Pinus pinaster* Ait. in the National Forest of Leiria, Portugal
Mariana PEDRO, Margarida TOMÉ, J. FREIRE, L. FONTES and A. DIAS

P2-02   Influence of *Pinus halepensis* cover on seedling growth of two co-occurring Mediterranean oak species
Bernard PRÉVOSTO, Yogan MONNIER, Gautier de BOISGELIN, Christian RIPERT, and Catherine FERNANDEZ

P2-03   Establishment of forest types as a tool for developing forest management guidelines in Mediterranean areas: the case of P*inus sylvestris*
Míriam PIQUÉ-NICOLAU and Pau VERICAT-GRAU

P2-04   Methodology to identify ancient trees in the Spanish national forest inventory Application: *Pinus halepensis* Mill.
Icíar ALBERDI, Ana ARNAIZ, Sonia CONDÉS and Isabel CAÑELLAS

P2-05   Modelling the spatiotemporal pattern of germination in Stone pine (*Pinus pinea* L.) stands in the Northern Plateau (Spain)
Rubén MANSO, Marta PARDOS, G. MADRIGAL, E. GARRIGA and R. CALAMA

P2-06   Relation between thinning and understory plant cover and biomass in a *brutia pine* plantation in northern Greece
Konstantinos MANTZANAS and Vasilios P. PAPANASTASIS

P2-07   The alteration of diameter distribution by site quality and age in even aged Crimean pine (*Pinus nigra* Arnold) stands in southern Turkey
Serdar CARUS and Yılmaz ÇATAL

P2-08   Effect of plant age and fertilization level on the survival and growth of *Pinus halepensis*
Juan L. NICOLÁS PERAGÓN, Luis F. BENITO MATÍAS and Jaime PUÉRTOLAS SIMÓN

P2-09   Modelling *Pinus pinaster* productivity in Australia and Portugal using 3-PG model
Luis FONTES, Auro ALMEIDA, Ian DUMBRELL and Margarida TOMÉ.

P2-10   Scaling cross-sectional growth and height growth in Mediterranean pines
Andrés BRAVO-OVIEDO and Harry T. VALENTINE

P2-11   Growth and dendrometric relationships of stone pine (*Pinus pinea* L.) planted in the coastal dunes of North Tunisia
Boutheina ADILI, P. BALANDIER, M.H. EL AOUNI and S. GARCHI

P2-12   The forest pre-management method and its perspectives for Aleppo pine forests planning: Critical analysis of an Algerian method
Kada BENCHERIF

P2-13   Aleppo pine (*Pinus halepensis* Mill.) stem form study in sub-humid reforestation of western Algeria: Construction of a form factors table
Kada BENCHERIF and Youcef BELOUATEK

P2-14   Boron deficiency in Mediterranean Pines
João BENTO and João COUTINHO

P2-15   Promoting mixed stands through conversion treatments
Alfredo BRAVO-FERNÁNDEZ, Sven MUTKE, Rafael SERRADA and <u>*Sonia ROIG*</u>

P2-16   Management tools to estimate forest structure and reproductive characteristics of Aleppo pine forest in North Africa
<u>*Abdelaziz AYARI,*</u> *Ane ZUBIZARRETA, Daniel MOYA and Salah GARCHI*

P2-17   Prediction of annual tree growth and survival for thinned and unthinned even-aged maritime pine stands in Portugal from data with different time measurement intervals
<u>*Luís NUNES,*</u> *José TOMÉ, Maria PATRICIO and Margarida TOMÉ*

P2-18   Chemical composition and herbicidal activity of essential oils from some coniferous species growing in Tunisia
<u>*Abdelkarim BEN MIMOUNE,*</u> *Ismail AMRI, Lamia HAMROUNI, Mohsen HANANA and Bassem JAMOUSSI*

P2-19   Overstocked stone pine stands. Can late and heavy thinnings be sustainable?
Maria Chiara MANETTI, <u>*Emilio AMORINI,*</u> *Tessa GIANNINI, Andrea CUTINI*

P2-20   Pulp and paper characteristics of Aleppo pine wood (*Pinus halepensis* Mill) by soda-anthraquinone process
<u>*Ahmed HADDAD,*</u> *Alain MARECHAL, Dominique LACHENAL, Gérard JANIN, Mohamed LABIOD*

Ecology

P3-01   Allelopathy and Biodiversity: impact of Aleppo pine colonization on plant diversity of Mediterranean abandoned agricultural lands
M. SANTONJA, A. BOUSQUET-MÉLOU, Virginie BALDY, S. DUPOUYET and <u>*Catherine FERNANDEZ*</u>

P3-02   Colonization of *Pinus halepensis* in southern Mt. Carmel, Israel: Science, Values and Management
<u>*Liat HADAR,*</u> *Yagil OSEM, Sagie SAGIV and Avi PEREVOLOTSKY*

P3-03   Ecology and distribution of Calabrian pine stands in the Sila Plateau (Calabria, Italy)
Orazio CIANCIO, F. IOVINO, G. MENGUZZATO, A. NICOLACI, Susanna NOCENTINI, <u>*Davide TRAVAGLINI*</u> *and A. VELTRI*

P3-04   Fire related traits of *Pinus nigra* plant communities in the Mediterranean:
a data base for Greece and Spain
Dimitri KAZANIS, Juli G. PAUSAS, Ramon R. VALLEJO and <u>*Margarita ARIANOUTSOU*</u>

P3-05   Structural and floristic features of a *Pinus halepensis* forest on coastal dune of the Zemmouri Sahel (Algiers, Algeria)
<u>*Rachid MEDDOUR,*</u> *Ouahiba MEDDOUR-SAHAR and Arezki DERRIDJ*

P3-06   Testing a distribution model for *Pinus pinea* in Spain: two approaches through independent presence-only data sets
<u>*Eduardo LÓPEZ SENESPLEDA,*</u> *R. ALONSO PONCE and R. CALAMA*

P3-07   Total and soluble organic carbon and active organic matter along the soil profile of a chronosequence of three Stone pine forests on Mount Vesuvius
<u>*Maria GIORDANO,*</u> *Anna DE MARCO, Armando ZARRELLI, Vincenzo PERINO and Amalia VIRZO DE SANTO*

P3-08   Organic matter dynamics in the soil under *Pinus pinea* in a monoculture and in a mixed wood on Mount Vesuvius
<u>*Anna DE MARCO,*</u> *C. ARENA, Maria GIORDANO and A. VIRZO DE SANTO*

Wednesday June 8th • 13:10 – 14:50

Posters related to **Fire Sciences** will be presented by their authors (underlined names)

P4-01 A unique system for examining the genetic consequences of fire for native *Pinus halepensis* populations
Yuval EITAN, Rachel BEN-SHLOMO, Ofer STEINITZ and <u>Gidi NE'EMAN</u>

P4-02 Assessing the impact of fires on pine populations of south-eastern France
<u>Thomas CURT</u>

P4-03 Criteria on species selection for ecological restoration following major disturbances in Maritime Pine stands – comparing two Ericaceae specie
<u>Ana VASQUES</u>, Paula MAIA, Ramon VALLEJO, C. SANTOS and J. KEIZER

P4-04 Does prescribed burning affects the secondary metabolism of established stand trees of Mediterranean pines?
A.V. LAVOIR, Vanina PASQUALINI, Elena ORMEÑO, Lila FERRAT, S. GREFF, C. LECAREUX and <u>Catherine FERNANDEZ</u>

P4-05 Litter hydrocarbons accentuate flammability of Mediterranean species
<u>Elena ORMEÑO</u>, Catherine FERNANDEZ, Virginie BALDY

P4-06 Effects of prescribed burning on photosynthesis and water status of *Pinus laricio*
<u>Lila FERRAT</u>, Frédéric MORANDINI, Francesca MASCARENHAS, Amanda ELINEAU, Hervé COCHARD and Isabelle POGGI

P4-07 Effect of fuel treatments on potential crown fire behaviour in Aleppo pine forests (*Pinus halepensis* Mill.) in Greece; A simulation study
<u>Ioannis D. MITSOPOULOS</u> and Alexandros P. DIMITRAKOPOULOS

P4-08 Fire effects on *Pinus* phenotypes
<u>Ana HERNÁNDEZ-SERRANO</u>, Miguel VERDÚ and Juli G. PAUSAS

P4-09 Fungal succession after fire in *Pinus pinaster* Mediterranean forests in Northwest Spain
P. VÁSQUEZ, <u>Luis SANTOS-DEL-BLANCO</u>, R. FRAILE, M. HERNÁNDEZ-RODRÍGUEZ, J. OLAIZOLA, J.A. ORIA-DE-RUEDA and P. MARTÍN-PINTO

P4-10 Growth and structure of a young Aleppo pine planted forest after the application of six thinning regimes
<u>Jabier RUIZ-MIRAZO</u> and José Luis GONZÁLEZ-REBOLLAR

P4-11 Effect of fire regime on litter flammability and on structure ` of *Pinus halepensis* stand
<u>Anne GANTEAUME</u>, Marielle JAPPIOT, Corinne LAMPIN-MAILLET, Thomas CURT, Laurent BORGNIET, Roland ESTÈVE, Willy MARTIN and Aminata N'DIAYE

P4-12 Modelling post-fire mortality of Mediterranean pines
Filipe X. CATRY, <u>Paulo M. FERNANDES</u>, Juli G. PAUSAS, Francisco C. REGO, and Francisco MOREIRA

P4-13 Salvage logging in burned *Pinus halepensis* stands: morphological and ecophysiological status of dominant perennial species one year later
<u>Daniel MOYA</u>, P. FERRANDIS, E. MARTÍNEZ-DURO, Javier HEDO, Jorge DE LAS HERAS and Francisco Ramon LÓPEZ-SERRANO

P4-14 Post-fire regeneration variability of *Pinus pinaster* Ait. in the centre of Portugal
<u>Mariana PEDRO</u>, P. MAIA, A. VASQUES, A. LIMA, T. LAMEIRAS, A. ESTEVENS, N. ABRANTES, R. PINHO, P. SILVEIRA, J. KEIZER, J. Sandes SILVA, and Francisco MOREIRA

P4-15   Optimization of silvicultural treatments in *Pinus halepensis* Mill. Stands for reducing wildfire hazard
Thekla TSITSONI, Dimitrios T. ZAGAS, I.D. RAPTIS and T.D. ZAGAS

P4-16   Regeneration of *Pinus halepensis* stands: influence of site preparation treatments
Gautier DE BOISGELIN, Thierry QUESNEY, Louis AMANDIER, Christian RIPERT, and Bernard PRÉVOSTO

P4-17   Resilience of *Pinus nigra* forest ecosystems to fire: the case of Mt Taygetos, Greece
Anastasia CHRISTOPOULOU, Dimitris KAZANIS, Pavlos ANDRIOPOULOS, I. BAZOS, Y. KOKKORIS and Margarita ARIANOUTSOU

P4-18   The influence of recurrent forest fires on the abundance of *Pinus halepensis* Mill.
Mt. Carmel, Israel Naama TESSLER, Lea WITTENBERG, Noam GREENBAUM and Ella PROVIZOR

P4-19   The interplay between *Pinus halepensis* and Forest Fire Regime of Mt. Carmel
Dan MALKINSON and Lea WITTENBERG

P4-20   Post-fire dynamics in the *Pinus halepensis* forests of Bejaia (Northern Algeria)
Farid BEKDOUCHE and Arezki DERRIDJ

P4-21   Post-fire recruitment of *Pinus pinaster (*Ait.) – the importance of fire severity
Paula MAIA, Ana VASQUES, I. FERNANDES, Juli PAUSAS2 and J. KEIZER

P4-22   Thinning post fire regenerated Aleppo pine stands in the short time reduces carbon storage
Raquel ALFARO-SÁNCHEZ, Jorge DE LAS HERAS, Daniel MOYA, F.R. LOPEZ-SERRANO, Javier HEDO, Enrique J. HERNÁNDEZ-TECLES, and J.L. GONZÁLEZ-JIMÉNEZ

P4-23   Fire behaviour modelling in a maritime pine Portuguese forest to support management decisions at the stand and landscape levels
Brigite BOTEQUIM, Paulo M. FERNANDES and Jorge G. BORGES

P4-24   Fire resilience assessment using remote sensing in *Pinus halepensis* Mill. Forests of Southeastern Spain
Javier HEDO, E. RUBIO, Daniel MOYA, T. DADI, Jorge DE LAS HERAS, and F.R. LOPEZ-SERRANO

P4-25   Predicting the time-window for full recovery of *Pinus halepensis* Mill. after a future recurrent wildfire in three Aleppo pine forests of northern Euboea Island, Greece
Evangelia N. DASKALAKOU, Kosmas ALBANIS, Asimina SKOUTERI and Costas THANOS

P4-26   Local variability of serotinous cones in a Canary Island pine (*Pinus canariensis)* stand
Unai LÓPEZ DE HEREDIA, Rosa Ana LÓPEZ, Paula GUZMÁN, Nikos NANOS, Eduardo GARCÍA-DEL-REY, Pascual GIL MUÑOZ and Luis GIL

Thursday June 9th • 13:10 – 14:50

Posters related to **Climate Change, Genetics and Breeding, Pine and Insects Interaction** and **Conservation** will be presented by their authors (underlined names)

Climate Change

P5-01 Climate / growth relationships in *Pinus cembra* in the Southern French Alps under Mediterranean bioclimate
Mélanie SAULNIER, Jean-Louis EDOUARD, Christophe CORONA and Frédéric GUIBAL

P5-02 Contribution of the maritime pine forest sector from the National Forest of Leiria (Portugal) to the mitigation of climate change
Mariana PEDRO, Ana Cláudia DIAS and Margarida TOMÉ

P5-03 Fire limits of Mediterranean pine
Thomas CURT and Juli PAUSAS

P5-04 Potential climate change effects on wildfires in Sardinia and Corsica and resulting impacts to Mediterranean forests and socioeconomic values
Michele SALIS, Haiganoush K. PREISLER, Bachisio ARCA, Alan A. AGER, Mark A. FINNEY and Paul A. SANTONI

P5-05 The relationships between climate and radial growth in *Pinus nigra* salzmanni from the south of France
Thomas AMODEI, Frédéric GUIBAL and Bruno FADY

P5-06 Restoring thinning practices to decrease drought stress in natural Scots pine forest in a dry inner-alpine valley in Switzerland
Arnaud GIUGGIOLA, Andreas RIGLING, Andreas ZINGG and Matthias DOBBERTIN

P5-07 Assessing vulnerability and adaptive capacity to climate change in the Urbion Forest Sector: integrating social and biophysical perspective
Marco OTAROLA, Felipe BRAVO and Gregorio MONTERO

P5-08 Remote sensing of drought stress in *Pinus halepensis* planted forests for predicting mortality: A research strategy
Michael DORMAN, Avi PEREVOLOTSKY and Tal SVORAY

P5-09 Natural regeneration of *Pinus halepensis* forests in semi-arid regions (Yatir Forest)
Hagay YAVLOVICH, Yagil OSEM, Jaime KIGEL and Nir ATZMON

P5-10 Plasticity of *Pinus sylvestris* root architecture and EcM colonisation in response to constant vs. seasonal drought
Barbara MOSER, Tabea KIPFER, Sarah RICHTER, Marek METSLAID, Simon EGLI, Jaboury GHAZOUL and Thomas WOHLGEMUTH

P5-11   Dendroclimatological analysis of climate change influence on Aleppo pine (*Pinus halepensis* Mill.) forests productivity in Tunisia
El Ali EL KHORCHANI, Claude GADBIN-HENRY and Khaldi ABDELHAMID

Genetics and Breeding

P6-01   Low seed efficiency among individuals of the narrow ranged *Pinus nigra* ssp mauretanica in Algeria
Drifa ADJAOUD, E. AKKOUCHE, R. GUETTAL, Fazia KROUCHI and Areski DERRIDJ

P6-02   Environmental factors effects on the production of cone and seed in Aleppo pine forests in Tunisia
Abdelaziz AYARI, Daniel MOYA, Ane ZUBIZARRETA and Mohamed Nejib REJEB

P6-03   Influence of high temperatures on germination of *Pinus pinea* seeds of three provenances
Luis Fernando BENITO-MATÍAS, N. HERRERO SIERRA, I. JIMÉNEZ, and Juan Luis PEÑUELAS RUBIRA

P6-04   Evaluation of the straightening ability in *Pinus pinaster* Ait. Progenies
Ainhoa CALLEJA-RODRÍGUEZ, Roberto SAN MARTÍN, Ana OLIVERA, Francisco J. LARIO LEZA, Pablo MARTÍNEZ-ZURIMENDI, Fermín GARRIDO and Rosario SIERRA-DE-GRADO

P6-05   Drought tolerance of inter-provenance hybrids of *Pinus pinaster*
Raúl DE LA MATA POMBO, Rafael ZAS and E. MERLO

P6-06   Conserving *Pinus nigra* salzmanni, a rare black pine from the western Mediterranean threatened by wildfires and genetic pollution
Bruno FADY, Anne ROIG, Norbert TURION, Jean THEVENET, Franck REI, Olivier GILG, Mehdi PRINGARBE, Daniel CAMBON, Jack ROYER and Patrice BRAHIC

P6-07   Variability between provenances of *Pinus pinaster* Ait in the architecture of roots and its response to inclination
Fermin GARRIDO, Roberto SAN MARTIN, Ainhoa CALLEJA-RODRÍGUEZ, Francisco LARIO and Rosario SIERRA

P6-08   Estimation of variability and genetic parameters of adaptive traits in *Pinus brutia* from a half-sib progeny test: consequences for natural or breeding populations
Fayssal GHOULAGI and Christian PICHOT

P6-09   Phenotypic and genetic sources of variability of cavitation resistance in *Pinus canariensis*
Rosana LÓPEZ, Hervé COCHARD, Eric BADEL and Luis GIL

P6-10   Genetic variation in cone and seed traits in a black pine (*Pinus nigra* Arn.) clonal seed orchard
George NIKOLAOU and Paraskevi ALIZOTI

P6-11   Determining the optimal stock-type of containerized pine species for forest restoration in dry Mediterranean areas
Juan Luis PEÑUELAS RUBIRA, Jaime PUERTOLAS and Luis Fernando BENITO-MATÍAS

P6-12   Mediterranean conifer genetic field trials: data management and valorisation through the ForSilvaMed database
Christian PICHOT, João CARVALHO, Maria Regina CHAMBEL, Jose CLIMENT, Fulvio DUCCI, Ernesto FUSARO, Mohamed Larbi KHOUJA, Sven MUTKE, Hassan SBAY and Gabriel SCHILLER

P6-13   Provenances variation in *Pinus pinaster* at two sites in Morocco
Hassan SBAY

P6-14   The Yatir Aleppo pine forest
Gabriel SCHILLER

P6-15   Fragmentation and connectivity in Iberian pines: testing multiple hypotheses
Iva KOVAčIć, Santiago GONZÁLEZ-MARTÍNEZ, Juan José ROBLEDO-ARNUNCIO, José Manuel GARCÍA DEL BARRIO and Ricardo ALÍA

P6-16   Genetic variation of insular and continental natural Aleppo pine (*P. halepensis*) populations in Greece
Filipos ARAVANOPOULOS, M. TSAKTSIRA, Ch. KARANIKAS and A.B. SCALTSOYIANNES

P6-17   A high saturated genetic linkage map of *Pinus pinaster* based on AFLPs, ESTs, SSRs and SNPs
Marina DE MIGUEL, Nuria DE MARIA, M. Ángeles GUEVARA, Luis DIAZ, Emilie CHANCEREL, Christophe PLOMION, Ismael ARANDA, M. Teresa CERVERA

Pine and Insects Interaction

P7-01   Effect of the pine wood nematode, *Bursaphelenchus xylophilus*, on the flammability and the moisture content of *Pinus pinaster* wood
Valeria REVA, *Ricardo OLIVEIRA*, Luís FONSECA, Celeste PEREIRA, Isabel ABRANTES and Domingos X. VIEGAS

P7-02   Genetic analysis by ITS RFLP and sequencing of Pine Wood Nematode, *Bursaphelenchus xylophilus*, isolates from Portugal
Joana M. S. CARDOSO, Luís FONSECA, André LOPES and Isabel ABRANTES

P7-03   Strong Phylogeographic pattern in the pine cone weevil: the relative contributions of vicariance versus evolutionary histories of pine hosts
Géraldine ROUX-MORABITO, Coralie BERTHEAU, Alain ROQUES and Carole KERDELHUE

P7-04   Quaternary history of the pine processionary moth
Jérôme ROUSSELET, Ruixing ZHAO, Dallal ARGAL, Mauro SIMONATO, Andrea BATTISTI, Alain ROQUES and Carole KERDELHUÉ

P7-05   The pinewood nematode: a major invasive pest of European pine forests
Philippe CASTAGNONE-SERENO, T. GUILLEMAUD, Manuel M. MOTA, C. CASTAGNONE and Pierre ABAD

P7-06   Phenotypic plasticity of maritime pine to insect herbivory
Rafael ZAS, Xoaquín MOREIRA and *Luis SAMPEDRO*

Conservation

P8-01   New Relict Endangered Populations of *Pinus sylvestris* in Turkey
Mustafa YILMAZ

P8-02   Stand structure and spatial relationships between trees, shrubs and regeneration dynamics in a Stone pine forest (*Pinus pinea* L.) in central Italy
F. BOTTALICO, V. CAPPELLI, Orazio CIANCIO, V. GARFÌ, C. LISA, Susanna NOCENTINI, N. PULETTI and *Davide TRAVAGLINI*

P8-03   The black pine of the Maghreb *Pinus nigra* Arn. subsp. *mauretanica* (Maire & Peyerimhoff) Heywood
Rachid MEDDOUR, Ouahiba MEDDOUR-SAHAR and Arezki DERRIDJ

P8-04   *Pinus uncinata* Ramond ex DC: Conservation and proposal of management at its southwestern limit of distribution (Castillo de Vinuesa, Soria, Spain)
Felipe MARTÍNEZ-GARCÍA, Mª Eugenia LÓPEZ DÍEZ, José Mª POSTIGO-MIJARRA and Marta BENITO GARZÓN

Tuesday June 7th • 13:10 – 14:50

Posters related to **Ecophysiology, Stand Dynamic and Forest Management** and **Ecology** will be presented by their authors (underlined names)

Ecophysiology

P1-01 Influence of drought in the canopy transpiration of *Pinus canariensis* living at the upper limit of its distribution in Tenerife

Patricia BRITO[1], J. KUCERA[2], D. MORALES[1] and Maria Mª Soledad JIMENEZ[1]

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Pinus canariensis Chr. Sm. Ex DC. is an endemic species of the Canary Islands where it forms pure stands under widely different ecological conditions. In Tenerife, the distribution limit is between 800 and 2,200 m asl on north-facing slopes and from 500 up to more than 2,500 m asl on south-exposed slopes. A common habitat feature of pine forests in Tenerife is a Mediterranean climate with strong seasonal changes in water availability and evaporative demand. In woody plants from Mediterranean regions stomatal aperture has been shown to decline significantly during the warm and dry season and thus transpiration is approaching minimum values or even ceases.

In a previous work (Luis *et al*. 2005) done in an area located in the middle of its distribution in Tenerife (1,650 m asl) there was pronounced seasonal trend in soil water availability and evaporative demand, but canopy transpiration did not show any clear seasonal trend because summer drought is often mitigated by a high relative humidity of the air and a high frequency of clouds due to the north-east trade winds.

The aim of this study is to know how is the canopy transpiration of the same species but living under more extreme meteorological conditions at the timberline in one stand situated at 2,070 m asl at Teide National Park, Tenerife (Spain) with a density of 291 trees per hectare, where a meteorological station with continuous recording of main factors was installed (MINI-32 unilog, EMS, Brno, R. Checa). Sap flow of twelve *P. canariensis* trees differing in diameter at breast height (DBH, between 24 and 49 cm) was monitored continuously during a whole year (March 2008-February 2009) with a 12-channel battery-operated sap flow-meter (P4.1; Environmental Measuring System, EMS, Brno, Czech Republic).

A potential correlation between DBH and mean daily tree transpiration (Et) was derived from the trees under study. Based on this relationship and the number of tree distribution per hectare with respect to DBH, daily canopy transpiration (Ec) was then calculated by integrating actual Et for each specific day over all the DBH classes.

Meteorological data showed a pronounced seasonal trend in soil water availability with two clearly different periods, one wet and cold (middle of September to middle of May) and another one warm and dry (middle of May to middle of September). The annual total of Ec was 74,21 mm, and in this occasion the behaviour of this pine species was more similar to other Mediterranean species since the majority of the flow (86% of total flow) took place during the wet and cold period while during the dry and warm period only was registered the 14% of total. Daily mean Ec was 0,254 mm and 0,092 mm for both periods respectively, showing the great influence of the drought in the canopy transpiration.

References
Luis *et al*. (2005) *Agr. For. Met.* 135: 117.

POSTER CHAPTER

P1-02 Physiological performance of *Pinus canariensis* trees at the timberline in Tenerife

Patricia BRITO[1], J.R. LORENZO[1], D. MORALES[1] and Maria Mª Soledad JIMENEZ[1]

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Environmental limitations to the distribution of forest trees become most obvious at the timberline ecotones. Extremes in environmental factors such as temperature, water supply, irradiation, etc. accumulate stress situations than trees can hardly withstand. Therefore, the role of upper timberline ecotones as indicators of environmental changes is widely recognised. The alpine timberline in the Canary Islands is mainly formed by the endemic pine species (*Pinus canariensis* Chr. Sm. Ex DC.) and dominated by a climate with summer droughts and frost conditions in winter. Due to its high altitude it is also exposed to exceptionally high radiation. In this work, it is intended to monitor the physiological performance of *P. canariensis* trees at the upper limit of its distribution in Tenerife by characterizing photosynthesis, plant water relations, chlorophyll fluorescence, pigments and antioxidants in adult pines in relation to environmental factors.

An experimental plot was established at 2,070 m asl in Teide National Park, Tenerife (Spain), where a meteorological station with continuous recording of main factors was installed. Water potential (PMS, Oregon, USA), relative water content, RWC, chlorophyll fluorescence parameters (Handy-PEA, Hansatech, UK) and gas exchange (LCpro, ADC, Hoddesdon, UK.) were measured in the needles periodically during a year, at the same time samples for pigments and antioxidants analysis were taken and analyzed by HPLC (Mod.1525, Waters MA, USA).

The meteorological data showed two clearly different periods, one wet and cold from middle of September to middle of May and another one warm and dry from middle of May to middle of September. During the dry period, CO_2 assimilation rates decreased at the same time that water use efficiency increased; predawn water potential attained -1,6 MPa while the relative water content was 81%; chlorophyll content remained invariable during the whole year. Predawn Fv/Fm values were optimums during most of the year with the unique exception of the colder months (values of 0.6). It was also observed a decrease in Fv/Fm values at midday in accordance with the xanthophylls cycle changes, showing a good adaptation to these conditions. The Canary Islands pine behaviour at the timberline differs of that observed in a place situated in the medium zone of its distribution in Tenerife (Peters et al. 2003, 2008), where it showed less changes during the year according to less extremes conditions of the site.

References
Peters et al. (2003) Trees. 17: 492-500.
Peters et al. (2008) European Journal of Forest Research. 127: 293.

Keywords: Ecophysiology, Gas exchange, Pigments, Canary Islands pine, Timberline

P1-03 Drought effect on xylem vulnerability to cavitation and hydraulic traits in *Pinus halepensis* Mill.

Amira BEN MNA[1] and Roland HUC[1]

[1]*Ecologie des Forêts Méditerranéennes, INRA, Domaine Saint Paul, site Agroparc, 84914, Avignon cedex 9, France, huc@avignon.inra.fr*

Rapid transpiration during drought increases water tension in the xylem and the risk of cavitation in the conducting units of trees and water transport dysfunction. Low vulnerability of xylem to cavitation may account for resistance to drought and explain some species distribution patterns. Resistance to drought-induced cavitation is an intrinsic property of the conductive elements, and is usually characterized by the xylem water potential causing 50% loss of hydraulic conductivity (P_{50}), a proxy of vulnerability to cavitation.

Pinus halepensis Mill. is widely distributed in the Mediterranean region, and different provenances introduced in south-east France displayed different survival rates, supposedly associated to different of resistance levels to drought.

We compared P_{50} values of branches of the same age of *P. halepensis* sampled in a common garden where several provenances were planted and from the Font-Blanche forest where it occurs naturally as a result of recolonization. The planted provenances were chosen for their different aptitudes to survive to drought conditions. Results indicate a difference of response of the shoots regarding vulnerability to drought, with mean xylem tension for P_{50} ranging from -5.6 MPa to -4.4 MPa with a better xylem resistance displayed by pines from the natural forest site and by one of the provenance having a low survival rate in plantation. This suggests that vulnerability to cavitation may not be the driving factor of resistance to drought for that species.

Those results will be discussed in the light of other morphological traits associated with water conduction and water loss (namely specific conductivity and leaf specific conductivity). Short-term and long term effect of drought on these hydraulic traits will be analysed based on additional measurements made on trees from the Fontblanche forest, that were subjected or not to an artificial 30% rainfall decrease and from forest sites in south east France along a rainfall gradient.

Keywords: Ecophysiology, Aleppo pine, vulnerability, hydraulic conductivity, drought acclimation, xylem

P1-04 Towards understanding the mechanisms and magnitude of fertilizer responses in thinned, mid rotation *Pinus radiata* stands in a Mediterranean climate: Components for potential incorporation in decision support tools.

Ben DU TOIT[1], Phillip M. FISCHER[1] and Vavariro CHIKUMBU[1]

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Nutrient and water availability (and the interaction between those) strongly controls forest productivity in the Mediterranean climate zone, Western Cape Province, South Africa. The study Investigated:
(a) techniques to gauge soil water availability in pine stands and
(b) effects of fertilization on re-building the canopy, foliar efficiency and on volume growth in recently thinned mid-rotation *P. radiata* stands across a water availability gradient in the study area.
(a) Water availability. Daily water balances can easily be constructed for stands in close proximity to weather stations. However, in remote and mountainous terrain, where lateral flow of water may enrich lower landscape positions, alternative approaches are needed. We investigated the use of the carbon isotope ratio ($\delta^{13}C$) in tree carbohydrates as this is known to be affected by water availability. A water balance that was constructed for stands on convex terrain positions (water shedding sites) in the study area revealed that prolonged stress periods occur during summer and that the annual ratio of the actual : potential evapotranspiration (water supply/demand ratio) ranges from 0.27 to 0.39 across sites tested. The $\delta^{13}C$ in latewood tree rings was significantly correlated the water supply/demand ratio (measured over the dry summer period). This result suggests that $\delta^{13}C$ levels in tree ring samples may be used to classify *P. radiata* stands into various water availability classes for purposes of extrapolation across sites.
(b) Mechanisms and magnitude of fertilizer responses. Fertilization with factorial combinations of different levels of nitrogen (N) and phosphorus (P) had an immediate effect on the leaf nutrient profile and leaf area recovery after thinning. Vector analysis of foliar nutrient levels suggested that both N and P were limiting because of deficiencies before fertilization. Leaf area index (LAI) in the most responsive N x P treatment combinations showed a significant increase over the unfertilized control treatments as early as 12 months following treatment, allowing for rapid re-building of the canopy. By 20 months after treatment, LAI in P treated plots was virtually double the unfertilized controls, the effect being highly significant. Periodic annual volume increment (PAI) was slow to respond, however, during the second year after N and P applications, the first significant improvements in PAI over the unfertilized control were recorded. The foliar efficiency (volume increment per unit of leaf area index) increased significantly (from 4.3 in the driest site to 7.0 m^3 ha^{-1} yr^{-1} LAI^{-1} on the wettest site). On drier sites, PAI increased by 5 to 6 m^3 ha^{-1} yr^{-1} with optimum N and P fertilization. However, the higher foliar efficiency on wetter sites, coupled with rapid and significant increases in LAI, allowed the wettest sites to increase PAI by more than 10 m^3 ha^{-1} yr^{-1} over the control following fertilization with optimum N and P combinations.
Indices of soil water availability, foliar efficiency and/or response magnitude to fertilizer may be incorporated in future decision support tools to enhance productivity of *Pinus radiata* stands in the study area.

P1-05 Monitoring drought effects on Scots pine (*Pinus sylvestris*) and forest resilience

Laurent BORGNIET[1], Ali THABEET[1], Thomas CURT[1], Christophe BOUILLON[1] and Michel VENNETIER[1]

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During the 2003-2006 period, a severe heat wave and a long drought took place in the Mediterranean southern Alps. Scots pine forests were likely to be affected and heavy die-back appeared locally.

A spatial analysis was performed to localize and to quantify the growth loss and dieback in Scots pine forests along a latitudinal transect from the limestone foothills to the internal valleys of the Southern Alps. We combined multitemporal remote sensing analysis with forest inventory and dendrochronology. We first tested very high resolution sensor on mountainous area covering 28,000 ha.

Six HRV Spot images were acquired at the late summer period from 1995 to 2006 aiming at exploring the relationships between the variations of Normalized Difference Vegetation Index (NDVI) and topography. We used Pearson's r and generalized additive models (gam) to define relationships of several topographic attributes (elevation, slope, aspect, plan curvature, relative slope position and topographic relative moisture index) with NDVI.

It was found that elevation, aspect and topographic relative moisture index are the most relevant topographic attributes among the tested attributes. A sharp decline in NDVI of Scots pine was observed between 700 and 1,000 m of elevation, on the south-facing and on very moist steep slopes. In a second stage, Modis and Landsat time series data sets were acquired (1999-2010) in order to characterize dieback at regional scale and to determine detectability thresholds.

The results of this mesoscale analysis confirm the good detection of diebacks. We also observe forest recovery after the drought period suggesting that these ecosystems are rather resilient. Cross validation of dendrochronological plots and image analysis show their ability to absorb disturbances. These results may have implications on our short-time vision of conifer forest dynamics under changing climate regimes taking place in longer time-scale.

Keywords: Scots pine, dieback, remote sensing resilience

P1-06 Why do large, nitrogen rich *Pinus halepensis* Mill. seedlings better resist stressful transplanting conditions? A physiological analysis

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Under large and high nitrogen (N) concentration *Pinus halepensis* Mill. seedlings frequently have improved survival and growth relative to small and low N seedlings in Mediterranean woodland plantations. To provide a mechanistic explanation of such trend, we studied the physiological performance of Aleppo pine seedlings of contrasted size and tissue N concentration under contrasting stressful planting conditions in spring and summer. Large seedlings with high N concentration (*L+*), and small seedlings with either high (*S+*) or low (*S-*) N concentration, were planted on two sites of different herb competition intensity that created contrasting stress conditions. Seedling survival, growth, gas exchange, N remobilisation (N_R) and uptake (N_U), and water potential were assessed through the first growing season. Herbs reduced survival and growth, but seedling response varied among phenotypes. At the end of the first growing season, *L+* seedlings survived more than both small seedling types in presence of herbs but no differences were observed in absence of herbs. Mortality differences among phenotypes occurred in spring but not in summer. Both shoot and root in *L+* pines grew more than in small pines independently of herb competition. Mortality and growth differences were linked to physiological differences. *L+* pines had greater root growth and gas exchange than small seedlings, irrespective of their N concentration. In spite of differences in root growth, no differences in water potential were observed among seedling phenotypes. Without herb competition, N_U provided most N in new organs while N_R provided most it with herb competition (under stressful conditions). In all cases *L+* pines had greater N_U and N_R than small seedlings. Between small plants, *S+* had greater N_U and N_R than *S-* pines. We conclude that the functional differences among seedlings had different consequences for transplanting performance. Improved transplanting performance in large pine seedlings relative to small plants was linked to greater gas exchange, root growth and N cycling. Our results suggest that seedling size had a greater role in the performance of transplanted seedlings than N concentration.

Keywords: Aleppo pine, competition, ecophysiology, gas-exchange, nitrogen remobilisation, restoration, root growth, survival, water potential

P1-07 NOTG: a 3D mechanistic model to study fine scale water and carbon budgets of multi-specific, heterogeneous ecosystems

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Many natural terrestrial ecosystems, and, increasingly, forest plantations, are made of a mixture of species and display significant structural heterogeneity. Yet most carbon based biophysical models are best suited for homogeneous, monospecific canopies.

The 3D, individual-based TREEGRASS model was initially developed to study the importance of the spatial structure of the tree layer on the productivity and water budget of tree/grass ecosystems. As such, it filled a gap in the modelling options available for studying savannas.

In this paper we present NOTG (Not Only Tree/Grass), an evolution of TREEGRASS that simulates the full carbon, water, and nitrogen cycles of multi-specific, heterogeneous ecosystems. The most important changes have been the implementation of a mechanistic soil organic decomposition sub-model, generic plant phenological types (deciduous, non opportunistic evergreen, and opportunistic evergreen), and a comprehensive description of plant C and N pools, including storage. The model is designed to study water and carbon fluxes at the stand scale over one to a few years.

While being very specific in its scales of applications, NOTG gives the opportunity to study the fine scale mechanisms driving carbon and water fluxes from the individual to the ecosystem, while accounting for spatial heterogeneity of light, water, and nitrogen resources.

In addition to model description, two illustrative applications are presented:
1) for studying the alleviating effect of the tree cover on grass water stress in a tropical savanna, and
2) for studying the net ecosystem exchange in a mixed heterogeneous Mediterranean forest.

Keywords: ecophysiology; ecology; climate change impacts

P1-08 Seasonal changes in the physiological status of regeneration under two structural typologies and a natural light gradient in mixed *Pinus pinea – Quercus ilex* stands in Spain

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The current environmental situation characterized by a changing climate, tends to aggravate species water stress. This fact, joined to the high ecological, landscape and productive values of Spanish mixed stone pine-holm oak stands make necessary to deepen in the ecophysiological background of regeneration. Seasonal courses of chlorophyll *a* fluorescence, gas exchange parameters and water status, joined to environmental variables were measured in two mixed stone pine-holm oak stands at three significant moments along the day (predawn, morning and midday). A plot was set up in each stand and physiological monitoring was carried out in 48 seedlings corresponding to two height classes (0.2 to 0.5 m and 0.5 to 1.3 m) and three main species found in the stands (*Pinus pinea, Quercus ilex* and *Juniperus oxycedrus*). Data analyzed until this moment (September and October) showed higher significant differences between species, than between height classes. The differences occurred at midday and predawn, being more remarkable in September when environmental conditions were still limiting. The highest photosynthetic rate was shown in *Quercus ilex* although the species experienced the most negative water potentials ($_{pd}$ and $_{md}$), in contrast to *Pinus pinea* which showed the highest water potentials. At late summer, values of Fv/Fm lower to the optimum were found both at predawn and midday, indicating some degree of photoinhibition, intimately related to the species. In October, when climate conditions were softened (milder temperatures and rainfalls), all measured parameters increased their values. These measurements showed the different physiological behaviour of three species that occupy the same environment. Once a complete season is measured we expect to find more differences related to species, height class and structural typologies that we will help us to understand the physiology of these three species.

Keywords: *Pinus pinea, Quercus ilex, Juniperus oxycedrus*, ecophysiology, gas exchange, fluorescence, light, water availability, temperature

P1-09 Response of mature Scots pines to drought stress: comparing various foliar and stem wood indicators

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Climate change scenarios predict increasing temperature and reduced precipitation during summer in central and southern Europe. In the Rhone valley of Switzerland Scots pine (*Pinus sylvestris*) forests are already declining with high mortality rates following dry and hot summers. Mean annual precipitation for pine forests ranges from 500 to 900 mm, in drought years as low as 300 mm.

An irrigation experiment was set up in 2003 in a 90 year old Scots pine forest, located at 600 m altitude with annual precipitation of 600 mm. The four irrigated and four control plots were randomly assigned. They are 0.1 ha in size with 75 trees on average. The irrigation, which is carried out at night during the months of April to October, roughly doubled the mean annual precipitation. Various tree crown parameters were annually assessed on all trees, including relative foliage amount in 5%-steps and mortality. In 2004, thirteen dominant trees were selected, seven from the irrigated and six from the control plots covering the whole range of foliage classes.

Their inter-annual growth was assessed weekly using the pinning method. These trees were harvested in April 2006 and analyzed for tree ring width, stable carbon isotope ratios, shoot and needle length, fresh and dry weight and projected needle area.

Irrigation had a significant effect on all of the parameters. But tree foliage class also correlated significantly with most parameters showing the influence of the sample tree selection. Mean needle length, fresh and dry needle weight, shoot length and ring width all correlated positively with estimated foliage amount. Specific leaf area and dry/fresh needle weight were negatively correlated. Water use efficiency, as estimated from stable carbon isotope ratios, correlated highly with a calculated drought index and was higher for trees with lower foliage amount.

Trees with more foliage began stem growth earlier and ended later than trees with low foliage. Irrigation increased foliage amount between 2003 and 2007 by roughly 6%, while trees in control plots showed a loss of 10% foliage, probably due to the dry years 2003-2005. Mortality was 6.1% on the control plots as compared to 2.5% on the irrigated plots. Irrigation increased needle length by up to 70%, shoot length up to 100%, ring width up to 150% of the control trees. Ring width and water use efficiency reacted already in the first year of irrigation, shoot and needle length with a one-year delay. Irrigated trees showed longer stem growth and a delayed earlywood/latewood transition than control trees. Their water-use efficiency decreased significantly, even for trees for lower foliage amount.

Keywords: drought stress, irrigated experiment, Scots pine, Rhône valley, Water use efficiency, stem growth period

Stand Dynamic and Forest Management

P2-01 Application of the 3PG forest growth model to stands of *Pinus pinaster* Ait. in the National Forest of Leiria, Portugal

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Process-based models provide an improved level in the representation of biological processes, allowing more precise estimates than empirical models due to their sensitivity to temporal variables in growth conditions (Amaral *et al.*, 2005). In this way, process-based models can represent important tools to understand how climate change influences on the Net Primary Productivity (NPP) of forest ecosystems. This study evaluates the ability of the process based model 3-PG (Landsberg and Waring, 1997) to simulate the biomass of leaves, wood biomass, volume and basal area associated to maritime pine stands in the National Forest of Leiria.

Data from 72 plots provided by successive forest inventories in the National Forest of Leiria, between the years 1972 and 2006, was used. The obtained results shows that 3-PG model provides good estimates for the wood biomass, reasonable estimates for volume and basal area and poor estimates for biomass leaf, especially in lower classes of quality station. The trend analysis for the residues of prediction with the age of maritime pine stands shows that higher residues are associated to older stands. However, this is not just due to the age but also to the model projection range (number of years since the beginning of the simulation). In contrast, stands with higher densities obtain smaller residues of prediction.

Further development of 3-PG to predict Portuguese maritime pine growth should be undertake in order to obtain more input parameters specific of the *Pinus pinaster* Ait. species as well better soil variables such as Fertility Rating (FR) and available soil water. It is also important to understand the real impact of the model projection range in predicting forest growth. This work was developed under the project ModNet: "Modeling net primary productivity and carbon balance of Portuguese forest ecosystems at different scales."(01/05/2007-30/04/2010: FCT PTDC / AGR CFL / 69733/2006).

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Keywords: maritime pine, net primary productivity, model 3-PG

P2-02 Influence of *Pinus halepensis* cover on seedling growth of two co-occurring Mediterranean oak species

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Change from pine forest towards mixed conifer-broadleaf woodlands is a scenario promoted by forest managers based on the rationale that mixed stands are more resilient (Resco de Dios, 2007) Oak seedlings naturally established in Aleppo pine in the course of succession but this process is long and uncertain. Moreover, the role played by *P. halepensis* on broadleaves seedlings is still debated as some studies have emphasized the negative consequences of Aleppo pine forests on spontaneous vegetation (Bellot *et al.*, 2004; Maestre *et al.*, 2003)

In order to better assess the influence of Aleppo pine overstorey on the survival and development of oak seedlings in southern France we have designed an experiment in which acorns were sown under different types of pine cover.

We installed twelve 25*25m plots in an area naturally afforested by pine in which we applied one of the three thinning treatments: heavy thinning removing two thirds of the basal area, moderate thinning removing one third of the basal area and the control (30 m^2/ha). In each plot, 104 sowing points of three acorns-half of the points with *Quercus ilex*, half with *Quercus pubescens* were introduced. Survival, growth of the emerged seedlings and development of the ground vegetation around the seedlings were monitored during three years. In addition, predawn leaf water potential, fluorescence and soil moisture content were measured at different dates.

Results showed that growth was enhanced in the heavy thinned stands due to higher light availability and *Q. ilex reached* greater dimensions than *Q. pubescens* in all treatments. Growth was positively correlated with shrub cover especially in *Q pubescens* seedlings. Predawn water potentials were lower in the control and for *Q pubescens* seedlings. However, soil moisture in the 30-50 cm layer was lower during the summer dry period in the heavily thinned stands than in the other stands in relation with a higher soil temperature and a more developed ground vegetation. Therefore, the better performances of oak seedlings observed during this experiment in the more opened stands will not necessarily persist in the future and the moderately thinned stands could constitute a good compromise.

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Keywords: Silviculture, *Quercus pubescens, Quercus ilex*, light availability, water stress

P2-03 Establishment of forest types as a tool for developing forest management guidelines in Mediterranean areas: the case of *Pinus sylvestris*

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Forest management guidelines are currently under development for Catalonia (North-East Spain), a highly forested Mediterranean region, with more than 50% of area covered by forests. Forest management guidelines are an essential tool for multifunctional management, with the intention of bridging forest planning instruments at regional level with instruments at forest stand level.

Prior to develop forest management guidelines in Catalonia a previous classification of forest types at stand level was established. This classification was based on two attributes: tree species composition and site quality, based on ecological variables, which determines the potential productivity. So then, management guidelines establish certain objectives and silvicultural models for each forest type, taking into account current global change context.

This work shows the methodology and results obtained in

(a) the classification of species composition (types of pure and mixed stands) and

(b) the definition of site quality classification based on ecological variables for the main forest species.

The methodology was based on a combination of expert knowledge and quantitative analysis of data from the Spanish National Forest Inventory (IFN). Regarding species composition, data from IFN plots pointed out the great importance and potential of mixed stands, which represent the 46% of total forest area in Catalonia. With regard to site quality classification, experts determined that only two or three quality classes should be differentiated for most of the species analysed, based on the premise that it is reasonable to set different site qualities only when they lead to different goals and management.

Finally, it is presented an example of the process and results obtained for defining *Pinus sylvestris* types of forests (two pure forest types and seventeen mixed forest types).

Site quality classification based on ecological variables for *Pinus sylvestris* involved three consecutive stages:

(a) the identification and division of different ecological forest types of *Pinus sylvestris* in Catalonia,

(b) group dynamics of a panel of experts to establish the number of site quality classes as well as the key ecological variables related to site quality, and their ranges and relative importance, and

(c) statistical analysis of the relation between a growth indicator obtained from IFN and some ecological variables easily identifiable by the manager.

The result of this process is a dichotomous key which assigns a quality class to each combination of environmental variables. This key allows the manager to quickly and objectively assign the most likely site quality of a forest stand.

Keywords: Forest types, site quality, mixed forests, expert approach, National Forest Inventory, Catalonia, *Pinus sylvestris*.

P2-04 Methodology to identify ancient trees in the Spanish national forest inventory. Application: *Pinus halepensis* Mill.

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The value of ancient trees for biodiversity assessment is well recognised. These trees are considered as high interest ecological niche. To identify the number and species of old living trees is needed for forest management with conservation proposes. New tendencies involve maintaining instead of removing dead trees and old living trees to increase forest biodiversity. Nevertheless there are not clear definitions to identify them. Generally, there is a unique threshold for all species (related to DBH or total height). But tree species longevity has a wide range of variation.

Main aim of this paper is to determine a methodology to identify ancient trees based on threshold diameters per species using the data from Spanish National Forest Inventory. It is necessary to establish relations between age and available variables provided by large scale inventories. Diameters are always measured in National Forest Inventories and they show good correlations with tree ages.

In the Spanish National Forest Inventory (NFI), permanent plots are established systematically at the intersections of a 1-km x 1-km grid. In each plot dominant tree ages and increment growth diameter are determined by a core extraction at 0.5 cm over ground.

Different diameter-age curves were generated studying their asymptotes and characteristics seeking the most appropriate one. This information was crossed over with species distribution function determining the threshold diameter which is related with a specific number tree percentile. Diameter-age curves were based on cores from 464 trees with diameter from 14 to 58 cm and ages from 19 to 158 years.

The proposed threshold is calculated for Aleppo pine (*Pinus halepensis* Mill.) which is the most representative Spanish Mediterranean pine; in addition, it generally appears as dominant in the forest stands where it is present.

Keywords: tree age; old living tree; diameter-age curves, biodiversity

POSTER CHAPTER

P2-05 Modelling the spatiotemporal pattern of germination in Stone pine (*Pinus pinea* L.) stands in the Northern Plateau (Spain)

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The Northern Plateau of Spain accounts for over 50,000 ha of managed *Pinus pinea* forests. The species plays an essential role throughout the region, due to the high profitability of its edible seeds and its ability to occupy challenging sites, which would remain unforested otherwise. Current management has been oriented to maximize nut production, leading to low density even-aged stands, through shelterwood regeneration fellings. However, the present silviculture scenario faces a common natural regeneration failure, implying extra investments to achieve it by direct seeding. In this study, we attempt to identify whether germination involves a bottleneck for natural regeneration process and to detect environmental (insulation) and climate factors that control this phase. Eventually, we model the probability of a pine nut to germinate in relation to the aforemention variables. Our experimental design consists of two 40 m x 60 m plots installed in 2006, in a representative *P. pinea* stand, under two different densities. From 2006 to 2010, fifty pine nuts were placed at the beginning of July inside eighteen cages (to avoid predation) within each plot. Cage location was established to account for three levels of insulation (depending on its position with respect to the closest crown) and two pasture types, with three replications each. Number of germinants was recorded every fifteen days for twelve months or until total germination took place.

First results show significant differences between years in germination rate. From a spatial perspective, no significant effects were found among levels of the two tested factors. Within years, although the process commenced during the fall season; for every studied period, considerable germination rates occurred within a narrow optimal range of temperature and relative humidity conditions. These conditions took place in autumn and spring, being cold temperatures the limiting factor for the first period, while germination was instead constrained by low humidity levels during the latter. Taking into account that seed dispersal occurs during the warm period and maximum predation rates take place in winter, fall germination could be one of the key factors for successful regeneration events. On the other hand, the proposed model provides an estimation of the spatial and temporal pattern of germination in the species as a function of easily measurable variables that will allow for predictions in simulated scenarios. Modelling of these circumstances will constitute a valuable tool for forest management.

Keywords: Stand dynamics and forest Management, natural regeneration, germination rates and probability, Mediterranean pine, limiting conditions

P2-06 Relation between thinning and understory plant cover and biomass in a brutia pine plantation in northern Greece

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The main purpose of this research was to study the combined effects of thinning of a brutia pine (*Pinus brutia* Ten.) plantation and fertilization with biological (through legume seeding) and chemical nitrogen on the understory vegetation. The experimental area was located in the farm of the Forest Research Institute of Thessaloniki, in northern Greece. A split-plot experimental design was applied. Thinning of the 30 years old brutia pine trees was carried out in 1997 and three spacings were created: 2x4, 3x6 and 4x8 m or 1,240; 550 and 310 trees per hectare, respectively, in two replications. The whole area was seeded with the grass *Phalaris aquatica* (40 kg/ha) and fertilized with P (150 kg/ha). In each tree spacing, three understory treatments were employed:
a) seeding of *Trifolium subterraneum* and *Medicago lupulina* (40 kg/ha), and
b) N fertilizer application (150 kg/ha in autumn of 1997, spring and autumn of 1998 and in autumn of 1999) and
c) control. Cover and yield of understory vegetation was measured for two years (1999 and 2000). An analysis of variance was applied with the statistical program MSTAT.
Tree diameter at breast height was significantly higher at the open spacing (310 trees/ha) than in the medium (550 trees/ha) and dense (1240 trees/ha) ones during the period of the experiment (1997-2000). Understory treatments did not affect the tree diameter, probably because of the high tree age.
During the first, relatively wet, year (1999), the cover of vegetation at the open spacing was the same as in the, while in the following, relatively dry, year (2000) it was higher at the dense spacing followed by the medium and the open tree spacing. The cover of litter followed the opposite trend. Seeding with legumes resulted in a significant increase of vegetative cover compared with the nitrogen fertilizer during the first year but it had no difference compared with the control, while in the second year the results were opposite. Nitrogen fertilized and control treatments had greater cover of litter than the one with legume seeding.
Biomass production of the understory vegetation varied according to the available moisture during the two years of the experiment. In the second (dry) year, biomass decreased by 50% compared with the first (wet) year indicating the impact of the reduced rainfall in the former as compared with the latter year. The increase of tree density significantly decreased the yield of understory biomass. Specifically, the open spacing had greater yield than the medium and dense ones. Understory treatments produced also significant differences on the yield of biomass. Nitrogen fertilization resulted in significantly higher biomass than in the legume treatment and the control. The differences in yield biomass were greater in the first wet year (nitrogen fertilization had 35% greater yield than legume seeding) while in the second year they were lower (only 15%), apparently due to reduced moisture.
In conclusion, tree diameter and understory biomass were increased as tree density decreased. Nitrogen fertilization resulted in the highest yield of understory vegetation in wet conditions, while legume seeding improved the vegetation cover in less favourable conditions. Moisture was the critical factor for biomass production and plant cover of the understory vegetation.

Keywords: Tree spacing, N fertilization, legume seeding, plant cover, biomass production

P2-07 The alteration of diameter distribution by site quality and age in even aged Crimean pine (*Pinus nigra* Arnold) stands in southern Turkey

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In this study, the alteration of the diameter distribution by site quality and age, presented by the actual structure of natural, even aged, pure and undisturbed Crimean pine (*Pinus nigra* Arnold) stands in the Mediterranean Sea region of Turkey, has been related to the models constructed by basing on the models has been obtained from forty five temporary plots. Diameters at breast height (1.3 m, in 1 cm classes) of all trees within the plots (plot area = 0.04 to 0.2 ha) were recorded. The age of three to five sample trees also was recorded to allow an estimation of site quality. The data obtained from this study, were applied regression models including Beta, Gamma, Weibull, Normal and Log-normal statistical distributions. The models predict the number of trees per hectare in a diameter class from diameter, age and site index in a stand. A linear model has been constructed for each distribution, and the coefficients in the model have been computed with the help of multiple regression analysis. F-test value calculated for determination of appropriateness of regression model was found the highest in Log-normal distribution model. For this reason, it was reached to the result that the most suitable model was Log-normal distribution model. Standard error and multiple correlation coefficients have also been determined. Besides, the fitnesses of the models to data have been also tested using the Error Index (EI) and the relative Error Index (EI_{rel}) methods improved by Reynolds *et al*. (1988). Later, the estimate values that the determined models gave have been graphically compared with the actual measurements. Log- normal model seems to be more suitable than the other distribution models. Model represents the distribution into diameter classes of trees in a stand in the rate of about 45% (R^2 = 0.447) depending on stand age and site index.

Keywords: Diameter distribution, Statistical distribution, Turkey

POSTER CHAPTER

P2-08 Effect of plant age and fertilization level on the survival and growth of *Pinus halepensis*

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The objective of this study is to compare the quality of one- and two-year old *Pinus halepensis* seedlings that were grown with different levels of N (total amount). All seedlings were produced from the same provenance of seeds, using the same container (300 cc of capacity) and substrate (fertilized peat moss).

Several types of fertilization were applied, so that the end of culture within each age group had two levels of N total contribution: 60 and 110 mg N to one-year old seedlings and 110 and 160 mg N to two-year old seedlings. *Pinus halepensis* were out-planted in abandoned agricultural land. Before out-planting, at the end of the nursery culture, nutritional content was analyzed.

Experimental design was randomized complete block, within each block were planted four treatments studied (two ages of seedlings x two levels of nitrogen fertilization). For three years, measures of survival, height growth and diameter growth were analyzed.

Keywords: *Pinus halepensis*, age, fertilization level, out-planting

P2-09 Modelling *Pinus pinaster* productivity in Australia and Portugal using 3-PG model

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Maritime pine (*Pinus pinaster*) is the first forest tree species for timber production in Portugal. In Western Australia *Pinus pinaster* was introduced early in the 19th century and since 1942, Australian commercial plantations have been established from the Portuguese Leiria provenance only. Site, soil and climate of Maritime pine stands are mostly similar in both countries although Australian new plantations are aiming dryer areas. Silviculture adopted in Australia and Portugal in terms of rotation length, thinning regimes, weed control and stocking is considerably different. In addition, Australia has a more advanced breeding programme and new plantations are established using improved seed only.

Until recently Maritime pine forest modelling research efforts in Portugal and Australia have been mainly concentrated on empirical forest models. In the context of global change such approach has limitations and therefore it is necessary to establish research on process-based models.

The 3-PG model developed by Landsberg and Waring (1997), which has been widely successfully used for many forest tree species and site conditions, was chosen. The objectives of this work were:

(1) to parameterize and validate 3-PG for *Pinus pinaster* Portugal and Australia;

(2) if different parameters will be needed for each country, the reasons for the main differences will be investigated;

(3) to assess the use of 3-PG to predict *Pinus pinaster* growth in drier areas.

The dataset used in this work comprises forest growth and physiological Maritime pine data from Portugal and Australia coming from: permanent sample plots, inventory plots, research plots and published work. Work carried out so far is not able to establish a single set of 3-PG *P. pinaster* parameters for Portugal and Australia. Work is currently being extended using more field data to reach a solid scientific analysis (both for Portugal and Australia).

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Keywords: *Pinus pinaster*, process-based model, productivity, Australia, Portugal,

POSTER CHAPTER

P2-10 Scaling cross-sectional growth and height growth in Mediterranean pines

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We fit a one-parameter model, based on pipe theory, that relates cross-sectional growth with height-growth, i.e., $Gt + k = (1 + \alpha) k\, Gt (Ht + k / Ht)$.

Data are from *Pinus sylvestris, Pinus nigra, Pinus pinaster* and *Pinus halepensis* stands in Spain. Results indicated that the model is valid for projection lengths of ten years or less. The parameter value (α) varies among species. There are no differences among site qualities for
P. pinaster, P. nigra and P. halepensis. However, we found slight differences in *P. sylvestris*.

We conclude that basal area growth ratio increase faster than the height growth ratio from strict Mediterranean climate stands (*P. halepensis and P. pinaster*) to mesic Mediterranean stands (*P. sylvestris and P. nigra*).

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Keywords: pipe theory, tree allometry, individual-tree model

P2-11 Growth and dendrometric relationships of stone pine (*Pinus pinea* L.) planted in the coastal dunes of North Tunisia

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The stone pine (*Pinus pinea*) is a valuable species grown all over the Mediterranean basin, for its wood, but also for its nut. It was planted in the coastal dunes of North Tunisia about 50 years ago to produce booth fruit and timber. In order to better plan the management of these stands, establish the thinning regime, and forecast wood volume crop, we investigated the dendrometric relationships between stand age, mean diameter at breast height (DBH), mean height, and projected crown area (PCA) in three forests located at Mekna, Ouchtata and Bechateur.

Ninety plots in total (500 m^2 each) were sampled in the three different sites. Soils are often sandy and characterised by a low nutrient fertility. The climate is sub-Mediterranean with an annual mean temperature above 13°C and an annual mean precipitation ranges from 400 to 1,500 mm. Mean tree age, height, DBH, and PCA were measured on a subsample of five trees distributed on the whole stand on each plot. PCA was assessed by measuring tree crown diameter in two opposite directions. Regressions between the different variables were made using Statgraphics Centurion XV (StatPoint, Inc., Virginia, USA).

The regression analysis performed on the data of 441 trees aged from 18 to 46 years old showed significant ($p < 0.0001$) relationships between age, DBH, height and PCA. A site effect was often noticeable but with small amplitude. DBH and height were linked to stand age with a R^2 ranging from 0.49 to 0.64 and 0.51 to 0.72, respectively, depending on the considered site. Height and DBH was linked together (R^2 largely higher than 0.52) and there was also some relationships with stem basal diameter, so that prediction of stem wood volume production can be made from simple bole form equations from DBH. PCA is in some extents an indicator of tree competition and can also be used to compute light availability in the stand. PCA was correctly correlated with DBH ($R^2 > 0.58$) and therefore DBH can be used to assess PCA.

According to the results stand management (thinning and branch pruning) can be designed to optimise tree growth and wood production.

Keywords: Pinus pinea, growth curves, stand dynamics and forest management, wood volume prediction

P2-12 The forest pre-management method and its perspectives for Aleppo pine forests planning: Critical analysis of an Algerian method

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The pre-management method is finalized in Algeria by Mr. GRIM.S and was applied essentially on the Aleppo-pine forests of the 'Daia mounts' and 'Saida' during the period 1976-1986. It affected some Aleppo pine zones in 'Djelfa' during 1968-1973 years. The main characteristic of the method is the 10 ha geometric parceling, resulting from orthogonal partition of a given forest territory (primary network). This system is constituted from 4 m large rides that are distant in average 300 meters each-other, and opened in the North-south and East-west directions. This preliminary carving is completed with a second one at the quadrangular polygon level and consists in a 25 m large tie ridge, representing in a way, a systematic thinning. Although it seems inopportune to pass judgment on the interest of the method (missing of reference information), one must remind the great controversy that followed (still it is) for the great sacrificed wooded areas and consequently for the physical and landscaped protection constraints engendered. However it presents some advantages such as the possibility to access to different points of the forest, more objective descriptive and dendrometrical inventory, better supervision and protection and above all, an opportunity for the inexperienced Algerian foresters to be familiarized with sylvicultural and forest planning traditions, not counting significant quantity of extracted wood during the forest partition. Certainly the great merit of the method is the highlighting (thanks to the primary network lines) the heterogeneity of Aleppo pine stands, described quite often as homogeneous, fact that probably contributed to the planning projects failure. Indeed, major part of Aleppo pine forests in Algeria is localized in semi arid zones and present most of the time great structural heterogeneity and are subject to unexpected changes. Both analytical and topographical parceling will always present limits and to be perfectly adapted to the two constraints, heterogeneity and changes, there is no way apart the geometric one. The forest pre-management method (GRIM.S.1986) proposes such model but this way of systematic partition may lead to accentuated heterogeneity of the polygon while this one must be homogenous. One may reproach the method for the absence of flexibility while flexible parceling taking into account the stands heterogeneity and the risks of fast changes, and that moreover is geometric, seems to be adequate for semi-arid-pine forests. New approach could limit the existing disadvantages, through keeping the quadrangular geometric principle, but with not necessarily equal surface polygons (10 ha). In other words, lines of the primary network (vertical and horizontal as well) will be not necessarily North-south and East-west, not orthogonal or equidistant, but relatively spaced out according to the spatial organization of the affected territory. Another concept to be associated to this flexible geometric partition is the functional zoning, distinguishing wooded zones, multi-resources zones, recreation zones, etc.

Keywords: pre-management, geometric parcelling, flexible polygons, Aleppo pine

P2-13 Aleppo pine (*Pinus halepensis* Mill.) stem form study in sub-humid reforestation of western Algeria: Construction of a form factors table

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Form factors are very important for standing stem-volume estimation at both tree and forest stand levels. But this estimation becomes easy and faster when for each species is established a table where are ordered these factors according to the trees height. This contribution proposes such table for an Aleppo pine reforestation realised in 1890 in the region of Tlemcen (North-west of Algeria).

The method used for its establishment uses advantageously the existing relation between natural and artificial (breast-height) factors and requires a limited number sample trees (50 to 80 only). Factors are calculated as naturals but practically are used as artificial. Such decision is based on the exiting relation between the two types of factors. Indeed, among a serial natural form factors, there will be certainly one which is simultaneously natural and artificial: it's the one corresponding to the relative height 1.3 / h.

The obtained values, from 0.540 to 0.356 corresponding to respectively 6 to 25 m heights, express better taper of the stems in the study stand and allow practically quick evaluation of the standing stem-volume in our survey zone or in other similar stations.

Keywords: Aleppo pine, Form factor, relative height, stem-volume

POSTER CHAPTER

P2-14 Boron deficiency in Mediterranean Pines

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Pine stands are widely visible in Portuguese forestry areas. *Pinus pinaster* is the most dominant species occupying about one third of the total forest lands; in the whole country other pine species are also largely represented, such as the typical Mediterranean/Continental *Pinus pinea* and *P. halepensis* or the Atlantic/Mountainous *Pinus sylvestris* and *P. nigra*.

Pinus pinaster and *P. pinea* are classified as indigenous species in the regions of the country most influenced by the Mediterranean climate, which are mainly located inland and along the central and southern coast. For these areas *P. halepensis* is also a possible and suitable exotic alternative for reforestation.

Several forestry projects carried out in the interior part of the country often failed, resulting either in the initial death of seedlings or in poor growth of the remaining plants. Poorly shaped young trees with needles presenting chlorotic symptoms show repeated terminal necrosis buds, with loss of apical dominance and multiple lateral shoots, which gives them a shrubby aspect. Such inaptitude has usually been explained as the result of extreme climatic conditions with icy winters and very dry summers. The similarity between such appearance and boron deficiency symptomatology has led to further evaluation of the nutritional state of these plants. The results obtained from leaf nutrient analysis have increased the evidence of a boron deficiency.

In the last years the authors have been implementing several field experiments in different regions under the influence of the Mediterranean climate, testing boron application in maritime and umbrella pines representing different ecological conditions and age stages. In the present work, the results of such tests are reported, concerning the evolution of individual dendrometric variables and their mineral nutritional behaviour. Additional empirical observations are referred for Aleppo pines in the same regions. Complementary observations and boron contents evaluation will be carried in the future, for other representative and promising pine species as *P. sylvestris* and *P. nigra*.

Keywords: pines; maritime, umbrella, allepo pines; reforestation; boron deficiency

P2-15 Promoting mixed stands through conversion treatments

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Nowadays, Mediterranean forest ecosystems management is facing several important challenges to guarantee the sustainable production as well as the adaptation to global change. Although climatic change is a key factor to consider, socioeconomic changes from the last decades are quickly modifying the society demands from forests, the management planning and the silvicultural treatments design and application. In Spain and at the Mediterranean basin, *Quercus* woodlands formerly dedicated to firewood production currently occupy wide areas. These *Quercus* coppices present both serious silvicultural and economic problems, due to the abandonment of the traditional and intensive management techniques and harvesting (clear-cuttings in short rotations). Current woodlands are over-aged monospecific stands, with excessive density, with diameter and height growth stagnation and a great risk of wildfires with scarce production of forest goods or services. A proved good alternative for these woodlands is the conversion treatment to high forest over stump, whenever the site quality allows it. The conversion treatment of old Quercus coppices consists of thinning treatments with variable intensity and rotation, in addition to pruning and brush out operations.
The effects of conversion treatments, depending on ecological factors and silvicultural parameters (thinning intensity, thinning type and rotation, among others) have been studied during the last fifteen years in an experimental trial in Central Spain. The general climate is continental Mediterranean; soils are low depth and limy; vegetation is an homogeneous dense coppices of *Quercus ilex* with isolated *Pinus nigra* trees. The experimental design (three locations) includes different thinning intensities (from 0 to 100% of extracted basal area). Inventories have been carried out in 1994 and 2010; thinning treatments were done in 1995 and 2011. Analysis of the effects of the conversion treatment show the increment of diameter and height growth rates, the canopy recovery and the stand resprouting, finding differences in these effects between thinning treatments. Besides the induced changes at holm oak stand, the application of conversion treatment clearly changed the woodland dynamics. Fifteen years after the thinnings, floristic composition varied and abundant pine regeneration was installed in the woodland. In this work we describe the changes between inventories in tree species composition and diameter distribution, especially in the case of black pine. The conversion treatment caused changes in forest dynamics in the short term, increasing biodiversity and diversifying the forest structure. The fast installation of *Pinus* regeneration suggests the potential of the zone for the establishment of multipurpose mixed *Quercus-Pinus* stands in wide areas where *Quercus* species were favoured by human populations for firewood production. Conversion treatment of coppices, with the creation of mixed stands, constitutes a good management alternative for extensive areas and an interesting technique to adaptation to global change.

Keywords: stand dynamics and forest management, *Quercus ilex*, *Pinus nigra*, biodiversity

P2-16 Management tools to estimate forest structure and reproductive characteristics of Aleppo pine forest in North Africa

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The Aleppo pine forests (*Pinus halepensis* Mill.) are very important along the Mediterranean Basin, but are the main tree species in North Africa due to the covering surface and the important economic role. Their forest management is not fully developed and new tools are required. We sampled a large area from eastern Algeria to the eastern coastal part of Tunisia to characterize the forest structure and the reproductive characteristics of natural even aged forests of Aleppo pine forest in four different bioclimatic zones. Three different ways of sampling were carried out: classical inventories (recording all individuals) and two simplified inventories using one (Average size) or five (Dominant) pine trees per plot. The analysis of covariance showed significant differences in total height, trunk diameter, crown coverage and reproductive characteristic depending on the sampling way, the climate and the pine tree density. Non-significant differences between bioclimatic zones in trunk diameter and crown coverage for the different sampling approaches were recorded. We checked that the dominant tree sampling is a good estimator for site quality, whereas the average size tree sampling can be used as representative tree of the population for growth and reproduction.

Keywords: *Pinus halepensis* Mill., bioclimatic zones, forest structure, estimator, dominant tree, average size tree.

P2-17 Prediction of annual tree growth and survival for thinned and unthinned even-aged maritime pine stands in Portugal from data with different time measurement intervals

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The Portuguese national forest strategy published in 2006 divided the Portuguese forest territory into three main functions: wood production, multifunctional systems and protected areas. Wood production is mostly related with pure even-aged stands of two species, the maritime pine (*Pinus pinaster* Ait.) and the blue gum (*Eucalyptus globulus* Labill.). Sustainable forest management of these productive areas requires adequate prediction of stocks and growth. To face the challenge of fast changing scenarios, growth models need to provide adequate predictions in a wide range of time intervals. Individual-tree growth and yield models are especially useful for management planning, because they are capable of simulating a wide variety of management activities, particularly thinning. They often describe annual changes in growth and survival of individual-tree providing detailed information about stand structure and composition. Available data sets for fitting individual-tree models frequently have measurement intervals greater than one year and many times these intervals are irregularly spaced. Also thinning can occur between measurements. This causes difficulty when modelling annual tree growth and survival. An annual individual-tree growth and survival model is developed for pure even-aged stands of maritime pine in Portugal, using data with irregularly spaced measurement time intervals and considering thinning effects. The central components of the model are the equation for diameter growth, the equation for height growth and a survival function. Variable growth and survival rates are assumed in the modelling approach. The model is distance-independent and will be useful for intensively managed areas of pure even-aged stands of maritime pine in Portugal.

Keywords: stand dynamics and forest management; maritime pine; growth; individual-tree modelling

P2-18 Chemical composition and herbicidal activity of essential oils from some coniferous species growing in Tunisia

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The yield and the chemical composition of the essential oils obtained by hydrodistillation from needles, stem and female cones of *Pinus pinaster,* the cones of *Pinus brutia* and *Pinus halepensis* were determined by GC and GC/MS analysis. Significant differences were found between the yield and the constituent percentages of the different oils. The yield based on the dry weight (W/W) were ranged between 0.22 and 0.6% and varied among organ and species. Among the identified components in *P. pinaster* oils, needles oil may be considered as z-caryophyllene and α-pinene rich oil (29.3 and 19.88% respectively), the main constituents in cones were α-pinene (23.3%), and z-caryophyllene (25.8%), and δ-3-carene (6.18%), but stem were considered rich oil α-pinene (87.99%). The study of the chemical composition of essential oils obtained from the cone of these three species show that the major components on three samples were z-caryophyllene (18.2-25.8%), α-pinene (12.4-27.02%) and δ-3-carene (5.1 - 15.88%). Generally, samples oils were considered rich on hydrocarbonated mono and sesquiterpenes.

The herbicidal activity of these oils was investigated by the method of direct contact in Petri dish towards the germination, seed vigour and seedling growth of the most aggressive weeds in Tunisian cereal crops such as *Sinapis arvensis*, *Phalaris canariensis* and tow cultivated species that *Triticum durum* and *Hordeum vulgare*, the phytotoxicity of tested oils was compared with a commercial herbicides 2.4-D isooctylester and glyphosate. The obtained results show that the oils inhibit the germination and the seedling growth of all tested plants which explain their possible use as bioherbicide.

Keywords: Pinus sp, essential oils, needles, cones, stems, phytotoxicity, weeds

POSTER CHAPTER

P2-19 Overstocked stone pine stands. Can late and heavy thinnings be sustainable?

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One of the most important Mediterranean pine species characterising the Italian coastline is the Stone pine (*Pinus pinea* L.). The Stone pine stands are mainly artificial ecosystems having got high ecological, recreational and landscape values. The multifunctional role is the peculiar feature of these systems, but the different functions can be widely performed only in the framework of a careful and well-scheduled silvicultural management. Conversely, in many Italian pinewoods, the lack of a regular silvicultural treatment conditioned heavily both stand stability and functionality, increasing too the sensitivity to disturbances such as climatic change and fire hazard. This is the case of Castel Fusano pinewood, located inside the National Natural Reserve of the Roman Coast (Rome, Italy), one of the most interesting Stone pine area due to its size, location, cultural history and forest dynamics. The pinewood is 1.100 hectare sized and the failure of management has determined structural anomalies, decay and fall occurrences, as well as a notable accumulation of biomass and deadwood. In such conditions, the functional state of the stands is noteworthy compromised due to the high competition for water, light, and nutrients. In this context it is important to evaluate if even late and heavy thinnings are able to restore forest stability and ecological efficiency, to increase both structural and specific diversity, limit fire hazard and improve the touristic use of the pinewood. Four research permanent plots (1 hectar each) were established in stands aged 55-65 and two different thinning theses were applied. In addition, one area was established and reserved as control (no treatment). Thinnings, carried out in winter 2002-2003, were diversified in terms of type (from below to mixed) and intensity (medium to heavy). Mensurational surveys (tree density, specific composition, growth and productivity), structural parameters (social rank, structural diversity, canopy cover) and ecological investigations (leaf area index, transmittance, rainfall canopy interception) have been recorded before, after and five growing seasons later. Data analysis allowed to characterize the stands before the silvicultural practices, to evaluate the stand restore as a function of thinning type and verify whether the expected goals were, even partially, achieved. All the parameters and processes analyzed such as the absence of mortality and of fall down events in the period, the notable recovery of the removed biomass and canopy cover, the increase of holm oak presence, the better use of available space, the increase of pine growing efficiency and the positive effect on water and light use showed a positive evolutive dynamics and an increased resilience of the pinewood system to the disturbances.

Keywords: *Pinus pinea*, multifunctionality, silvicultural management, sustainability, stand dynamics

P2-20 Pulp and paper characteristics of Aleppo pine wood (*Pinus halepensis* Mill) by soda-anthraquinone process

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In Algeria, aleppo pine, *Pinus halepensis* Mill, considered the most important and dominant local forest species. It is a typically Mediterranean species, easily adaptable to various eco-climatic conditions, which grants it the privilege of being the most often used tree species in the country's reforestation programs. Nevertheless, its industrial utilisation rate remains still low, compared to the available mass of wood. Papermaking is a possible way for the valorization of the wood products resulting from thinning operations or short rotation logging. The present study observes the delignification of aleppo pine young wood by an alkaline process (soda-anthraquinone), which allows the preparation of a chemical pulp from this type of wood (small wood). The physico-chemical and morphological analysis of the pulp is carried out, along with the study of delignification, to better understand the reactivity of wood in alkaline cooking. The kinetics of delignification shows that a total cooking time of 135 min makes it possible to exceed the defibring point by giving a yield bordering 44% with a kappa number of 29. It is obvious that the results obtained encourage the use of aleppo pine young wood as a raw material for the Algerian paper industry.

Keywords: Algeria, aleppo pine, soda-AQ, delignification, yield, kappa number, pulp

Ecology

P3-01 Allelopathy and Biodiversity: impact of Aleppo pine colonization on plant diversity of Mediterranean abandoned agricultural lands

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Recent economic and social changes in north Mediterranean regions have led to an important rural depopulation. Consequently, meadows developed on abandoned agricultural lands (characterized by high species richness) undergo reforestation. Although the different stages of successional dynamics leading to the formation of forest ecosystems are well described, the functional mechanisms involved are poorly documented or unknown. Especially, allelopathic mechanisms are considered to play an important role in the replacement of plant species during succession. In North Mediterranean forests, _Pinus halepensis_ Miller, which is a pioneer and expansionist species, colonizes abandoned agricultural land characterized by high biodiversity. The result is an almost monospecific young forest which leads to paraclimaxes that delay the establishment of oak forest ecosystems. By its richness in secondary metabolites, _P. halepensis_ could play an important role in secondary vegetation succession through several processes.

The potential impact of _P. halepensis_ on plant diversity through allelopathy, and the role of microorganisms in these interactions were studied through _in vitro_ bioassays. We examined germination and growth of fifteen target species after application of different aqueous extract concentrations containing allelochemicals from shoots of young pines (about five years), with or without the presence of soil microorganisms. Young pines are known to contain high concentrations in allelochemicals such as phenolics and terpenoids. The fifteen target species were collected from an abandoned grove in the early colonization stages of Aleppo pine.

Using an experimental protocol that closely mimics natural conditions (with the presence of soil microorganisms and using shoot aqueous extracts at low concentration), the different target species appeared to have contrasting reactions to pine allelochemicals. Six species were inhibited, three were insensitive and six were stimulated by the pine allelochemicals, suggesting that _P. halepensis_ has the potential to significantly alter the composition and the structure of plant communities. However, microorganisms play an important role in plant-plant interactions by altering the expression of allelochimicals released into the ecosystem.

Keywords: Ecology, conservation, Allelopathy, biodiversity, bioassay, soil microorganisms, _Pinus halepensis_

P3-02 Colonization of *Pinus halepensis* in southern Mt. Carmel, Israel: Science, Values and Management

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The expansion of *P. halepensis* from plantations into natural sites is becoming a frequent occurrence across the Mediterranean zone of Israel. This issue has become a source of intensive debate among natural conservationists, foresters and other landscape managers who view it from different perspectives. These are associated with past ideology, limited biological and ecological knowledge, contradictory values and perceptions and a handful of emotions. We hereby present a science-based process, in which management decisions regarding the colonization of *Pinus halepensis* within a Nature Park area were based on an intensive research. The process began at the point in which a continuous colonization of pines in the natural garrigue (shrubland) was recognized by the park managers. Based on former knowledge and experience, the process was assumed to be dynamic and management related. Its implications were projected to influence the park at various aspects and levels, including ecological, functional, visual and aesthetic, as well as to affect land use practice. An adaptive management approach was chosen by the management team, in which an intensive research was initiated to serve as a basis for objective decision making. The research goals were to assess and map colonization extent and population dynamics, with relation to three human related factors: afforestation, cattle grazing and fire. The research findings were that the density of colonizing pines was mainly determined by the proximity to planted pines and that colonization was enhanced by cattle grazing probably through reduction of natural vegetation cover. The research results confirmed that pine colonization is significant, dynamic and strongly related to human impacts. However, it originated two different perceptions of the process and accordingly, different management strategies (alternative or complementary). The first approach - the "invasion scenario"- views pine colonization as an undesired human-dependent process and proposes to control it or even to eradicate. Accordingly, it focuses on the spatial dynamics and, more specifically, at the "invasion front", and attempts to manage the factors that influence pine colonization: seed sources, cattle grazing and vegetation structure. The second approach - the "succession scenario" - represents a more pragmatic point of view. It views *P. halepensis* as a native component of the ecosystem and its colonization being part of natural succession. According to this strategy, pine removal will only be performed in patches where colonization does not coincide with the park's goals. A set of criteria was designed to support management decisions, including view-sheds of scenic observation points, fuel-break zones, spots of special natural and anthropogenic interest, wildlife activity and nesting sites, rare plant populations, long term research plots and hiking trails. All criteria were mapped with GIS, and a management plan is now being under construction, alongside with a long term monitoring program. A "no intervention zone" and a "pine free zone" were defined. Throughout the process, decision making was found to be complex due to implications of intensive pine removal on the desired landscape pattern and on biodiversity, water balance and ecosystem functioning. Further research will be initiated to answer these questions. The process highlights the role of research in adaptive management but also the means by which management choices reflect fundamental perceptions and values.

Keywords: Stand dynamics and forest management; Ecology; Aleppo pine; Invasion

P3-03 Ecology and distribution of Calabrian pine stands in the Sila Plateau (Calabria, Italy)

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Apennine mountain forests are generally dominated by beech, with limited areas where silver fir is mixed with beech in different degrees. In Calabria and in north-eastern Sicily, Calabrian pine forests (*Pinus laricio* POIRET, ssp calabrica Delamare) (Blondel and Aronson, 1995) alternate with beech forests. On the Sila and Aspomonte mountain ranges in Calabria, these pine forests cover approx. 114,000 ha, over 50% of which are pure stands, both of natural and artificial origin. The most well known and vast Calabrian pine forests are in the Sila mountain range, covering approx. 74,000 ha, 53% of which are pure stands. They grow from 800 to 1,700 m asl in the Sila Plateau in the provinces of Cosenza, Crotone and Catanzaro (Ciancio et *al.,* 2006). The climate is mountain-mediterranean, with yearly rainfall between 1000 and 1600 mm and average temperatures between 9°C and 14°C. Soils are on acidic intrusive rocks and can be classified in the *Xerorthens*, *Xerochrepts* and *Xerumbrepts* groups (Di Mase and Iovino, 1996).

The large expansion of Calabrian pine in the Sila at the end of the continental epiglacial period can be attributed to the intense soil erosion following forest clearing for grazing and agriculture, which at the beginning was itinerant. This pressure on the forest continued until the end of World War II, although along the centuries there have been periods when the pressure lessened and the forest was able to expand again. Proof that pine expansion on degraded soils was caused by human pressure also comes from the results of a pedo-stratigraphic study near Lake Cecita in the Sila Plateau (Di Mase et al., 1996).

In this work we analyse present day distribution of Calabrian pine forests in the Sila and temporal dynamics of these areas and define environmental factors which influence pine distribution. The aim is to provide a knowledge base for sustainable management and conservation of these important Mediterranean mountain forests, especially in face of uncertain future environmental conditions.

We analysed present day Calabrian pine distribution and compared it with forest maps from 1935. We then defined the bioclimatic characters, according to the classification of Blasi et *al.* (2007), of the areas where Calabrian pine forests are present, analysing climatic diagrams based on historical data series, and discriminating the main influencing factors. We then characterized the soils with the Calabria Soil Map (ARSSA, 2003) and field surveys. Finally, we define the environmental factors which, together with management, have favoured Calabrian pine expansion and dynamics.

Keywords: *Pinus laricio* POIRET, *ssp calabrica* Delamare, ecological factors, bio-climate, forest dynamics

P3-04 Fire related traits of *Pinus nigra* plant communities in the Mediterranean: a data base for Greece and Spain

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During the last decades a tendency of large fire incidents burning across *Pinus nigra* forests has been recorded. Under the climate change scenarios, this tendency is expected to become more pronounced. An early assessment of how the plant community of *Pinus nigra* ecosystems will respond to this new fire regime could be achieved by gathering data concerning fire related life traits of the corresponding plant taxa. Accordingly, species composition data from *Pinus nigra* forests of Spain and Greece (as examples from Western and Eastern Mediterranean Basin) have been gathered and a database of 131 plant taxa was produced, containing 50 woody and 81 herbaceous taxa.

The database has fields related to taxonomy, growth and life form, regeneration mode, dispersal ability i.e. traits that are directly related to early post-fire response and performance. Out of the 131 taxa, for 56 taxa (43%) there was adequate available information in the literature regarding their early post-fire response as these taxa are also present in lowland Mediterranean ecosystems. Despite our efforts, no such information was found for the remaining 75 taxa, a gap in our knowledge that strengths the need for further research on the fire response of the biota of wet/cool Mediterranean-climate forest ecosystems. However, for some of these taxa, their potential early post-fire response was noted ('expert opinion') based on their phylogenetical proximity and life habit similarity with taxa of the same genus with documented traits. For eighteen different plant genera no data concerning any of their species could be produced. The reason behind this lack of information is related to the fact that the vast majority of published studies dealing with burned *Pinus nigra* forests focus on the response of the pines and not on the understorey species. Recent community based research from Greece is starting to produce such data.

The plant families with the highest number of taxa in the database are Compositae and Rosaceae, families whose members are typical examples of species adapted to long distance dispersal: In the growth and life form spectra of the database, perennial herbs and hemicryptophytes dominate, respectively. With the exception of 'annuals' and 'sub-shrubs', the commonest post-fire regeneration mode is resprouting.

However, it is among the 'perennials' that most species with remaining unknown response to fire are included. In conclusion, our results show that a significant percentage of the plant taxa inhabiting the understorey of *Pinus nigra* forest ecosystems in Spain and Greece share the potential of regeneration after a fire event. This is not the case for the pine, which depends on the availability of unburned patches across the burned landscapes to act as seed sources. In the same way, these unburned patches may prove important for several understorey species adapted to long distance dispersal. Therefore, any post-fire plan should start from the conservation of such patches.

Keywords: fire ecology, *Pinus nigra,* life traits, regeneration mode

P3-05 Structural and floristic features of a *Pinus halepensis* forest on coastal dune of the Zemmouri Sahel (Algiers, Algeria)

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The Mediterranean coastal dune geosystem is subject both too many natural stresses and high human disturbance. This is the case of the coastal forest of Zemmouri, a mixed natural stand of Aleppo pine and kermes oak, established on consolidated dunes. It represents one of the last remnants of coastal forest of the Algiers east coast. In this study, the authors propose to contribute to the structural and phytosociological analysis of this forest, very threatened by an increasing human pressure.

For the stand inventory, we measured a total of 636 trees (dbh ≥ 7 cm) on a sample of 40 plots of 400 m^2, distributed according to a systematic grid, due to apparent homogeneity of the stand. This stand is a young irregular grove, dominated by Aleppo pine with an average density of 406 ± 142 stems per ha. Kermes oak (5-6 m in height) is represented with 120 individuals per ha. The distribution by diameter class of trees shapes an exponential type curve, with a positive skew. This model reflects a lack of natural regeneration of Aleppo pine, which is partly hindered by a dense understorey and much more by human pressure. Majority of trees (63%) is moderate sized, with an average dbh of 15-30 cm (21.12 ± 5.33 cm) and height of 6-10 m (8.11 ± 1.5 m), reflecting strong environmental constraints. Clear-cutting is a major cause of forest degradation, estimated to 200 stems per hectare, or 50% of the current stand density. This forest is effectively much cleared, as shown by the space factor of Hart-Becking (IH = 55%), with a low dominant height (9.68 m).

By the Braun-Blanquet method, twenty one floristic relevés are made in best preserved sites with relatively closed canopy. Their analysis permits to describe a new thermomediterranean forest association, *Querco cocciferae-Pinetum halepensis* ass. nova (*Querco-Oleion sylvestris*). The species of preforest mantle (*Juniperion turbinatae*) are also well represented. Human impact, by ruderalization, results in proliferation of *Stellarietea mediae* therophytes.
 In terms of floristic diversity, the pinewood is notably poor; a total of 53 species is identified, with an average of 25 per 100 m^2. The biological spectrum of the association shows the predominance of phanerophytes (including ligneous climbers), with Ph > Th > He > G > Ch, privileged by a subhumid and hot bioclimate (714 mm per year, m = 7.9°C), despite four months of drought. This summer drought stress led to a high proportion of Mediterranean element *sensu lato* in chorological spectrum of the association (83% of the flora). There is particularly, as *Quercus coccifera*, a dozen typically Mediterranean sclerophyllous species.

The natural mixed pine and oak forest is a vegetation structure more resilient to environmental accidents than artificial plantations (pines, eucalyptus and acacias). Its native species are mainly suitable for sandy soils and provide efficient stabilization of ancient dunes. These considerations argue for the preservation of this rare type of habitat, with high patrimonial value, which is a good example of multifunctional forest.

Keywords: remnant forest, mixed stand, sandy coast, floristic analysis, structural features, phytosociology, Aleppo pine, *Quercus coccifera*, anthropic pressure, Algeria

P3-06 Testing a distribution model for *Pinus pinea* in Spain: two approaches through independent presence-only data sets

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Species distribution models can provide valuable and robust information for many objectives throughout plant ecology, but especially for restoration purposes. Nevertheless, the issue of their accuracy and consistency need to be carefully addressed, as well as the reliability of the calibration and validation data sets.

In this work, three independent data sets were used to calibrate and validate a distribution model for *P. pinea* in Spain, applying a methodology based on the ecological field theory and the Mahalanobis' distance that uses presence-only data. The first data set was extracted from the natural stands of the species, and was used to build the model, while the second set derived from stands afforested and reforested during the last decades. Both of them were the result of a comprehensive and detailed examination of the wide available information about the current distribution of the species. Finally, the third data set (314 plots [i1]) comprised the set of plots of the Third Spanish Forest Inventory with natural regeneration of stone pine but no adult tree of the species (and therefore not included in the first data set). In addition, bootstrapping was performed to identify the degree of over-fitting in the model, which can put at risk model's generalization.

Results suggest that the validation of the model with these data sets not only tests its accuracy and reliability but also permits to extract conclusions about the suitability of past and future reforestations and afforestations, the coherence or divergence of the habitats of natural and artificial stands, the degree of naturalization the latter or the conservatism of the niche of the species. Moreover, the use of presence-only records assures the reliability of the data in highly altered ecosystems where absence data do not seem to be dependable.

All these topics are challenging issues in species distribution modelling in general, but particularly transcendent in species like *P. pinea* that, though native in Spain has been widely used in forestation plans.

Keywords: species distribution models, validation, *Pinus pinea*

P3-07 Total and soluble organic carbon and active organic matter along the soil profile of a chronosequence of three Stone pine forests on Mount Vesuvius

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Significant amounts of organic matter are stored in the deep soil layers. However, most studies dealing with organic matter amount, composition and turnover in forest soils concentrate on the organic layers and the upper mineral soil. In contrast the knowledge concerning the quantity and the stability of C pool in the deeper soil layers are quite limited.

The aim of this study was to assess, along the whole soil profile (organic and mineral layers), the amount of organic carbon as well as its soluble and active (microbial) fractions in three Stone pine forests. Within the National Park Vesuvius, a chronosequence was selected encompassing three stands, respectively 39 (BF), 69 (PG) and 99 years (CM) old. The chronosequence allowed estimating the changes with forest age in soil organic C and soluble C, and the below-ground distribution of the two C-pools. Measurements of microbial biomass and activity along the soil profile were performed to evaluate the active organic matter. Soluble C was analyzed for chemical structure by H CPMAS NMR spectra.

The oldest forest (CM), compared to BF and PG, had higher organic matter, C and N contents in the organic layers (litter and humus) and in the 0-5 cm mineral layer. PG forest, compared to CM and BF, showed the highest values of organic matter, N and C/N ratio in the deeper mineral soil. Soluble carbon was detected at all depths.

The fraction soluble C / total C was low in the upper mineral soil and high in the deep mineral soil. The most abundant components of soluble C were alkyls and alcohols at all depths and at all stands. Aromatic components appeared in the deepest layers. Microbial biomass, microbial respiration and the amount of fungal mycelium were highest in the organic layers.

When considering the active organic C as a fraction of total organic C:
1) the lowest values of fungal mycelium and microbial respiration occurred in the organic layers;
2) the youngest forest stand showed the highest amount of fungal mycelium in the mineral soil whilst the oldest forest stand had the lowest microbial biomass and respiration.

The results indicate that organic matter turnover was more active in the upper mineral soil layers and decreased with depth and forest age leading to a major accumulation in the deepest layers of the oldest forest stand.

Keywords: *Pinus pinea*, microbial biomass and respiration, C pools

POSTER CHAPTER

P3-08 Organic matter dynamics in the soil under *Pinus pinea* in a monoculture and in a mixed wood on Mount Vesuvius

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Plant cover influences chemical, physical and biological properties of soil. In particular, the quality of the produced litter affects decomposition and the cycle of nutrients as well as soil organic matter dynamics and the carbon sequestration in the soil.

The aim of this work was to evaluate the effects on soil chemical and biological properties of *Robinia pseudoacacia,* an alien species that has been used for afforestation of volcanic substrates on Mount Vesuvius (Naples, Italy) and has invaded chestnut, holm oak and pine forests in the area. Two coeval (around 40 years old) *Pinus pinea* forests in the Vesuvius National Park were selected, i.e. a monoculture (P) and a mixed wood (PR) created by the invasion of *R. pseudoacacia*. Soil was sampled from the 0-5 cm layer under the canopy of *Pinus pinea* in the monoculture and in the mixed wood and under the canopy of *Robinia pseudoacacia* in the mixed wood.

Soil organic matter (SOM), water holding capacity (WHC), pH, total N and C concentrations, soil basal respiration, microbial biomass (C_{mic}), metabolic quotient (qCO_2) and the coefficient of endogenous mineralization (CEM) were measured at the two sites.

PR soil, either sampled under *Robinia pseudoacacia* or under *Pinus pinea*, had higher pH, WHC, SOM and N content as compared to P soil. Microbial biomass was lower in PR soil than in P soil whilst CEM and qCO_2 were higher. No difference in soil basal respiration between the two soils was found.

The data suggest that *Robinia pseudoacacia* affects *Pinus pinea* soil:

1) by increasing soil organic matter and N concentrations,

2) by inhibiting soil microbial biomass, and

3) by inducing stress conditions as indicated by the higher qCO_2 and CEM in PR soil compared to P soil.

Keywords: alien species, *Robinia pseudoacacia*, microbial biomass and activity

Fire Sciences

P4-01 A unique system for examining the genetic consequences of fire for native *Pinus halepensis* populations

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Wild-fires play a major role in shaping landscapes and ecosystems worldwide. The climate regions of the Mediterranean basin are among the most fire-prone areas, where evolutionary, ecological and management aspects of post-fire regeneration have been extensively studied. Nevertheless, the impact of fire on the genetic structure and diversity of populations has been studied much less.

Aleppo pine (*Pinus halepensis*), is a common wind-pollinated and wind-dispersed Mediterranean tree that has a good recruitment capacity after fire. The genetic structure of three native Aleppo pine populations on Mt. Carmel was recently analyzed. Two of the populations have not been burnt for more than 50 years ('Beit-Oren' and 'Antenna') and one population was last burnt in 1978 ('Mitla'). DNA was extracted from fresh needles from more than thirty reproductive pines in each study site. The genetic profile of each individual was determined using thirteen nuclear microsatellite loci. Our preliminary results indicate that the genetic variance between populations accounts for only 1% of the genetic variance.

The Beit-Oren population is significantly different from Mitla (F_{st} = 0.013, p = 0.012, aerial distance 900 m) and from Antenna (F_{st} = 0.011, p = 0.043, 3,275 m), whereas Mitla and Antenna do not differ (F_{st} = 0.000, non-significant, 3,900 m). The fact that burned Mitla do not differ from unburned Antenna, may indicate that the effect of fire on the genetic composition is minor. However, a pre- post-fire comparison is still required for solid evaluation of fires effect on genetic structure.

In a recent large fire (December 2010) the study sites of Mitla and Beit-Oren were re-burnt including the sampled trees. The pre-fire sampling and genotyping of trees provides a unique opportunity to study the effect of fire on spatial genetic structure of populations in the same site. Genetic analyses of this year recruiting seedlings will allow a comparison of inter-generations change in genetic composition and spatial genetic structure between three genetically similar populations with different types of fire history: A fire-free population (Antenna), a population that was burned once (2010) (Beit Oren) and a population that was burned twice (1978 and 2010) (Mitla).

Keywords: *Pinus halepensis*, fire, genetic composition

P4-02 Assessing the impact of fires on pine populations of south-eastern France

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Wildfires are major disturbances in Mediterranean ecosystems of south-eastern France, and recurrent fires are hypothesized to have shaped the pine populations through a selective mortality of trees. Models of tree survival on an individual basis have been established for several Mediterranean pines after field surveys in burned areas (Rigolot, 2004; Fernandes and Rigolot, 2007; Fernandes *et al.*, 2008). They indicated a size-dependent mortality specific of each pine species. But the effect of fires on the structure of pine populations are still lacking because large samples (generally more than 1,000 per species) are needed.

We used large databases (Cemagref and French national forest inventory) to assess to which extent the height, diameter at breast height (dbh) and bark depth differed between *Pinus halepensis*, *Pinus pinaster*, *Pinus nigra* and *Pinus sylvestris* in burned *versus* unburned areas. We also tested the effect of fire recurrence since the plots have been burned one to four times along the past decades. The fire history is known from fire maps since 1960. The results indicate a clear impact of fires on pine populations and an effect of fire recurrence. Clear interspecific differences existed in relation to traits explaining the resistance to fire or its avoidance such as the height-to-dbh ratio and bark depth. Mediterranean pines (*P. pinaster*, *P. halepensis*) populations after fire especially differed from those of mountain pines (*P. nigra*, *P. sylvestris*). These data confirm the classification proposed by Fernandes *et al.* (2009) with *P. pinaster* being a fire resister, *P. halepensis* being fire-sensitive and a fire-evader able to survive after fire, and *P. sylvestris* and *P. nigra* likely to be restricted to low-severity surface fires.

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Keywords: plant traits, postfire survival, fire resistance, bark depth, growth increment

P4-03 Criteria on species selection for ecological restoration following major disturbances in Maritime Pine stands – comparing two *Ericaceae* species

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Wildfires in Maritime Pine plantations (*Pinus pinaster*) are very common in Portugal. When the seed bank is damaged due to repeated fires, the introduction of native species can be needed to improve biodiversity and ensure the main ecosystem functions at the understory level. The hydro-sowing technique, although little used in Portugal, is promissory for use in ecological restoration following wildfires. However, when selecting species for sowing, it is important to carry out an analysis of their suitability based on their autoecology as well as on the goals of the restoration measures.

This work aims at applying, by way of illustrative example, a criteria-based decision-support approach for species selection using two species of the Ericaceae family. This family was chosen because on its wide distribution in mainland Portugal and the two species being considered (*Arbutus unedo* and *Erica australis*) were chosen for their different types of fruits and seed dispersion periods. A secondary criterion for choosing these two species was their economic use, for apiculture activities in the case of *Erica australis* and liquor production *in the case of Arbutus unedo*, so that their sowing can contribute to valorisation of the ecosystem by the local populations.

We first carried out a review of the criteria that are used for species selection for ecological restoration purposes, analyzing the different biological, ecological and cultural characteristics of the species in the context of the management of Maritime Pine stands in Portugal. The germination potential of the two selected species was then evaluated by experiments taking into account on the best pre-germination treatments according to literature. In order to assess the importance of seed provenance, there were used seeds from three different sites, located at the north and south boundaries and in the centre of the geographical distribution of the species' in Portugal.

Analysis of the species selection criteria-indicated that in a scenario of passive management of Maritime Pine forests, *Arbutus unedo* may be preferred. Namely, its seedling recruitment is not favoured by fire, as opposed to the case of *Erica australis.* Also lower flammability of *Arbustus unedo* is an advantage, in the context of minimizing structural fire hazard. Nonetheless, in recent literature no consensus exists on the role of species flammability matter.

Germination results showed a moderate to low germination potential for both species. *E. australis* (44.4%) presented a higher maximum germination value than *A. unedo* (26%). In both species the best results were obtained for the seeds of the south provenance. The observed differences between provenances underline the importance of seed provenance when harvesting seeds for ecological restoration.

Keywords: Restoration, Mediterranean, *Ericaceae*, Fire ecology

P4-04 Does prescribed burning affects the secondary metabolism of established stand trees of Mediterranean pines?

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Forest fires play a major role in Mediterranean plant dynamic. They occur on a long time range but their frequency increases due to anthropogenic impacts, resulting in increased ecosystem vulnerability. To preserve forests with economic and/or cultural value, forest management organisms develop various techniques to prevent fires. In conifer stands, prescribed burning is considered the best tool to reduce fuel, especially for litter. For this reason, prescribed burning of underbrush is conducted in particular to reduce biomass fuel and protect against forest fires future. But the impact of prescribed burning on the tree layer are still controversial, especially regarding the development and vitality of these trees after fire and its effects on tree physiology are poorly understood. In this study, we evaluated the effect of prescribed burning on secondary metabolism of two Mediterranean pines (*Pinus halepensis* and *P. laricio*) under *in situ* conditions in Mediterranean regions (Provence and Luberon). Terpene and phenolic (including flavonoid) in needles were studied; these metabolites are known to be involved in plant defence. Two experimental areas were divided in plots which were unburned (control), burned one time and burned twice.

Prescribed burning showed a low impact on secondary metabolism of established stand trees for both species. When prescribed burning was recurrent (two burnings with a three years interval), we observed a higher terpene content in *P. halepensis* needles on the plot burned twice than on the control plot. We also observed a tendency to decrease with the burning date: the more recent was the burning, the higher was the terpene content. Regarding flavonoids, their content increased in *P. laricio* needles only two months after fire, while no effect was observed for *P. halepensis,* indicating that these species showed different strategies related to the allocation of resources to these defensive secondary metabolites. Differences in response observed between the two pines appear to be related to different sensitivities of the two pines meet prescribed burns. This information is discussed here with regards to the use of prescribed burnings in forest management.

Keywords: Fire science, ecophysiology, ecology, fire prevention, secondary metabolism, pine sp., terpenes, phenolic compounds, flavonoid, plant defence

POSTER CHAPTER

P4-05 Litter hydrocarbons accentuate flammability of Mediterranean species

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There is no doubt that European Mediterranean ecosystems, including pine forest and garrigue, are highly flammable and naturally prone to fire. This phenomenon is of special concern during summer months since the low precipitations and high temperatures, together with the poor capacity of soils to retain water, accentuate plant flammability. Internal factors, such as plant thickness, surface area-to-volume ratio, architecture and plant chemistry (cellulose, hemicelluloses, lignin and phosphate) also modify plant flammability. What is poorly understood is the role of terpenes, highly volatile and flammable hydrocarbons which are stored in high amounts within leaves. This is especially true in numerous Mediterranean species which invest an important part of their resources in terpene production and storage in order to cope with stress conditions occurring during summer months. Despite their volatility, terpenes still reach important concentrations in litter probably due to their slow degradation by microorganisms and low affinity for water which limits their migration to soil.

We studied the impact of these highly flammable hydrocarbons on leaf litter flammability of six Mediterranean species which appeared to feature high (*Pinus halepensis*, *P. Pinaster*), intermediate (*Cistus albidus*, *P. pinea)* and low litter terpene concentrations (*C. laurifolius*, *C. ladanifer*). Plant flammability was measured in terms of ignitibility (ignition delay), combustibility (combustion time, spread rate, flame intensity) and sustainability (flame residence time, flame height) which refer to how well the fuel ignites, burns and for how long respectively. As performed by other authors, consumability, a supplementary plant flammability indicator, was taken into account and estimated as the proportion of mass of litter consumed by fire.

Measurements were carried out with both epiradiator (1 g) and burning table (fuel load of 1 kg/m^2) tests with samples showing a humidity rate lower than 5%. Accordingly to plant terpene content, plant flammability appeared to be high, intermediate and low. Likewise, flammability parameters measured were correlated to leaf terpene concentrations. These results indicate that leaf chemistry, and especially terpene content, plays an important role in plant flammability and fire risk in Mediterranean ecosystems. These results are discussed in terms of both fire benefits for Mediterranean species and potential management strategies to undertake based on results reported in this study.

Keywords: Fire science, Ecology, Mediterranean ecosystems, fire, flammability, plant chemistry, internal factors

P4-06 Effects of prescribed burning on photosynthesis and water status of *Pinus laricio*

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In the Mediterranean area, forest fires represent an important and periodical threat. In Corsica (France), in order to prevent large-scale fires and to protect forests, prescribed burning are conducted within forests of increasingly young Corsican pine (*Pinus nigra* ssp. *laricio* (Poir.) Maire var. *corsicana* (Loud.) Hyl.). Previous studies shown that pines, during burning, can be directly affected by heat transfer to needles, and by the loss of integrity of xylem vessels (embolism), compromising their survival in case of summer dryness.

The aim of this study was to understand and localize these damages on very young *Pinus laricio*. Experimental prescribed burns across pine needle beds (500 g m^{-2} fuel load) were performed under young Corsican pine (7 ears old) in a departmental nursery at Ajaccio during May 2010. Pines were separated into four configurations: control, nude pines, pines with protected trunks (ceramic wool) and pines with protected canopy.

The heat stress was first thermodynamically characterized. To this end, the evolution of the temperature during fire spread was measured into the trunk (bark, cambium and pith, 10 cm above the soil) and in the canopy (1 m above the soil) using K-type thermocouples.
The impact of fire was then evaluated by three approaches:
1) photosynthesis, through measurements of chlorophyll fluorescence;
2) xylem integrity (axial hydric conductivity); and
3) morphological parameters (micromorphometric variations of stem diameter, burned foliage, death percentage) before and at regular intervals after the prescribed burn.

Measurements exhibit that the air temperature increased up to 850°C and 150°C at the trunk and the canopy levels, respectively. For the nude trunks, cambium temperatures close to 60°C, which is the threshold where lethal tissue damages occur, were measured.
Thermal stress was detected 24 hours after burning with a transient decrease of photosynthetic efficiency for non protected trees, then a decrease of stem diameter and axial hydric conductivity for trees configurations with exposed trunk (non protected and foliage protected ones).
These results are discussed with regards to the use of prescribed burning in forest management.

Keywords: Pinus laricio, prescribed burning, heat stress, photosynthesis, xylem, cambium

P4-07 Effect of fuel treatments on potential crown fire behaviour in Aleppo pine forests (*Pinus halepensis* Mill.) in Greece; A simulation study

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Wildland fires are the most destructive disturbance of the natural lands in the Mediterranean Basin. The abandonment of management practices of Aleppo pine forests in Greece has increased fuel loads and fuel continuity in these ecosystems, resulting in forest stands that are vulnerable to catastrophic crown fires. Wildfire behaviour can be modified by altering the quantity, structure, and arrangement of fuel (flammable vegetation) by fuel treatments such as thinning and prescribed burning. The type and arrangement of treated areas have been demonstrated to influence wildfire behaviour.

This paper models crown fire behaviour in Aleppo pine stands and investigates how fuel treatments affect potential fire behaviour. Fuel complex characteristics that influence fire behaviour were measured in a representative Aleppo pine stand in central Greece, using standard surface and canopy fuel inventory methods. Nine different fuel treatments (control, prescribed burning, controlled grazing, thinning without slash removal, thinning with slash removal, thinning and prescribed burning and slash removal, thinning and controlled grazing and slash removal, thinning and prescribed burning without slash removal, thinning and controlled grazing without slash removal) were applied by adjusting surface fuels (total load, load-by-size class, depth) and canopy fuels (available canopy fuel load, canopy base height, canopy bulk density) under extremely dry and normal fuel moisture conditions.

Under normal conditions, stand thinning followed by prescribed burning and/or controlled grazing with slash removal averted crown fire initiation in most cases. Under extremely dry fuel moisture conditions, the simulation showed that the proposed fuel treatments did not appear to be effective in averting crown fire initiation and spread. Combinations of prescribed fire and/or controlled grazing can be used to reduce wildfire hazard in Aleppo pine forests.

Restoration of Aleppo pines ecosystems must include an analysis of how the proposed treatments would affect fuel complex properties. It is essential that fuel treatments are incorporated in forest management plans of Aleppo pine forests in Greece.

Keywords: crown fire modelling, fire hazard, fuel treatments, Aleppo pine forests, Greece, fire sciences

POSTER CHAPTER

P4-08 Fire effects on *Pinus* phenotypes

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Fire plays a vital role in the perpetuation of natural stands and it is widely accepted as one of the underlying factors driving plant evolution in Mediterranean-type ecosystems. Therefore, a large number of plant species have developed adaptations that confer resistance to fire. In the last few decades, the increase of crown fires and the reduction of fire intervals are especially threatening pine woodlands.

There is limited evidence at the population level that fire promotes over-representation of individuals with phenotypes associated to serotiny and bark thickness. The aim of this study is to test whether populations of *Pinus pinaster* and *Pinus halepensis* under different fire regimes have differential segregation of phenotypic characters (e.g. serotiny or bark thickness).

Fifteen populations were located in the east of the Iberian Peninsula and were chosen because of their contrasting fire regimes and climates. We measured and georeferenced forty individuals per population. Bark thickness and diameter at breast height were recorded for each tree. Cones (open and closed) were counted and aged by whorl counting and serotiny level estimated as the percentage of closed cones with respect to the total number.

Serotiny in *P. pinaster* and *P. halepensis* reflects their resilience strategy in relation to fire. This character is advantageous to deal with frequent crown fires and to attain successful post-fire recruitment. Nevertheless, bark thickness is a resistance strategy. Results confirm for two pine species that populations evolved under a high-intensity fire regime have a higher serotiny level than those under low fire frequency. By contrast, *P. halepensis* populations subject to low-intensity fire regime showed to have trees with thicker barks. Moreover, *P. pinaster* showed high bark thickness on young trees in populations threatened by recurrent fires.

P4-09 Fungal succession after fire in *Pinus pinaster* Mediterranean forests in Northwest Spain

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Maritime pine stands (*Pinus pinaster* Ait.) in Mediterranean ecosystems are typically affected by fire. Much research has been devoted to the dynamics of recovering after fires, and the consequences of fires on Mediterranean ecosystems. However, only recently has been acknowledged the key role of fungi on these processes. Here we present the results of a 4-year survey aimed at describing the succession of fungal communities following fire in a *Pinus pinaster* stand in Northwest Spain.

After a large wildfire in 2002, six 2 x 50 m study plots were placed in burned and unburned areas corresponding to early and late succession stages in order to assess the effects of fire on fungal communities. Fungal fruiting bodies were collected weekly during autumn, identified at the species level and weighted. Information about the saprotrophic or mycorrhizal status of every species was also retrieved.

115 fungal taxa were collected during the four year sampling (85 at late stage, 60 at early stage), from which only thirty appeared along the whole succession. After fire, pyrophytic species such as *Pholiota carbonaria, Peziza violacea and Rhizopogon luteolus* were found. Overall, mycorrhizal species richness was significantly lower in the early stage treatment and mycorrhizal population not only increased the number of species from early to late stage but also shifted in composition with taxa found only in either early or late stages. Fungal fruit body biomass was affected by fire in opposite ways depending on the saprotrophic or mycorrhizal status of the species: mycorrhizal decreased 6-fold, while saprotrophic increased 4-fold.

Our results describe the important effects of fire upon the diversity and abundance of fruiting fungal species in the studied area, providing information about the composition of the fungal communities at early and late stages after disturbance. Private species appearing in early succession stages deserve our attention to better understand their role in the recovery of the whole ecosystem, stressing the importance of the symbiotic interactions with *Pinus pinaster* seedlings. On the other hand, a better knowledge of late stage private species will help to monitor biodiversity in well preserved stands.

Keywords: Fire sciences, Ecology, Fungal communities, Biodiversity, Forest fires, Ecological succession

P4-10 Growth and structure of a young Aleppo pine planted forest after the application of six thinning regimes

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Forest thinning is a mid-rotation management technique that is usually employed to increase timber production and economic return. Modifying forest structure through thinning can, however, also serve other purposes such as the promotion of biodiversity and wildfire prevention. The latter are the predominant goals in Mediterranean regions of low timber production, where areas recently afforested with Aleppo pine (*Pinus halepensis* Miller) are common.

This study was carried out in the context of the creation of a fuelbreak in a young Aleppo pine planted forest in south-eastern Spain. The objective was to compare the effects of six thinning regimes on tree growth and stand structure four years following treatment. Three thinning intensities (Light, Medium and Heavy) were combined with two thinning methods (Random by tree selection and Regular by tree spacing). Allometric regression equations were calculated to estimate tree biomass. The Heavy Regular thinning (followed by the Medium Regular and Heavy Random regimes) significantly reduced growth in stand basal area and biomass.

Four years after thinning, the amount of tree biomass measured in these regimes was a third of that measured in the non-thinned Control area, and this helped maintain a low wildfire risk. Individual tree growth, in contrast, was greater in the Heavy and Medium thinnings than in the Light ones, which were similar to the Control. The Heavy Random thinning successfully transformed the regular tree plantation pattern into a close-to-random spatial tree distribution, resembling that of natural Aleppo pine stands. Compared to the Control area, all thinning regimes resulted in lower variability and differentiation in tree size. Wildfire prevention can benefit both from a random tree distribution, which maintains canopy fuel discontinuities for longer, and from regular tree spacing, which minimises the development of undergrowth.

Overall, the Heavy Random thinning seemed the most appropriate in a young afforestation area to reduce fire risk and the artificial tree distribution simultaneously. This treatment could constitute a first step from a planted to a more natural and resilient forest. On the other hand, Regular thinning regimes may be more suitable for the creation of a fuelbreak when undergrowth poses a high fire risk, particularly when applied at a Light intensity. This intensity avoided understocking the stand and the associated decrease in timber production and carbon sequestration.

Keywords: Pinus halepensis; Thinning; Forest structure; Tree growth; Wildfire risk; Diversity

P4-11 Effect of fire regime on litter flammability and on structure of *Pinus halepensis* stand

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Recurrent fires are more frequent in the Mediterranean basin due to global climate change. The effects of fire recurrence (different numbers of fires and intervals since the last fire) on the structure of *Pinus halepensis* stands (pure or mixed stands) were studied in southeastern France. Fuel bed description was carried out on aboveground vegetation at understorey and overstorey levels, and on litter in thirty nine homogeneous study sites. The structure of the understorey was categorized following a gradient of fragmentation including: (i) isolated shrubs, (ii) vegetation patches made up of a single species and (iii) homogeneous vegetation layers including different species of the same height (Ganteaume et al. 2009). To assess the effect of fire regime on the flammability of pine dead fuels, samples of *P. halepensis* litter were collected undisturbed (i.e. keeping the structure of litter layers). Three classes of litter depth were studied (low, medium and high) to account for the variability existing in the field. Flammability experiments were carried out in laboratory using a glowing firebrand and a 10 km h^{-1} wind. The main variables recorded were: ignition frequency, time-to-ignition, flaming duration, flame rate of spread, flame propagation, mean flame temperature, maximum flame height and rate of consumption (Ganteaume *et al.*, 2010). Results showed that the decrease of time interval since the last fire caused an opening of the canopy, except for the lowest vegetation stratum (grasses and low shrubs) that did not vary significantly. There was no significant change in horizontal connectivity between fuel beds (% of layer cover) as a function of the fire regime. Conversely, the vertical connectivity (% of tree cover, height of the trees and of the layer) was affected by the fire regime, especially in pure pine stands. Fire regime also influenced the litter layer and litter depth decreased with an increase in the opening of the stand that could be due to fire. The ignition frequency was higher in mixed pine-oak stands than in pure pine stands whereas the time-to ignition, flaming duration and rate of consumption were the highest in pure pine stands. The maximum flame height and the flame propagation decreased with the increase of the number of fires and the time-to-ignition was the highest when the interval since the last fire was the shortest. Increases in litter depth resulted in increased mean flame temperature, maximum flame height and flame propagation. These results could be explained, in part, by the proportions of the different litter components. Modelling of fire behaviour, using the FIRETEC fire simulation code (Linn & Cunningham, 2005; Pimont *et al.*, 2009), showed that the rate of spread (ROS) in pine open stands was lower than in the dense mature stands. In this latter, the ROS was heterogeneous, higher in the overstorey than in the understorey.

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Keywords: wildfire recurrence; fire interval, vegetation structure; *Pinus halepensis*, rate of spread modelling, litter flammability, undisturbed litter sampling

P4-12 Modelling post-fire mortality of Mediterranean pines

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We investigated and compared the post-fire responses of three Mediterranean pine species in different fire scenarios, namely under wildfire and prescribed fire conditions. The species analysed are *Pinus pinaster* (maritime pine)*, P. pinea* (stone pine) and *P. nigra* (black pine). The fire sites cover a wide range of ecological conditions, where *P. pinaster* is the dominant pine species*.* We gathered data from eleven sites, corresponding to five wildfires and six prescribed fires in central and north Portugal. The joint database includes the post-fire status (alive or dead) of 1,871 pine trees, as well as a number of other tree and site characteristics. The studied variables include fire severity indicators, fire type (wildfire or prescribed fire), tree characteristics (species, diameter, height, bark thickness) and topography, among others. Binary logistic regression methods were used to test and evaluate the influence of these variables on pine resistance to fire and to fit predictive mortality models.

Post-fire tree responses were strongly affected by the crown volume damaged (CVD). Additionally, other factors such as the type of fire, tree size, bark thickness and tree species, had a significant but less important influence on pine mortality models. Our results suggest that trees with less than 30-40% of crown damage will probably survive regardless of fire type, but above this level, the trees are more likely to die in wildfires than in prescribed fires. The probability of mortality for a tree with 80% crown volume damaged is 60% higher in a wildfire than in a prescribed burn, which means that other factors are affecting trees susceptibility. The different tree responses observed in the two fire types might be a consequence of different types of fire injury not captured by CVD (e.g. twig destruction and root damages) or the phenological status. While the prescribed fires correspond to low intensity burns conducted from late autumn to late winter (cool wet season), the wildfires occurred during the summer months (hot dry season) when fire weather conditions are severe and trees are physiologically more active.

Models indicate that *P. nigra* is slightly more fire sensitive than *P. pinaster* in prescribed fires; however, no significant differences were found between *P. pinaster* and *P. pinea* mortality in wildfires. Results also suggest that tree size increases fire resistance of smaller trees (until they reach 30-40cm DBH) but has the opposite effect on larger (older) trees.

Crown volume damage was the more important predictor in the pine mortality models and this variable alone explained 71% of the variance in tree responses (Nagelkerke R^2). The explained variance increased to 77% when including fire type in the model, but only relatively small increases were attained when adding additional variables. ROC curves indicate very good model adjustment, with 95% to 97% agreement between the predicted values and observed outcomes.

Keywords: Mediterranean pines, fire ecology, wildfires, prescribed fires, mortality models

P4-13 Salvage logging in burned *Pinus halepensis* stands: morphological and ecophysiological status of dominant perennial species one year later

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The salvage logging is one of the most common emergency actions to implement in the short-term management after a fire but its ecological effects are not totally clear, particularly those referred to seedling establishment. It has been often argued that soil scarification by wood removal operations can facilitate seedling rooting, but the reduction of shadow by removal of dead wood was demonstrated to increase summer mortality of Aleppo pine (*Pinus halepensis* Mill.) seedlings.

In summer 2009, a mid-high severity fire burned over 1,000 ha of Aleppo pine forest in south-eastern Spain. Six months after fire, a salvage logging was carried out in the burned stand but we delimited a control area with no treatment (uncut). After cutting, we established three 25-m linear transects separated 5 m, in both areas, to characterize pine seedling recruitment. Pine seedlings intercepting lines were counted and their total height recorded. We also characterized the recovery of the companion vegetation. Fourteen square plots (2 m x 2 m) were randomly set in the study area, ten in the cleared area and four in the control uncut area. During summer 2010, we recorded the total height and the cover of three dominant understory species: a resprouter, the Esparto grass (*Stipa tenacissima* L.) and two bush seeders, Rosemary (*Rosmarinus officinalis* L.) and Rockrose (*Cistus clusii* Dunal.). To estimate the soil water availability and the water stress in the plants during the summer drought, we performed the pressure chamber method (using a Compact Plant Water Status Console) recording the predawn leaf water potential which is related to the overall water status of the individuals. We also recorded and calculated the net photosynthetic response to PAR, the transpiration and the water use efficiency for four individuals from each species in the studied plots. These measurements were carried out at ambient conditions (8:00 to 11:00 AM, solar time) using a portable gas exchange system (LI-6400XT) equipped with CO_2 and H_2O infrared gas analyzer (6400-07 Needle Chamber).

We found that pine recruitment was negligible (less then hundred pine trees per hectare). Pine-seedling survival after summer was showing no differences although seedling density and growth were significantly higher in control plots. Morphological and ecophysiological variables were not significantly different in both areas before the drought period. In late summer, the seedling growth in control plots was higher for the three companion species, although only significant in the case of Rockrose. In contrast, cover increase was significantly higher for all of them. Regarding to the status of the plants before summer, the Esparto grass showed the highest mean leaf water potential value in both treatments.

After the drought period, the leaf water potential values were higher in the cleared area although not significantly. The comparison of linear regressions relating PAR and net photosynthesis revealed significant differences depending on the species and the treatment, showing higher slope values those recorded in the uncut area for both seeder species.

pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia
135

We found significant higher values for water use efficiency of Esparto grass in the salvage area, meanwhile the seeder species did not differ between treatments. Transpiration of the three species was significantly higher in the uncut area. We found that all individuals under burned logs survived the summer 2010 (very hot although not extremely dry compared to historic recordings). The water status of the studied species was not significantly affected by the removal of the dead cover. However, higher transpiration and lower water use efficiency found in the covered area, resulted in the stimulation of the total height and cover, especially for Esparto grass individuals. This confirmed that the salvage logging neither affected seedling emergence nor seedling survival of Aleppo pine individuals. However, the changes in the microclimate due to wood removal may stimulate growth of Aleppo pine seedlings and the main shrub companion species.

Keywords: Post-fire management, leaf water potential, photosynthesis, *Rosmarinus officinalis*, *Stipa tenacissima, Cistus clusii*.

P4-14 Post-fire regeneration variability of *Pinus pinaster* Ait. in the centre of Portugal

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Several studies had been developed in order to determine the influence of fire in the structure and dynamics of Mediterranean pine ecosystems, although few have assessed the regional variability in the amount of regeneration and the factors driving it. Existing studies have shown that the main factors explaining the observed variability in the amount of pine regeneration include pre-fire vegetation structure (in particular, the age structure of the burned stands), fire severity, type of post-fire management (clear-felling and slash management) and environmental/topographic factors. Although many studies have addressed one or two of these factors, only a few addressed all these drivers simultaneously. Also the regeneration of the understory vegetation (vegetation structure and floristic composition) in pine stands burned has not been highlight in Portugal. Unpublished studies in this area indicate that the early-post fire species richness of the understory vegetation is higher in pine stands than in eucalypt stands. However, there is no consensus in the literature. Therefore, the project FIREREG has arose with the main purpose of quantify and modelling the regional variability of post-fire natural regeneration (from seeds) in pure pine, pure eucalyptus and mixed stands. For that, the mid-term post fire regeneration of the tree layer, as well as of the understory, (6-7 years after wildfire) is being evaluated in three different regions of Portugal. The study sites are regularly positioned in a 500 m^2 grid, along the eucalypt, pine and mixed forest burnt in 2005 in central Portugal. Each plot consists of a circle with 145 m^2, where the structure of the forest stand is evaluated, together with the collection of indicators of the pre-fire structure. Inside the plot, four subplots with 10 m^2 are established, and the variables collected in them include woody vegetation specific richness, cover and height. The vegetation structure and composition is to be related with characteristics of the pre-fire vegetation, fire severity indicators, environmental variables and management practices. At the present, sixty four plots have been analyzed, from which forty eight were eucalypt stands, eleven mixed stands and four pine stands. Pine regeneration has been frequent in all the plots, even in eucalypt stands. This can be explained by the presence of neighbour pine stands and by the fact that most of these plots were dominated by maritime pine in the past and converted to eucalypt stands. The most frequent families found were Ericaceae and Fabaceae, including the species *Erica cinerea*, *Calluna vulgaris*, *Erica umbellata*, *Erica ciliaris*, *Ulex micranthus* and *Pterospartum tridentatum*. Comparisons of the specific woody vegetation richness in the plots are being assessed as well as the factors that explain this variability. When assessing the potential influence of post-fire forest management practices in the woody vegetation, preliminary results suggest that diversity and frequency of native tree species (e.g, *Quercus robur*, *Quercus faginea*, *Quercus suber*) is higher in plots with no observe evidences of soil mobilization. Further data analysis will be presented during the poster session, as data is still being collected and analysis is still in a preliminary stage.

Keywords: Fire sciences, post-fire regeneration, *Pinus pinaster* Ait.

P4-15 Optimization of silvicultural treatments in *Pinus halepensis* Mill. stands for reducing wildfire hazard

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Greece is a Mediterranean country in which the problem of fire is great, due to the climatic conditions prevailing in summer (high temperatures and drought). This problem is major in the zone of the evergreen broadleaves where mostly pyrophilic species of the genera *Pinus, Quercus, Erica* and *Cistus* appear. These species are known to be highly flammable and big areas are burnt every year. The increased wildfire characteristics, emanating from fuel accumulation in conjunction with the xerothermic conditions prevailing in these environments, set suppression actions inefficient, thus threatening human life and property. Having encountered the high cost demanding for the suppression actions, the efforts had now concentrated to the modification of fuel stratum characteristics based on silvicultural interventions. The research was conducted at the forests of Kassandra Peninsula which occupies an area of about 35,000 ha and where *Pinus halepensis* reaches its optimal growth. In the current research an attempt is being made to quantify the optimum combination of silvicultural treatments in order to efficient reduce the potential spread and intensity of the wildfire. The quantification is based on the establishment of 52 experimental plots of 500 m^2 and the estimation of the silvicultural characteristics of a sample of $n = 1488$ individuals of *Pinus halepensis* Mill. In all sample plots the silvicultural parameters measured for all individuals, were: the number of stems per plot, the diameter (DBH, cm) at breast height for trees with diameter > 4 cm, basal area (G, cm^2), total heigt (H, m), crown length (L, m) and canopy cover (%). In addition, slope and aspect topographic parameters were estimated for each sample plot. Critical wildfire hazard indicators such as Torching and Crowning Index estimated before and after the establishment of silvicultural treatments via the NEXUS wildfire simulator software. NEXUS incorporates the most commonly used models of surface and crown fire behaviour to simulate its full range possible in a forest stand. It offers the possibility to modify canopy characteristics independently in order to assess the effects of silvicultural treatments on fire behaviour. In the current study several surface fuel models were used as inputs covering a wide range of the typical Mediterranean vegetation. The analysis clearly showed that silvicultural intervations reduced wildfire hazard in all cases without exposing the ground under the canopy layer in a large extend, thus minimizing the disturbance level. The ratio between efficiency and implementation cost of these treatments is high, constituting a compatible solution to the limited available financial resources for wildfire suppression.

Keywords: Mediterranean Ecosystems, *Pinus halepensis* Mill., Wildfire Severity, Silvicultural Treatments, Nexus.

POSTER CHAPTER

P4-16 Regeneration of *Pinus halepensis* stands: influence of site preparation treatments

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Aleppo pine can easily regenerate after fire and this process has been well documented (e.g. Ne'eman *et al*., 2004). In contrast, recruitment in fire-free conditions is difficult and has received much less attention. In southern France, the renewal of ageing Aleppo pine stands is problematic and site preparation techniques have to be applied to favour pine recruitment (Prévosto and Ripert, 2008).

Three experimental sites were disposed in old pine forests along a gradient of site conditions in southern France: site of Barbentane (superficial soil, dry and hot climate), Saint-Cannat (medium site conditions) and Vaison-Séguret (deeper soils, colder and wetter climatic conditions). In each site, stands were thinned (regeneration cut) and then vegetation treatments were applied on experimental units varying from 0.02 to 0.11 ha and replicated four times. Treatments applied in the three sites were: mechanical chopping, chopping followed by scarification in one direction and control. In two sites prescribed burning, chopping + scarification in two directions were also tested as well as the presence of logging slash. Several years after treatments application, number and dimensions of seedlings were recorded on one-square-meter plots disposed along transects in the different treatments.

Highest pine densities were found in the scarification treatments that most severely impaired the ground vegetation and that provided the greatest bare soil abundance. Prescribed burning was also efficient to promote pine regeneration provided sufficient fire intensity was reached during this operation. In contrast, regeneration was low in the chopping treatment and almost absent in the control. This study showed that adapted site preparation treatments are needed to favour pine natural regeneration and are essential if a competitive grass layer is present (e.g. *Brachypodium retusum* or *Brachypodium phoenicoides* in this study).

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Prévosto B., Ripert C., 2008. Regeneration of *Pinus halepensis* stands after partial cutting in southern France: impacts of different ground vegetation, soil and logging flash treatments. Forest Ecology and Management, 256 : 2058-2064

Keywords: mechanical treatment, prescribed burning, scarification, recruitment

Pinus pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia
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P4-17 Resilience of *Pinus nigra* forest ecosystems to fire: the case of Mt Taygetos, Greece

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Post fire recovery of *Pinus nigra* greatly depends on the availability of remaining unburned patches of mature individuals acting as seed sources. Therefore for evaluating the regeneration potential of a burned Black pine forest it is essential to identify the availability of such patches within the periphery of the fire scar. Remote sensing and GIS techniques were employed for detecting and delineating existing non burned stands across the megafire that burned Mt Taygetos in Peloponnese in summer of 2007. Total burned area of *Pinus nigra* has been estimated to exceed 45% of its initial distribution.

Spatial analysis performed with GIS predicted that regeneration of *P. nigra* is expected to be satisfactory in the greater part of the burned area. In order to elucidate the role of the unburned stands, field campaigns were organized early during the second post-fire. Two sites were considered for sampling, in each of which 3 x 100-m long transects directed outwards from the edge of each unburned patch were established. Pine seedling emergence as well as pine seedling and sapling densities were monitored along these transects, for two consecutive years. Monitoring of plant community regeneration (species composition in both burned and unburned stands) was also performed.

Preliminary results showed that most young pine individuals (83%) were found at a distance of 0 to 40 m away from the unburned patches. Still, few young pines were found up to a distance of 95 m. Seedling and sampling survival was highest in the understory of large resprouting individuals, such as *Pteridium aquilinum,* indicating the positive effect of these fast growing resprouting herbs on the establishment and survival of *P. nigra* seedlings. Within the unburned patches fifty nine understorey species have been recorded, the vast majority of which was also found to satisfactory regenerate in the burned areas. Species richness at the burned areas was found to be higher than at the unburned patches, mainly due to the post-fire establishment of herbaceous taxa. Several of them were species whose germination and establishment is known to be promoted by fire, whereas there were herbaceous taxa which do not have any regeneration mode but function as 'colonizers' in order to establish on the burned soil.

Consequently, the potential availability of any remaining unburned site is critical for ensuring post-fire recovery not only for *P. nigra* itself but also for understorey plant taxa that possess an effective dispersal mechanism. In general, according to our initial findings, plant species of *P. nigra* forest communities present a wide range of early response to fire. Further research is required in order to identify functional groups using similar hierarchical approach that has been applied in lowland pine forest ecosystems.

Keywords: fire ecology*, Pinus nigra*

P4-18 The influence of recurrent forest fires on the abundance of *Pinus halepensis* Mill.– Mt. Carmel, Israel

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Forest fires represent one of the most important ecological factors in Mediterranean ecosystems. Considered as a natural disturbance, fires play a key role in the evolution, distribution and organization of this environment. Particularly, in *Pinus halepensis* forests, the importance of fire towards the maintenance of their structure and biodiversity has long been documented. Recent alternations in fire regime due to coupled effect of possible climate change and intensification of human activities, can lead to changes in vegetation structure and species composition.

The Mediterranean ecosystem of Mt. Carmel, in the NW of Israel, is subjected to increasing number of forest fires, some of which occur in areas that have been previously burnt.

Accordingly, the study aimed at assessing the effect of recurrent burnings on the regeneration and the spatial distribution of *Pinus halepensis*, as reflected by the number of trees in 18 sites, differing by the number of previous fires and time lapses since last burning. Four treatments were addressed: '*single-fire*' sites burnt in 1989, 1999, 2003, 2005, 2006; '*two-fire*' sites, burnt in 1982/2006, 1983/2006, 1983/1989, 1989/2003, 1989/2005, 1998/1999, and 1999/2005 and '*three-fires*' sites burnt in 1989/1998/1999 and 1989/1999/2005, in addition to four control (non-burnt) areas.

Methods included field survey; at each site, hundred 1 m^2 quadrates were randomly placed to record the number of the trees, statistical differences between the sites were calculated using nonparametric ANOVA (Kroskal-Wallis) test. The results reveal differences in the number of pine trees presented at each treatment. Generally, the amount of pines is inversely related to the number of fires. For example, trees density in the sites that were last burnt during the spring of 2005 varied between 1.2 tree / 1 m^2 (single-fire) and 0.25 and 0.39 tree / 1 m^2 in the two and three-fires sites, respectively, whilst in the control site 0.46 tree / 1 m^2 was recorded. Similarity, trees density in the areas that were last burnt during summer 2006 were 3.26 and 2.51 tree / 1 m^2 for the single and two-fire site, and 0.39 tree / 1 m^2 in the control plot. Equivalent trend was apparent at all treatments. The effect of recurrent fires, however, was particularly evident when time interval between two successive fires was less than 20 years; the time needed for *Pinus halepensis* to mature and produce an adequate seed bank. Apparently, not only the number of fires, but also the fire season has a major effect on regeneration dynamics. Seemingly, spring fires may lead to strong decrease in *Pinus halepensis* germination and regeneration. Under Mediterranean climate, germination of pine seeds occur only after the first winter rain, therefore, in case of long dry period between the fire and the precipitation the seeds might be exposed to predation.

Keywords: Mediterranean, Mt. Carmel, *Pinus halepensis* Mill., Recurrent forest fires

POSTER CHAPTER

P4-19 The interplay between *Pinus halepensis* and Forest Fire Regime of Mt. Carmel

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In contrast to the densely forested landscape found today on the Carmel Mountain Ridge, explorers and expeditions from the 19th century describe the area as primarily denuded of vegetation. Locally, isolated stands of *Pinus halepensis* were described. During the early part of the 20th century first afforestation were initiated, and the dominant tree species planted was *P. halepensis*. Paralleling the maturing of the planted forest, grazing practices became less common, resulting in succession of *Quercus-Pistacia* maquis patches. Until the early 1980's large forest fires (more than 100 ha) were a rare event in the region, but by the end of the 20th century such events became more frequent. The last Carmel fire occurred from 2/12 to 6/12/2010 was the largest forest fires in Israel's history and by far most devastating. The combination of a prolonged dry spell of more than eight months coupled with easterly dry winds provoked the condition for the outsized burning. The fire consumed an area of 2,200 ha, mainly comprised of natural and planted *P. halepensis* stands.

Previous studies to the fire regime of Mt. Carmel revealed that fire distribution in region is not randomly scattered, rather the probability of pine forest to be consumed by large fires are three times higher than their relative proportion in the Carmel reserve and national park. Additionally, the age of the pine trees appear to play a key role, facilitating the propagation of the fire, and intensifying its severity. Using historical and up to date mapping of the region, the current study aims at understanding the current fire regime and its spatio-temporal distribution in relation to the maturing pines, natural or planted, of Mt. Carmel. We correlate between stand properties, and human activities with fire properties, and demonstrate a shift in the fire regime in the region.

Keywords: Forest Fire regime, Mt. Carmel, *Pinus halepensis*, fire spatial distribution, afforestation

P4-20 Post-fire dynamics in the *Pinus halepensis* forests of Bejaia (Northern Algeria)

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The Landscapes of the Mediterranean region are shaped by the action of recurrent fires. This disturbance is considered as a natural ecological force against which the native plants have developed several adaptive mechanisms of survival and regeneration. Most studies on the influence of fire on plant communities in the Mediterranean basin concerned its northern side while data on the same topic is lacking for the southern part of this basin. Our contribution provides the first data on the role of legumes and *Cistus* species in the regeneration of pine communities after wildfire in the southern part of the Mediterranean basin.

Our study sites were distributed over the *Pinus halepensis* forests of Bejaia (Northern Algeria). The dynamics of leguminous after a low intensity fire and *Cistus* species after a high intensity fire were surveyed according to the diachronic method on permanent plots during the first year of the post-fire succession. The demography of legumes seedling showed two peaks, a first major one in December (i.e. two months after fire) and a lesser second one in March. The above-ground biomass of legumes collected during the survey was very low during the first four months after fire then it reached important values with time. With regard to total biomass, the legumes constituted the most represented family during the first months after the fire. Seeds of *Cistus* showed a unimodal pattern of germination which was concentrated in December and January.

Various factors affecting the colonization of burnt communities by *Cistaceae* are discussed.

Keywords: *Pinus halepensis* forests, Post-fire dynamics, Legumes, *Cistaceae*, Algeria.

POSTER CHAPTER

P4-21 Post-fire recruitment of *Pinus pinaster* (Ait.) – the importance of fire severity

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This study focuses on the investigation of the *Pinus pinaster* recruitment, after a heterogeneous severity fire, in order to analyse
1) in what extent the regeneration is affected by different severities and
2) which fire severity index, from the ones used here, correlates better with post-fire *P.pinaster* recruitment, and therefore, is of better use from a post-fire management point of view.

The study area is a west facing slope with *Pinus pinaster* plantation, burned in August 2008, at 30 years of age. It is located in Colmeal, Central Portugal, in the mountain range of Serra da Lousã, in the border between the municipalities of Góis and Arganil. No serotinous cones have been observed for this population, leading to conclude that, in this case, the soil seed bank may play a more important role than the aerial seed bank.
The study sites were chosen according to a global, straightforward categorization of the fire severity, in two distinct categories. Visual assessment of the burnt slope allowed to identify areas where the canopies where totally charred or consumed, and no green needles were left (High Severity – HS) contrasting with areas where the canopies where only scorched, and eventually some green needles were still present (Low Severity – LS).
This categorisation led to the establishment of three pairs of transects, in the transition areas of these main fire severity classes; one transect was placed in a LS area, while the other was placed in the neighbouring HS area. Then, three plots composed of four 2.5 x 2.5 squares where established in each transect, and a fire severity index, based on the minimal diameters of the burned twigs was calculated (Twig Severity Index – TSI).
For this severity estimation, the diameter of the three thinnest twigs of 5 to 10 randomly selected shrubs was measured, and the average diameter found on each plot was weighted by the maximum found on the slope. This resulted in an index ranging from 0 to 1, directly proportional to the fire severity on the plot. Other severity measures, related to the flame height and degree of canopy consumption, were also taken, but won't be addressed at this stage. The number of *P.pinaster* seedlings in the plots was monitored in a regular basis, together with other aspects of the post-fire vegetation regeneration. The data analysis is still ongoing.
At the slope scale, it was found that *P.pinaster* seedlings density is roughly twice as high in the plots located in the LS than on the HS areas. The reasons for that may be :
1) less mortality of seeds that were already on the soil when the fire occurred, or
2) enhanced conditions for germination due to post-fire litter inputs from the canopy.

There are evidences of a strong relation between *P.pinaster* seedling density and the TSI at the transect scale, but not so strong at the plot level, which implies that spatial variability may play an important role.
Further data analysis is needed; however, this preliminary analysis suggests that severity may have an important effect on *Pinus pinaster* recruitment after fire, and that both fire severity classifications approached can be of interest to evaluate the potential for the post-fire regeneration of this species.

Keywords: stand dynamic and forest management, *Pinus pinaster* (Ait.), post-fire recruitment, severity

P4-22 Thinning post fire regenerated Aleppo pine stands in the short time reduces carbon storage

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In the Mediterranean Basin, Aleppo pine (*Pinus halepensis* Mill.) is one of the most important conifers adapted to fire and drought. Usually, the forest management for this species is focused on the reduction of wildfire-hazard rather than timber production. In stands naturally regenerated after the fire, the over-stocking induce to increase both the fire risk and in the immaturity risk linked to fuel continuity (both vertical and horizontal), low tree growth and reproductive potential. Our research is based on two even-aged post-fire Aleppo pine stands sixteen years old, located in south-eastern Spain. In each burnt location permanent sampling plots (10 m x 15 m) were set and different silvicultural treatments were carried out five and ten years in order to reduce the high pine tree density resulted after the natural regeneration. Tree height and trunk diameter were recorded for the sampled pine trees. Furthermore, eighty-one Aleppo pine trees were sampled from these two studied sites in Calasparra (Murcia, semiarid ombroclimate) and Yeste (Albacete, dry ombroclimate). The sampled trees were recorded, extracted, weighted and carried to laboratory for drying and processing (obtaining dry biomass and leaf area).

The obtained data were treated according the factors: site and management. The latter was divided into final tree density (depending on thinning intensity reducing to 800 or 1,600 trees per hectare) and the age of the stand when the treatment was applied. We also included control stands, with no treatment whose tree density was about 7,000 trees per hectare in the dry stand and 125,000 trees per hectare in the semiarid stand. We developed allometric relationships to estimate above and below-ground biomass, leaf area index and the total carbon stocks of the stands. We found significant differences within sites (Dry Mediterranean climate in Yeste counteracts the Semi-arid Mediterranean climate in Calasparra) and within final densities. The results showed that early thinning was increasing the dry biomass accumulated in the individual trees and their mean annual productivity in both sites. The highest improvements of individual biomass were obtained in stands of 1,600 trees per hectare in the semiarid site and in 800 trees per hectare stands for dry site. Biomass is enhanced depending on the time passed after the treatment. Earlier treatments (5 years old) showed higher individual biomass values due to the longer recovering time after thinning. However, the untreated stands showed the highest biomass values and therefore the highest amount of carbon storage.

Therefore, thinning is strongly recommended to decrease the fire risk and the intraspecific competition, thus improving individual tree growth and reproduction. In Yeste, the stands thinned after five years to lower density were close to reach the values found in untreated stands but concentrated in a lower number of living trees. In Calasparra (the lower site quality), the thinned stands were far to recover the total biomass values. Although Forest Management Planning ocused into maximizes biomass and carbon storage in the short-term, should not include thinning in early stands as a management tool.

Keywords: *Pinus halepensis*; Post-fire treatments; Biomass; Allometry Forest Management

POSTER CHAPTER

P4-23 Fire behaviour modelling in a maritime pine Portuguese forest to support management decisions at the stand and landscape levels

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Wildfires have a substantial impact on forest landscape composition and constrain the economic viability of maritime pine (*Pinus pinaster* Ait) in the Portuguese commercial forestry. A set of explanatory variables from Leiria National Forest (10,881 ha), an even-aged maritime pine public forest, related to geographical information and non-spatial information including surface fuel models (Fernandes *et al*, 2009, Cruz, 2007) and stand variables (height, crown base height, crown bulk density) derived from 539 inventory plots were instrumental to provide information to enhance the effectiveness of methods for actively integrating stand-level fuel treatments with explicit landscape-level management planning. Specifically, several modelling applications to detect significant fire-landscape interactions between stand-level features and fire behaviour were fitted through logistic regression and classification tree analysis to classify maritime pine stands according to fire risk levels.

Fire simulation was carried out with FlamMap 3.0.0 (Finney *et al.* 2003) for three typical meteorological scenarios derived from historical weather records gathered from May to October over 1998–2008 to represent moderate, average and critical fire weather conditions. For each scenario, modelled fire behaviour characteristics, landscape data and stand variables (tree density, basal area, quadratic mean diameter, dominant height) were overlaid in ArcGIS and a database that stores landscape pixels that are homogeneous according to those attributes was established for each scenario to identify stand characteristics and spatial pattern metrics of fire prone areas.

The database with the most critical combination values (4% fuel moisture content, 40 km/h wind speed) was selected as input for modelling analyses.

Logistic regression modelling was applied to develop models suited to end users ranging from typical forest practitioners to researchers, providing:
(1) two compatible modeling fire behaviour equations to predict crown fire activity (*Pfcrown*) depending on the available variables, i.e. Model I, based on simulator input data (slope, crown base height, fuel model and canopy cover), and Model II, using easily measurable stand characteristics suiting forest managers (dominant height, basal area and fuel model);
(2) a logistic mortality model for the percentage of basal area killed in a stands after a wildfire, based on inventory data.

Furthermore, a classification tree approach was employed to :
(1) model the type of fire (surface, passive or active crown fire) and the difficulty of fire suppression (Alexander & Lanoville, 1989) from biometric data to support forest management; and
(2) quantify the influences of meteorological, fuel and topographic variables.

The results demonstrate the potential of the strategies pursued to understand the influence of both biometric and environmental variables and to identify high-risk in maritime pine stands and, consequently, to support hazard-reduction silvicultural practices, through the development of management guidelines for fuel and stand structure modification in these fire-prone forest stands.

Keywords: Fire Sciences

P4-24 Fire resilience assessment using remote sensing in *Pinus halepensis* Mill. forests of Southeastern Spain

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In the Mediterranean areas, there is an increasing recurrence of wildfires caused by the climate change. Knowledge on the behaviour, adaptation and resilience of the Mediterranean communities to fire is important to develop tools for an adequate forest management according to the predicted scenarios.

In summer 1994, several large forest fires burned almost 450,000 ha in Spain. Two large forest fires occurred in South-eastern Spain, burning around 25,600 ha in Calasparra (Murcia) and 12,900 ha in Yeste (Albacete) of *Pinus halepensis* Mill. forests. Both regions are characterized by a typical Mediterranean climate, but located in different ombro-climates, semi-arid and dry, respectively. In order to evaluate the short and medium-term resilience of these ecosystems, we developed a resilience index (RI) that uses remote sensing information and field data.

The remote sensing information consisted of a time series of 16 Landsat-TM / ETM+ images. This data set of Landsat images corresponded to the pre-fire stage (spring 1994), and post-fire stage (spring 1995, 1997, yearly 1999-2010) and were used to provide maps of fire severity, and to actualize land-use maps. The Normalized Burn Ratio (NBR) was calculated to obtain the severity of the wildfire calculated as a difference (dNBR). This map of severity is one of the factors determining the resilience index. Other factors also included in the index definition were biotical (forest structure and adaptative traits to fire of the main species) and abiotical factors as landform (aspect, slope, stoniness) and climate. Here, the required layers of geo-referenced information were generated from the Second and Third Spanish National Forest Inventories (IFN2 and IFN3, respectively), the Digital Climatic Atlas of the Iberian Peninsula and Digital Elevation Models.

Landsat imagery was also used to characterize the actual recovery of vegetation in the two test sites (Yeste and Calasparra) and that, for a period of sixteen years after the fire events. In particular, the Normalized Difference Vegetation Index (NDVI) and the Vegetation Cover Fraction (VCF) were used for estimating the recovery curve of vegetation. These estimates, together with the field databases of the IFN2, IFN3 and with in situ data from our own monitored plots, were compared between them before being used for the validation of the resilience index.

Thus, the resilience index was validated in the two large fires, at two levels:
1) At local level using the recordings in situ from our permanent plots, the IFN2 and IFN3 plots; and
2) At landscape level (i.e. the whole burnt areas of Yeste and Calasparra) by using the images of the actual recovering of vegetation obtained from Landsat satellite.

This comparison allowed us to perform a spatial and temporal analysis that has confirmed the good correspondence between the resilience index (recovering capability) and the current recovery conditions of these ecosystems along a period of more than 16 years after the fire events.

Finally, we created a geo-referenced map from the study area including the obtained resilience index values. We improved processes and methodologies to obtain the resilience index which was found to be a cheap and easy tool to monitor large fires, characterizing them and predicting the natural recovering. It should be used in forest management to calculate the resilience and recovering of the burned Aleppo pine stands in order to planning restoration.

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Keywords: Fire science, restoration, Aleppo pine, natural regeneration, Landsat TM/EMT

P4-25 Predicting the time-window for full recovery of *Pinus halepensis* Mill. after a future recurrent wildfire in three Aleppo pine forests of northern Euboea Island, Greece

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Postfire, field measurements of sapling growth and reproductive dynamics were carried out in three, even-aged, Aleppo pine populations of northern Euboea Island, Greece (Gouves, Rovies and Pili, burned in 1994, 1996 and 1997, respectively) for three, successive growing seasons (2004-2006). Four permanent experimental plots were established (summer of 2004) at randomly selected sites in each forest and a total number of 300 pine saplings were tagged for long-term monitoring (Daskalakou et al., 2007).

A novel regeneration prediction method has been elaborated, aiming at forecasting *P. halepensis* full recovery, after a future, recurrent wildfire. The presented method is based on extensive field surveys (sapling density, cone bearing, seed production, canopy seed-bank build up) and evaluations of relevant, postfire parameters (seed aging effect, seed consumption by fire, seed predation, germination failure, seedling survival and sapling growth ability).

Taking into consideration the potential seed rain evaluations (2,564 accumulated seeds per square meter, per site, 10-12 years after fire) we estimate the required time for successful postfire forest reestablishment (at least 1,000 mature pine stems per hectare, a density similar to the unburned forest) in the case of a recurrent fire.

The time window for full recovery is found to be as short as 10-15 years (in Gouves), 8-11 years (Pili) and 7-11 years (Rovies) for the three young Aleppo pine populations of northern Euboea, respectively (marginal values correspond to worst and best postfire scenarios). These predictions seem relatively optimistic (compared to bibliographic data) but they are justified by the extremely optimal growing conditions in Euboea and the observed, markedly early, vegetative-into-reproductive phase shift of the even-aged, regenerating pine populations.

References
Daskalakou E., Albanis K., Skouteri A., Thanos C.A. (2007). Postfire growth and reproductive dynamics in *Pinus halepensis* (Aleppo pine) forests of northern Euboea Island, Greece, pp. 59-60, Conference Proceedings, MEDECOS XI, the International Mediterranean Ecosystems Conference, Perth, Western Australia, Australia, September 2-5, 2007.

Keywords: canopy seedbank, seed rain, sapling growth

P4-26 Local variability of serotinous cones in a Canary Island pine (*Pinus canariensis*) stand

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The endemic Canary Island pine (*Pinus canariensis*) has an effective strategy to counteract fire disturbance in the short term. It has a mixed strategy that combines the presence of serotinous cones and thick barks with the ability to re-sprout from the trunk after a fire, a rare trait in pine species. High frequency of fires in the Canary Islands is related to human action, as natural fires by lightning or vulcan activity have very low frequency; hence, the how and whys of the presence of serotinous cones in the species is still a topic of debate.

Previous studies showed that the frequency of serotinous cones varies from stand to stand. Here, we analyzed the presence of serotinous cones at a local scale. We selected a Canary Island pine stand in the transition zone between dry and humid forests in the south of Tenerife. Branches were pruned from twenty trees in order to evaluate the presence of serotinous vs. non-serotinous cones by direct verticile counting on the branches.

The opening temperature of serotinous cones was assessed in the laboratory. Percentages of serotinous versus non-serotinous cones varied from 0 to 93%, showing high variability between trees. Opening temperatures were very high (above 65°C) as compared to other Mediterranean pine species with serotinous cones.

Keywords: Fire resistance, opening temperature, *Pinus canariensis*, serotinous cones

Thursday June 9th • 13-10 – 14:50

Posters related to Climate Change, Genetics and Breeding, Pine and Insects Interaction and Conservation will be presented by their authors (underlined names)

Climate Change

P5-01 Climate / growth relationships in *Pinus cembra* in the Southern French Alps under Mediterranean bioclimate

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In the Southern French Alps submitted to Mediterranean bioclimate conditions, Stone pine (*Pinus cembra* L.) appears as an emblematic species in forest ecosystems. In the context of climatic change, this species, well-adapted to alpine conditions, will be particularly threatened by elevation of temperatures. Assessing climate–growth relationships is of high importance in order to understand how forest ecosystems evolve at regional scale.
Response functions (RF) and Moving Response Functions (MRF) over time were processed on a dense network of mean chronologies in order to assess the relation between Stone pine tree growth and climate. This original network is centred on the Southern French Alps influenced by Mediterranean synoptic systems. Climatic data are issued from HISTALP dataset

Results evidence a positive relationship of Stone pine radial growth with winter precipitation. Since the late 19th century, an aggravation of this rainfall-dependent character is shown by the MRF. Considering the increase in temperature and reduction both of summer precipitation predicted by General Circulation Models and of the snow cover and duration in the French Alps, stone pine is likely to be exposed to stressful conditions during the 21st century.

References:
Saulnier M., Edouard J-L., Corona C., Guibal F., 2010. Climate / growth relationships in a Pinus cembra high-elevation network in the Southern French Alps. Annals of Forest Science, in press.
Saulnier M., Corona C., Edouard J-L., Guibal F., Thomas A.: Cernes caractéristiques et anomalies extrêmes du climat dans les Alpes françaises entre 1500 et 2000. Colloque "Panorama de la dendrochronologie en France", Digne-les-Bains, 8-10 octobre 2009.

Keywords: Dendrochronology, Southern French Alps, *Pinus cembra*, response functions, climate- growth relationships

pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia

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P5-02 Contribution of the maritime pine forest sector from the National Forest of Leiria (Portugal) to the mitigation of climate change

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Nowadays, global warming is one of the most important issues in our society. The Intergovernmental Panel on Climate Change Fourth Assessment Report indicates that temperature on Earth will rise between 1.4 and 5.8° C in this century (IPCC, 2007). The forest sector can play an important role in the mitigation of climate change impacts as forests potentially remove a significant amount of dioxide carbon (CO_2) from the atmosphere. On the other hand, harvested wood products (HWP), such as wood buildings, furniture or paper, store part of the carbon contained in the wood harvested from the forest, for short or long periods, delaying its return to the atmosphere (IPCC, 2000). Maritime pine is the forest species with the largest representation in Portugal, occupying 885,000 hectares and containing the largest amount of carbon stored, estimated around 24,845 million tones (AFN, 2010). This study aims to evaluate the contribution of the maritime pine forest sector from the National Forest of Leiria to the mitigation of climate change. The emissions and removals of CO_2 and methane (CH_4) are quantified, from the forest to the final disposal of HWP, including industrial processing of wood. The carbon balance was calculated by subtracting to the net carbon removal, the fossil carbon emissions and the additional emissions of carbon as CH_4.

The results show that the global carbon balance associated to maritime pine forest sector ranged between -17 and 49 Gg Ceq yr^{-1} in the period 1980-2003. Thus, maritime pine forest sector has not always contributed to the removal of carbon, as the loss of biomass by forest fires or harvesting activities was higher than forest growth and carbon accumulation in HWP in use and in landfills for the years 1980-2003. Maritime pine forest has played a key role in the global carbon balance of the sector, contributing in average to about 90% of the total carbon removal, while HWP in use and in landfills had a minor contribution to the carbon removal, approximately 6% and 1%, respectively. Fossil emissions and additional emissions of CH_4 represented about 3% of the total carbon balance.

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Keywords: Maritime pine, Stand dynamics and forest management, Global warming, Carbon balance

P5-03 Fire limits of Mediterranean pine

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The temporal and spatial variability of fire regimes controls for a large part the fate of pine populations in Mediterranean ecosystems. Most pines are likely sensitive to the variations of the time interval between successive fires, and to their intensity. As fire regimes are hypothesized to shift with changes in land use and climate, it is of major importance to predict whether the dominant Mediterranean pine species could survive and regenerate under altered fire regimes, i.e. to indicate their fire limits in fire-prone environments.

To this purpose we simulated the post-fire survival and regeneration of four pine species (*Pinus halepensis, Pinus pinaster, Pinus nigra* and *Pinus sylvestris*) in different vegetation communities of southeastern France including shrublands and mixing with oaks. We used the LASS software (Pausas & Lloret 2007) to simulate pines under a large range of fire severities and fire intervals. We tested if the different pine species were able to persist in the landscape after 110 years of simulation, in particular the abundance of each pine cohort (seeds, immature, mature and mature high individuals).

The results confirm the importance of fire intervals to allow forming a canopy seed bank, and of the vegetation community that may prevent pine regeneration from seeds. Each pine species is expected to survive and regenerate within a specific range of fire regimes due to its demographic parameters. We discuss these simulation results in comparison to the substantial body of field data on pine regeneration and survival after fire, which exist in the literature.

References:

Pausas, J.G., Lloret, F., 2007 Spatial and temporal patterns of plant functional types under simulated fire regimes International Journal of Wildland Fire 16, 484-492.

Keywords: Fire regime, pine persistence, regeneration, LASS model

P5-04 Potential climate change effects on wildfires in Sardinia and Corsica and resulting impacts to Mediterranean forests and socioeconomic values

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The projected impacts of climate change in central west Mediterranean Basin are characterized by a greater variability and an increase in extreme weather events (heat waves, severe droughts, etc.). The global change may increase the wildland fire risk for the Mediterranean forests due to the combined effect of air temperature increase and humidity decrease on fuel moisture. Identifying areas that are characterized by high probability of large fire occurrence or extreme fire behavior in relation to the projected climatic change could represent an important component of fire management planning.

In this paper, we predict future wildfire incidence and risk factors that affect social and economic values in Sardinia and Corsica, including forests, by developing spatially explicit statistical models of wildfire occurrence based on landscape characteristics and weather conditions. Specifically, statistical models were built to explain current spatiotemporal patterns of wildfire incidence in terms of fire danger indices. We then calculated future fire danger rating indices from a regional climate model, and we applied these values to the statistical model to predict spatiotemporal patterns of future wildfire occurrence. The risk to forests and other values were then calculated and compared to actual levels.

The climate change data were obtained from the Mediterranean basin by a regional climate model with a spatial resolution of 25 km. These data predicted a future increase of the number of days with extreme fire weather conditions, which, in our modeling, led to a higher incidence of wildfires in the future. The analyses revealed spatial variation in fire risk factors that are useful in prioritizing fuel treatments and guiding other wildfire risk management activities under a changing climate.

Keywords: Climate change impacts, fire sciences, logistic models, regional climate models, extreme fire weather, climate anomalies, wildfire probabilities.

P5-05 The relationships between climate and radial growth in *Pinus nigra salzmanni* from the south of France

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The Salzmann pine, *Pinus nigra salzmanni*, is an endemic black pine native to France and Spain. Its restricted distribution in France and its susceptibility to threats such as wildfires make its current populations a protected habitat under European Directive 92/43/EEC of 21st May 1992 (Natura 2000). However, little is known about its ecology and how this species is able to adapt to a changing climate. The species is known to reach ages of several centuries and thus constitutes a very good model to study past climate using tree rings as proxy and to assess the relationships between tree growth and climate over time.

In this study we used a dendroecological approach to better understand the radial growth response of Salzmann pine to climate variation. Following a recent genetic study carried out by INRA URFM, we selected twenty trees each from three French populations located in southern Massif Central (St-Guilhem-le-Désert, Gorges du Tarn) and eastern Pyrenees (Conflent).

Using a panel of annual increment cores of ages reaching up to 450 years, we compared the spatial and temporal variability of radial growth in the three Salzmann pine stands and we calibrated ring-width to climate relationships for the first time in this region and for this species.
We show that
1) trees are sensitive to climate, and
2) among tree and among population variations are significant, indicating strong response and local adaptation to climate.

We conclude with how *Pinus nigra salzmanni* can respond to climate change considering how it responded to climate over the last centuries.

Keywords: *Pinus nigra salzmanni*, dendroecology, climate, tree ring

POSTER CHAPTER

P5-06 Restoring thinning practices to decrease drought stress in natural Scots pine forest in a dry inner-alpine valley in Switzerland

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The last three decades have been characterized by an increase in temperature and climate change scenarios suggest that drought episodes will increase in frequency and severity. Scots pines are already declining in Mediterranean regions and in dry inner-alpine valleys at low elevation. In parallel, forest management has been reduced since the last World War, leading to increasing stand densities and competition for water. Therefore, adapting current Scots pine forests management becomes crucial in order to mitigate the effect of drought periods.

A thinning trial had been installed in 1965 at the valley floor of the Rhone valley in a 45 years old pure Scots pine forest. Three treatments (light, medium and heavy thinning) with three repetitions were established. The pre-thinning basal area was ca. 40 m^2/ha and reduction in basal area was 15%, 46% and 70% for the thinning treatments respectively. In 1975, three additional control plots were established. Inventories of stem number and diameter at breast height were carried out before and after thinning and in 1975, 1991 and 2009.

In order to test if the treatments reduced drought impacts for the trees, we examined how the treatments influenced tree growth, tree mortality and water content in the soil. As soil water content was not measured in 1965, we repeated the treatments in spring 2010, to obtain the corresponding basal area as reported after the first thinning. 30 trees per treatment were felled in spring 2010, ring width measured and converted to basal area increment. Annual mortality rates were calculated for the periods 1975-1991 and 1991-2009.

Radial growth increases for the medium and heavy treatment by the factor of 2 and 4 respectively during the 10 years following thinning and remained on a higher level for decades. The annual mortality rates for the period 1975-1991 were 2.9%, 1.5%, 0.8% and 0.25% for control, light, medium and heavy treatment respectively. For the second period (1991-2009) mortality rates increase to 3.2%, 2.4%, 1.2% and 0.8%, causing a decline in basal area in control and light thinning. During the driest period of the year (summer 2010), water availability (soil water content) increases in parallel to the thinning intensity by +15%, +20% and +34% for light, medium and heavy thinning respectively.The increase in soil water content following thinning and the extreme increase in tree growth underline the drought limitation in these dry forests.

Our results suggest further that in dry forests of the inner-Alps or the Mediterranean region only heavy thinnings are suitable to maintain high basal area increment due to increased water availability. Hence thinnings might enhance tree vitality and increase tree resistance against drought, insects and pathogens.

Keywords: Scots pine, dry inner-alpine valley, drought stress, thinning, mortality rate, basal area increment, water availability

P5-07 Assessing vulnerability and adaptive capacity to climate change in the Urbion Forest Sector: integrating social and biophysical perspectives

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Recent evaluations about climate change impacts on the forest sector in Europe concluded that the Mediterranean region will be one of the most affected, expecting negative effects in the provision of forest goods and services. But, lack of information related to adaptive capacity of Mediterranean forest is reported - especially at landscape levels- and studies considering both social and biophysical dimension are mostly absent.

This study is oriented to assess the climate change vulnerability and adaptive capacity of the forest sector in the Urbion Model Forest in order to build a climate change adaptation strategy - based on biophysical and social perspectives - that could be integrated in the forest management system in Urbion.

A baseline for the provision of ecosystem goods and services (EGS) (timber, mushrooms, carbon sequestration) resulting of current forest management will be constructed as a function of climate variables and historical processes. Changes in provision of EGS and the response of forest ecosystem to alternatives management systems in different scenarios of climate change will be simulated.

The approach will be based in the adjusting of empirical yield and growth models, linking climate variables to the model's components. By integrating the outputs of exposition analysis and model adjusting, different scenarios of plausible futures of the Urbion region will be constructed. Finally, based on information collected of stakeholders, forest managers and experts, potential activities to implement in order to adapt forest management to alternatives scenarios of climate change will be generated. Field data collection, interviews, focal groups and workshops are the instruments selected to capture information.

Keywords: Climate change impacts; stand dynamics and forest management

POSTER CHAPTER

P5-08 Remote sensing of drought stress in *Pinus halepensis* planted forests for predicting mortality: A research strategy

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Global climate change impacts, such as mass tree mortality in forest ecosystems, are being observed with increased frequency worldwide. Development of physiologically-based models of tree mortality is essential for forest management due to logistic limitations in field measurements and manipulations. Drought-induced tree mortality is attributed to three main (non-exclusive) mechanisms: xylem cavitation, carbon deficits and biotic agents' effect. Isohydric species, such as many *Pinus* species, maintain relatively constant water potentials by sensitively regulating transpiration. It is hypothesized that carbon limitation is the principal mechanism of mortality due to drought in these trees.

Mortality of forest trees is difficult to predict. This is partly due to the gap of knowledge between the physiological and ecological points of view on the process, arising from its relative slow rate and rarity in space. Physiological responses of trees to drought stress can be measured in the field on small samples only, while continuous monitoring until mortality occurs is practically impossible. Consequently, the physiological data available on tree mortality is not readily related to the range of environmental variability experienced by trees in natural conditions. On the other hand, it would be very time consuming to combine extensive surveys of mortality in the field with measurement of accompanying physiological data, such as water stress degree, to better understand the physiological mechanisms of mortality. Remote sensing may be a useful method to address this issue, since currently it is the only method which allows obtaining meaningful data on vegetation physiology, while continuously monitoring large areas with high resolution in time and space.

Pinus halepensis is the most common tree species in the planted forests of Israel. Mortality of this species in unprecedented rates has been observed in many forests, following a series of dry years which started in 1998-99. We propose to combine remote sensing (vegetation indices related to the rate of photosynthetic activity, such as NDVI and NDWI) with ground measurements of growth and mortality rates, to investigate the mortality patterns of *P. halepensis* in Israel. Particularly, we intend to examine the link between long-term growth rate reduction and risk of mortality, in relation to the carbon deficit hypothesis. In the poster we will show preliminary results of spatio-temporal variation in vegetation indices in different forests along a climatic gradient as predicted from Landsat TM/ETM+ data and its relationship to tree mortality.

Keywords: Global Climate Change, NDVI, Landsat TM/ETM+

P5-09 Natural regeneration of P*inus halepensis* forests in semi-arid regions (Yatir Forest)

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Dryland afforestation is getting increased attention due to growing concerns of global climate change and desertification of drylands. Yatir Forest, the largest Israeli afforestation project, is located in the semi-arid region, at the physiological and ecological limits of its major species – the AleppoYatirForest was planted in the 1960's and has reached maturity. Cones and viable seeds were produced a few years after planting. However, very little if any regeneration of pines has been observed in Yatir. Natural renewal of the forest is one of the most important factors insuring its sustainability. Aleppo Pine is one of the most resistant and tolerant conifers. Still it is not yet clear whether the forest is capable of renewing itself despite the negative effects of drought, seed predation, inter and intra competition, and livestock grazing.

The general goal of the current research was to test the possibility that reproductive and establishment processes can be used to enhance natural renewal and achieve sustainability of the forest. We examined the potential seed production by *Pinus halepensis* trees and assessed germination and survival of young seedlings in the Yatir forest area, and compared this potential between different topographic aspects. In addition, various agrotechnical treatments (early planting, irrigation) that can help the seedlings establishment and survival were tested (using planted seedlings), as well as the effect of shading on root and shoot development of seedlings.

Monitoring and experiments showed that water availability is the main factor affecting natural regeneration in the Yatir forest. The dryness and the short rain period reduced seed production by the mature trees, probably reduce germination, and also cause seedlings collapse in late spring. In consequence forest thinning and grazing control will not be efficient enough for forest renewal without additional water to the seedlings.

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Keywords: Climate change, semi-arid region, afforestation, sustainability

P5-10 Plasticity of *Pinus sylvestris* root architecture and EcM colonisation in response to constant versus seasonal drought

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Phenotypic plasticity is regarded as a key mechanism for tree species adaptation to rapid environmental change, especially at the rear edge of pole ward shifting distribution ranges, where the capacity for genetic adaptation is low. Many studies have investigated how pines reduce aboveground water loss and increase water use efficiency of physiological processes in response to drought. Little is known however, on how pines adjust biomass partitioning between aboveground and belowground tissues under dry compared to wet conditions. Phenotypic plasticity of the root system may be especially important during the seedling stage, where even short-term drought events may reduce survival drastically. Moreover, pines obligately depend on the symbioses with ectomycorrhizal (EcM) fungi for successful seedling establishment and EcM species and drought can affect EcM colonisation and species composition, which may, in turn, affect the drought resistance of their hosts.
We compared allocation of *Pinus sylvestris* seedlings to aboveground and belowground biomass, root length and EcM colonisation in the organic vs. mineral soil layer under three different precipitation regimes simulated in a common garden experiment with mobile rain shelters located in the Central Alps, Switzerland. The precipitation regimes simulated a wet climate with 433 mm of water added from March-September, a constant dry climate with 218 mm, and a Mediterranean type climate with high rainfall during spring followed by a dry summer season.
P. sylvestris seedlings grown under both constant and seasonal drought had three times lower aboveground biomass than seedlings grown under wet conditions. Although root biomass also decreased under drought, seedlings invested disproportionately more biomass into the root system resulting in a higher root-shoot ratio. In both drought treatments, seedlings reduced root length in the organic soil layer by more than half compared to the wet treatment, but root length was constant across all treatments in the mineral soil layer. EcM colonisation was higher in the organic than the mineral soil layer but did not differ between precipitation regimes. The number of EcM species that colonised roots in different treatments and soil layers was proportional to root length. Under both constant and seasonal drought, seedlings increased resource uptake capacity by increasing the number of root tips per root length in both soil layers. By contrast, seedlings did not increase their cooperation with EcM fungi as indicated by constant mycorrhizal root tip density across treatments. Our results show that biomass allocation in response to drought is highly plastic in *P. sylvestris* seedlings, which may be beneficial for adaptation to increased frequency and duration of summer drought, as predicted for Europe under climate change.

Keywords: Climate change, phenotypic plasticiy, *Pinus sylvestris*, root architecture, summer drought

P5-11 Dendroclimatological analysis of climate change influence on Aleppo pine (*Pinus halepensis* Mill.) forests productivity in Tunisia

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The study of Aleppo pine (*Pinus halepensis*) reaction to interannual climate variations makes it possible to specify its ecology and to predict its future productivity in the context of climatic changes. This study focuses on sixteen *Pinus halepensis* populations in semi-arid and arid bioclimate in Tunisia. A tree ring chronology (width and wood density) for each population was measured using X-ray densitometric analysis. The response of each population to climate was statistically modelled using response functions.

The approach used in this work followed upon studies already undertaken on the reaction of the Mediterranean forest population following the total warming of the climate, involving growth models (response function) and Atmospheric General Circulation Model (AGCM).

The results of response function show that precipitation in October - May period have a positive effect on the radial growth and a negative effect on the wood density of *Pinus halepensis*. However, maximum temperatures in April and May have a negative effect on the radial growth and a positive effect on the wood density. The simulated growth following the atmospheric CO_2 doubling shows a strong reduction of the radial growth (between 7% and 100%) and an increase of wood density (between 3% and 13%). The populations located in southern limit of the forest in Tunisia react strongly to the CO_2 doubling; its radial growth reduction reaches 100% in the driest stations.

These results seem completely plausible since the future climate in Tunisia predicated by the ARPEGE AGCM will be drier and hotter than the current climate. The increasing evapotranspiration by the CO_2 doubling would induce a water stress higher than that induces by the current climate. The survival of the Aleppo pine in these areas would be then strongly threatened.

Keywords: Climatic change, atmospheric CO_2 increase, statistical Model, *Pinus halepensis*, Tunisia, Forest productivity, Dendroclimatology

P6-01 Low seed efficiency among individuals of the narrow ranged *Pinus nigra* ssp *mauretanica* in Algeria

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A study of seed efficiency has been carried out on 268 cones collected from 21 individuals of the narrow ranged *Pinus nigra* ssp *mauretanica* at Tigounatine which is part of Tikjda forest (Djurdjura southerner). The average number of cones sampled per tree is 13 ± 7.43
(range per tree: 4-38). Circumference of sampled trees averaged 169 ± 92 cm (range per tree: 48-348 cm).
Cone weight averaged 9.69 g; cone length 54.20 mm and cone diameter 25.68 mm with cone being two times longer than wider (ratio cone length/cone width averaging 2.12).
Total number of seeds/cone averaged 41.54 of which 16.25 rudimentary structures and 25.45 normal-sized seeds. Within this latter category we recorded 16.74 empty seeds and 8.62 filled seeds. Only 34.10% of normal-sized seeds were effectively filled.
Rudimentary structures, empty seeds and filled ones accounted respectively for 39.67%, 39.68% and 20.89% of the total number of seeds per cone. This indicates that seed yield per cone is lowered at a comparable rate by empty seeds and rudimentary structures resulting in seed efficiency as low as 20.89%.
Seed loss may have two sources: empty seeds which are likely to result from selfing and rudimentary structures which may result from inadequate pollination (due either to low pollen viability and/or to flowering asynchrony).
Among trees, seed efficiency ranged from a low of 2 to a high of 51%. Contribution of the two seed loss revealed different depending to trees : nine individuals showed comparable rates of seed loss owing to lack of pollination and selfing , seven showed a loss mainly due to selfing and five others a loss mainly due to lack of pollination. Trees fell in these categories independently of their circumference.
On trees from which high numbers of cones were collected, it appeared a certain level of within-tree heterogeneity in rate of seed loss. This leads to the hypothesis that within a given tree, there might be certain asynchrony among female cones for pollen receptivity even though a part of such within-tree heterogeneity might also be due to female cone position on branches.
For this very narrow ranged taxon not only there seem to be low pollination efficiency but also a relatively high level of selfing. Rate of seed loss owing to empty seeds provided by this present study is in agreement with previous findings on the same taxon from the same forest stand, while loss to rudimentary structures is considered for the first time.
Extending sampling to a larger number of individuals (with consideration of their rhythm of cone release) and sampling the same individuals for several years will help better understanding the reproductive strategies of this subspecies and will provide some decision support tools for the adequate way of seed collection in order to constitute a seed bank.

Keywords: *Pinus nigra* ssp *mauretanica*, Djurdjura, Algeria, seed number, seed efficiency, regeneration.

P6-02 Environmental factors effects on the production of cone and seed in Aleppo pine forests in Tunisia

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In Tunisia, the extensive rise in human use of Aleppo pine seeds constitutes the most and the main factor calling for better fructification of the species, additionally to the seed requirements for forest regeneration and predator sustenance. For the reason that fructification can be affected by various environmental factors, Tunisia's native Aleppo pine forests were investigated using 79 plots (40 x 25 m; 1,000 m^2) in order to study the species production of cones and seeds in the summer of 2006 under four bioclimatic zones and geographic gradients. These parameters, along with the sampled plots, stand characteristics and the average tree size measurements were submitted to simple and multiple regression analyses for explaining the variability in cone characteristics and the cone and seed yields per tree.

Results showed a positive correlation linking the cumulative rainfall, received in different bioclimatic zones 33 months prior, to the number of cones and seeds harvested from the sampled average tree. Similar useful effects were also obtained with latitude and altitude, causing in particular an increase of 23.1% in the total seed number per cone for every 100 km northward movement, and a 5.4% increase in the average cone weight for each 100 m altitudinal increase. However, longitude was the most significant geographical variable, and it's most distinct effect was due to a severe reduction of 29.9 and 41.8% in respectively the weight of the cone and its seed mass for each 100 km displacement towards the East.

Stand density had a strong adverse effect on the average tree's cone crop and seed yield, whereas basal area was positively linked to both variables. Density and basal area were regularly significant as explanatory parameters under multiple regression analyses. The cone crop and the total seed mass were positively correlated with all tree size measurements, but DBH and crown height were the most determinant variables.

Keywords: Aleppo pine, bioclimatic zone, geographic gradients, stand characteristics, tree size, cone crop, seed yield.

pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia
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P6-03 Influence of high temperatures on germination of *Pinus pinea* seeds of three provenances

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Fire is an important ecological factor in the Mediterranean forest ecosystems, and conifers are obligate seeders after fire.

Seeds of *Pinus pinea* were heated to a range of temperatures similar to those registered on surface soil during natural fires (from 125 to 200°C) and exposure times (from 1 to 3 min). To exanimate the effect of seed origin, three provenances were studied.

Temperatures above 175°C have a negative effect on the germination of all provenances. The increase in temperature and, of course, the longer exposure, generally decrease germination percentages

Keywords: *Pinus pinea*; germination; heat; fire

P6-04 Evaluation of the straightening ability in *Pinus pinaster* Ait. progenies

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Pinus pinaster Ait. is the conifer which major volume of wood is obtained in Spain. In this pine species the quality of the wood is low due to the lack of stem straightness. In addition, stem flexuosity produces an increase in the costs of transport and manufacturing of the row material. Recently, an alternative method for early selection of the stem straightness has been proposed, based on the efficiency of reaction wood in the stem straightening process instead of the evaluation of stem form (Sierra de Grado *et al*., 2008).

Biomechanical analysis showed in artificially tilted seedlings that differences in the secondary gravitropic and autotropic reactions in the stem straightening process are related to differences among provenances characterized by different straightness. We studied the variability among progenies in the gravitropic and autotropic reactions, and the efficiency of compression wood in the stem straightening process, following the same method.

Plants from thirty eight *Pinus pinaster* Ait. progenies from the Norwest Interior provenance and six different provenances commercial seeds controls were used. The progenies were phenotypically selected by Tragsa Company in Galicia (Norwest of Spain). When the plants were one year old, they were artificially tilted at 45°.

The kinetic study of the stem form changes (angles of deviation from the horizontal) were measured based on photographs taken during a 6-month period after tilting. Subsequently, compression wood was analyzed in four stem cross sections per plant. The compression wood efficiency in the straightening process (α parameter) was calculated with Fournier's biomechanical model (1994). Finally heritability of the studied variables was calculated.

Our results were used to make a Norwest Interior progenies ranking according to the compression wood efficiency and the secondary gravitropic movements that can be used for the early selection of progenies from the provenance mentioned before.

Keywords: *Pinus pinaster*, straightness, gravitropism, biomechanical process, early selection, genetics and breeding.

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Pinus pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia
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P6-05 Drought tolerance of inter-provenance hybrids of *Pinus pinaster*

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The study of phenotypic plasticity of forest tree species to water availability and drought has become a very relevant issue to understand how forests will be able to adapt to rapid climate changes in Mediterranean areas. Maritime pine populations are known to largely vary in their tolerance to drought. In Galicia (NW Spain), maritime pine occurs both in the Coast under favourable Atlantic climatic conditions and in the interior region where the Mediterranean influence led to intense summer droughts and large intra-annual temperature oscillation.

Within the frame of the Galician *Pinus pinaster* breeding program, inter-population hybrids between Coastal improved materials and drought-tolerant populations were generated to provide new breeding materials better adapted to the extreme environmental conditions of the Interior area of Galicia. The aim of the present study is to explore the variability in drought tolerance between these synthetic hybrids and the respective parental populations.

One year old cuttings of hybrids between selected genotypes of the Galicia-Coast breeding population and Galicia-Interior, Corcega, Soria-Burgos and Landas provenances and their respective natural populations were grown in the greenhouse under two watering regimes (well-watered and drought). Biomass partitioning and morphology of the root system were analyzed six months after starting treatment.

The watering regime did not affect the architecture of the root system, neither the proportion of fine roots, but seedlings grown under drought conditions were smaller, showed increased allocation of biomass to needles, and tend to have less coarse roots. On the other hand, survival and biomass allocation patterns significantly differ among the studied populations, with hybrids showing intermediate values regarding the parental populations.

We discuss how these resource allocation patterns may be part of drought tolerance strategies, how these strategies are inherited when two contrasting origins are crossed, and whether synthetic hybrids can be useful to achieve new base material within the Galician breeding program.

Keywords: Genetics and breeding, inter-population hybrids, drought tolerance, dry matter allocation, *Pinus pinaster*

P6-06 Conserving *Pinus nigra salzmanni*, a rare black pine from the western Mediterranean threatened by wildfires and genetic pollution

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Salzmann pine, *Pinus nigra salzmanni* (Dunal) Franco, is one of the rarest and most threatened forest trees in France. For this reason, its habitat is included in the European Union Habitats Directive. Although this remarkable tree covers extensive areas in Spain, it is threatened in its French natural habitat of the Pyrenees and the Cevennes for two main reasons.

First, its distribution area is made of relatively small stands which cover no more than 5,000 ha in zones of high wildfire incidence. Second, these stands are included in a large network of artificial stands reforested using Corsican black pine (*Pinus nigra laricio*) and Austrian black pine (*P. nigra austriaca*), two subspecies that are thought to hybridize with the native Salzmann black pine. As this pine is reputed the most drought resistant of all black pines, conserving this resource may also prove useful under climate change.

In this presentation, after briefly describing the taxonomy, the ecology and the evolutionary history of the *Pinus nigra* species complex, we detail the (in-situ and ex-situ) strategy used to conserve and use this patrimonial species in an ambitious program associating managers and scientists.

By making sure that our sample collection only includes autochthonous individuals (individuals over 150 years old, predating the first major reforestations of the 1860s), we demonstrate how genetic diversity was structured prior to major human disturbances and which were the populations of highest interest both for conservation and use. Using this sampling strategy and classical grafting techniques, we constitute the first ex-situ collection for the conservation of *Pinus nigra salzmanni*.

Keywords: *Pinus nigra salzmanni*, genetic resource conservation, autochthony, hybridization, differentiation

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P6-07 Variability between provenances of *Pinus pinaster* Ait in the architecture of roots and its response to inclination

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Considering the wide variability that the species *Pinus pinaster* Ait offers in practically all morphological and adaptive characters that have been studied, it doesn't seem risky to suppose that there exists a natural variability in the capacity of generating roots with different effects over anchorage. This variability might be related to the straightness of the different provenances as the trees can be under wind, snow conditions, etc that produce oscillations and risks of "toppling".

In this study we have analyzed potential differences between provenances through morphological and mechanical responses of roots in the presence of artificial plant inclination.

Ten provenances were chosen to cover the whole range of straightness variation. Seeds from the ten provenances were sown in containers (28 l). The slope trial consisted of ten randomized complete blocks with a seedling in container per provenance and block. In the spring of the second growing season, the containers tilted 45° down to the South, keeping in that position for four months. At the end of this season, seedlings were gradually taken out in order to analyze diameters at different depths as well as the number of roots per sectors (North, South, East, West) and the biomass either in tap and branch roots.

Results obtained show that there are significant differences between the diameters of the different provenances. Nevertheless, no relationship has been noticed between these diameters and the straightness that characterizes each provenance. Regarding the number of branch roots and the biomass no relevant differences were observed either by sectors or provenances.

Keywords: toppling, stability, anchorage, root architecture, plant morphology

P6-08 Estimation of variability and genetic parameters of adaptive traits in *Pinus brutia* from a half-sib progeny test: consequences for natural or breeding populations

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Covering 4 millions ha mainly in Turkey, *Pinus brutia* Ten. plays a major role in low to middle elevation eastern Mediterranean forests where natural or planted stands are of main ecological and economical importance. Although a large variability was observed among origins (provenances), the species is known to be more susceptible to drought than *Pinus halepensis* but more tolerant to low temperature and produces better quality stems. *P. brutia* ecological characteristics make it a good candidate for afforestation in inland Mediterranean regions. In the climate change context it is one of the promising candidates for species enrichment or substitution in temperate forests suffering from summer drought, in order to ensure forest stand sustainability.

In the last 35 years, national or international provenance *P. brutia* and *P. halepensis* tests were planted around the Mediterranean basin in order to estimate the adaptive diversity of theses species. More recently the estimation of the within provenance diversity and of the genetic control of main traits were address through progeny trials (Isik *et al*., 1999; Gülcü and Çelik, 2009).

We present here the first results of a 10 years-old *P. brutia* half-sib progeny trial planted in south of France near Montélimar (450 m asl , rainfall 900 mm). The experiment was settled within the FORADAPT INCO project (Plomion and Pichot, 2001) using seeds collected from three Turkish stands (500; 1,100 and 1,270 m asl). A similar experiment was established in Tunisia. Eighty-eight *P. brutia* families, and one *P. halepensis* provenance as control, were distributed over fifty seven incomplete blocks of sixty four individuals. Survival, growth in height and diameter, and cone production were measured. Significant differences among stands and among families within stands are observed and genetic parameters (heritability and correlation) are estimated from family variances.
These field test results are also compared to the analysis of seed germination in water stress conditions (PEG test) and to seedling height growth in nursery.

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Keywords: *Pinus brutia*, adaptation, common garden, progeny, survival, growth, reproduction, heritability

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pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia
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P6-09 Phenotypic and genetic sources of variability of cavitation resistance in *Pinus canariensis*

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In Mediterranean ecosystems, water shortage is the main factor constraining survival and growth of plants. Xylem hydraulic properties are a key factor for the general function of plants as they exert a strong influence on water transport and therefore on the potential for carbon uptake. Resistance to cavitation has been considered a major character involved in drought tolerance. However, variation in cavitation vulnerability could be accompanied by a trade-off with other water transport and physiological traits. We investigated stem xylem vulnerability to cavitation in *Pinus canariensis*, the only endemic pine of the Canary Islands (Spain). We used the 'Cavitron' technique (Cochard 2002; Cochard *et al*. 2005) to construct xylem vulnerability curves.

To assess genetic and environmental effects on vulnerability to cavitation, the xylem water pressure causing 50% loss of hydraulic conductivity (P_{50}) was measured in plants from eight contrasted ecological regions covering, the whole ecological range of the species, at a dry site (approx. 300 mm per year) and a wetter site (800 mm per year). Relationships with other plant traits (survival, ontogeny, growth) and with some environmental parameters were also examined.

We found a strong influence of the site of plantation on the vulnerability to cavitation, in the wet site P_{50} varied between -3.1 MPa and -4.6 MPa whereas in the dry site the highest values exceeded -6 MPa. All populations were plastic for this trait, showering lower P_{50} in the dry site. In contrast to survival, vulnerability to cavitation was not clearly related with the conditions of origin and unexpectedly some populations from favourable environments showed some of the lowest values of P_{50}. Growth traits also presented a high phenotypic plasticity but scarce differentiation among populations.
All this results are discussed on the framework of ecotypic differentiation and drought-tolerance of the species.

Keywords: Ecophysiology, Genetics and Breeding, *Pinus canariensis*, Cavitation resistance, Drought tolerance, Phenotypic plasticity

P6-10 Genetic variation in cone and seed traits in a black pine (*Pinus nigra* Arn.) clonal seed orchard

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Black pine *Pinus nigra* (Arn.) is a prominent Mediterranean pine with great ecological and economic importance. Thus, the need for genetically improved material for reforestation purposes in Northern Greece led to the establishment of a clonal seed orchard at Taxiarchis, Chalkidiki peninsula, Greece. The seed orchard was established in 1980 following a honeycomb experimental design in order to avoid kinship.

The orchard consists of sixty plus-trees originating from five geographic areas in Northern Greece, while each clone is represented by nineteen ramets. Fifteen cone and seed traits of black pine were recorded for two successive years (2009-2010) to assess the extent of clonal genetic variation. The following traits were evaluated: cone length, width, length to the widest point, volume, number of cone scales, prickle-like cone scale apophysis; seed length, width and thickness; wing length and width; number of seeds per cone, weight of one thousand seeds, percentage of full seeds.

The results obtained indicate the existence of ample genetic variation among clones for all the cone and seed traits studied. Significant differences among clones were detected for almost all traits. Clones that yielded the highest number of seeds per cone, the heavier seeds and exhibited the higher percentage of sound seed were identified. Clonal heritability estimates were moderate to high for almost all the traits studied, indicating increased selection efficiency. Also, the significant correlation coefficients recorded in among traits, indicated efficiency of indirect selection. The clonal variation detected for all traits, together with the clonal heritability and correlation coefficient estimates denote the potential of selection for further improvement of the seed crop quantity and quality.

Therefore, cone and seed traits should be considered when managing clonal seed orchards of black pine.

Keywords: Breeding, heritability, clonal differentiation, selection, seed orchard management

POSTER CHAPTER

P6-11 Determining the optimal stock-type of containerized pine species for forest restoration in dry Mediterranean areas

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Seedling quality and nursery practices have been intensively studied for the Mediterranean pine species in the last years. Nowadays, we have a good knowledge about the best morphological and physiological features of the seedlings and the nursery practices needed to ensure the maximum survival and growth in forest restoration of dry Mediterranean areas. However, the economic costs of producing different plant stock-types and its relationship with post-planting performance has not been considered in those studies. This economic relationship can change depending on site conditions and post-planting cares like weeding. We hypothesized that increasing stock-type size will increase survival and absolute growth after four years, and the money investment for producing larger stock-type will be returned by decreasing mortality and increasing tree cover.

We produced eleven different stock-types of *Pinus halepensis* and *Pinus pinea* by combining four different container capacities (150; 300; 650 and 1,000 cm^3) and three fertilization regimes (medium, high, and high plus autumn fertilization). The production, transport and planting costs of each stock-type were evaluated. A sample of 40 seedlings of each *Pinus halepensis* stock-type was planted on each of two sites differing in site conditions (a semi-arid degraded land and a more humid abandoned agricultural land). The performance of the *Pinus pinea* stock-types was tested against two different weeding treatments (weeding during the first two years and during the first three years) in a an agricultural abandoned land. We measured survival and growth four years after planting, and the cost of 1,000 living seedlings and 1 dm^3 of stem volume after four years.

As expected, container capacity was determined mostly the pre-planting morphology, production costs and post-planting growth of the different stock-types. Survival was generally lower in the seedlings raised in the smallest container, but no differences were found between the others in spite of the large morphological range obtained. Fertilization also increased seedling biomass, especially the above-ground biomass. Autumn fertilization increased *Pinus halepensis* biomass, but not in *Pinus pinea*. Fertilization also increased seedling survival and growth. The positive effect of fertilization on survival was higher in the *Pinus halepensis* seedlings raised in the smallest containers and planted in the harshest site. In general, fall fertilization treatment also increased post-planting growth respect to the high fertilization treatment. The costs of 1,000 living seedlings were lowest in the stock-type with the small and medium capacities (150 and 300 cm^3) and the highest fertilization level (high plus autumn fertilization). However, the cost of producing 1 dm^3 of stem volume was minimized when planting 300 cm^3 with the highest fertilization level. The positive effect of increasing seedling size did not counterbalance the negative effect of decreasing weeding duration, so it must be optimal regardless of the stock-type used.

These results confirms the positive relationships between seedling size and post-planting performance for Mediterranean pine species found in previous studies, but establish an operational limit to the increasing size. Seedlings produced in medium capacity containers (300 cm^3) with high fertilization levels, including fall fertilization, optimize the balance between planting costs and post-planting performance

Keywords: Seedling quality; optimal stock-type; *Pinus pinea*; *Pinus halepensis*

P6-12 Mediterranean conifer genetic field trials: data management and valorisation through the ForSilvaMed database

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During the last 40 years a large number of forest tree field trials (common garden) were established around the Mediterranean basin in order to evaluate among/within species genetic diversity and to select well adapted seed sources for afforestation. Because very few information about this experimental networks was available, an international concerted action was launched in 2002 by Silva Mediterranea for an updated survey of the Mediterranean conifer field trials. As a prerequisite for future international synthesis, the 'ForSilvaMed' database was initiated in 2007 taking advantage from a previous action developed within the INCO-DC 'Foradapt' project.
The database is managed and hosted by INRA in Avignon, France
(http://www.avignon.inra.fr/ForSilvaMed).
It aims at gathering the main characteristics of the plant material and of the field trials installed all over the Mediterranean.

Data provided using dedicated forms by the Mediterranean partners, are checked and integrated in the database. In January 2011, 1,043 genetic entries (mainly provenances) from twelve species and 148 field trials from seven countries were registered. Two thirds of this material belongs to the Aleppo-brutia complex or to *Pinus pinaster*. Information can be retrieved through the database web interface that allows interactive querying on plant material or on field trials.
Query results are presented in tables. A mapping service using Google maps facilities was also added. It allows plotting the origin of the material tested and the location of the field trials. Some data have still to be collected but most of the future work will be devoted to the validation and the merging of plant material data across-partners.
For each coniferous species or species complex, the available data sets from the measurements of the main (adaptive) traits such as survival, growth or phenology, will then be collected in order to achieve the international synthesis.
The availability of centralised and updated information about the Mediterranean conifer genetic field trials will undoubtedly stimulate the emergence of new international cooperation and research projects on genetic diversity and adaptation of Mediterranean forests

Keywords: Mediterranean conifers; database; common garden; adaptive trait; provenance

pinaster
Pinus pinea
Pinus nigra
Pinus halepensis
Pinus brutia
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P6-13 Provenances variation in *Pinus pinaster* at two sites in Morocco

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Forty seven provenances of *Pinus pinaster* from Morocco (seventeen), France (thirteen), Portugal (two), Spain (eight), Italy (six) and Tunisia (one) representing the natural distribution of the species, were tested on two sites in Morocco.

Data of the 17th year of tree height, diameter, survival and increment showed a significant differences in growth with varying results per site, except for Leiria (Portugal) and Galicia (Spain) ranking high in two sites. Survival differences were also identified.

The analysis for forty common provenances to the two sites showed significant site-provenance interactions. Some of the Atlantic provenances, especially the one from Portugal grow better on the sandy soil.

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Keywords: *Pinus pinaster,* provenances,variation, Morocco; genetics and breeding.

P6-14 The Yatir Aleppo pine forest

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This presentation partly summarizes results of research projects conducted in the Aleppo pine forest at Yatir, located at the northern edge of the Israeli Negev dessert, under semi-arid climate (~ 283 mm yr^{-1} average annual rainfall during 1964/5 to 2009-10).

Results gained from a provenance trial within the Yatir forest show that to improve sustainability of Aleppo pine plantations to be planted in semi-arid environments, with high probabilities to become even more drier, prospective seed sources (provenances) must be selected for higher heterozygosity, drought resistance and water use efficiency.

Harsh site conditions at the dessert edge provide an opportunity to exert heavy selection pressure among and within provenances of *a priori* drought tolerant species. The survivors should be used as the seed source for new plantations aimed at combating desertification.

In order to provide a sound scientific basis for stocking density recommendations in non-commercial forests, an improved understanding of the eco-physiology of Aleppo pine in dry regions is needed. A crucial component of that understanding is the relationship between climatic variables, soil conditions and transpiration.

As a broad conceptual framework, let us assume that soil moisture is a resource that can be shared among neighbouring trees. This means that there is a close relationship between stand density and water availability per tree. Let T_{min} be the minimum seasonal transpiration required for "healthy survival", i.e., not being weakened to the point of being susceptible to pests and diseases, or suffering carbon starvation.

The maximum sustainable tree density (D_{max}) can then be estimated as:

$$D_{max} = (R_{min} - I - E - D_p) / T_{min}$$

were R_{min} is the minimum rainfall level for which it is deemed necessary to plant; I is the amount of rainfall (at P_{min}) intercepted by the forest canopy and lost to evaporation; E is the amount of moisture lost from soil and understory vegetation by evapotranspiration (at R_{min}), and D_p is the amount of moisture lost to deep percolation (at R_{min}). It is fair to assume that there is an upper limit to the capacity of a tree to extend its root system laterally and horizontally. If D_i is the tree density below which further thinning will not increase water availability, the forest is not sustainable if $D_{max} < D_i$.

Measurements of the daily courses of ambient meteorological parameters above the forest canopy and ecosystem evapotranspiration (ET); ecosystem evaporation (E), pine forest transpiration (T_{canopy}) and soil water content (SWC) where done during the hydrological years (1 October to 31 September) 2003-2004, 2004-2005 and 2005-2006.

The sum of annual T_{canopy} was 134 mm yr^{-1} by 300 trees per hectare during the dry year 2005-2006 (rainfall of 224 mm yr^{-1}) enables the estimation of the average T_{min} annual rate, which amounted to 4.5 mm yr^{-1} or 4,500 l yr^{-1} per tree.

By using the equation where R_{min} = 200 mm, I = ~25 mm, E = ~68 mm, D_p = 0, and T_{min} = 4.5 mm; then D_{max} = 230 trees per hectare.

These results point to the necessity to further reduce the stock density to enable the sustainability of the forest under reduced annual rainfall amounts.

Keywords: Provenances, Drought resistance, Ecosystem water balance, Forest sustainability

P6-15 Fragmentation and connectivity in Iberian pines: testing multiple hypotheses

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One of the problems in contemporary ecology and conservation biology is the change of landscapes induced by anthropogenic activities, resulting in habitat loss and fragmentation. Understanding the influence of habitat alteration on population structure and persistence, and the potential of changes in connectivity to impact populations in heterogeneous landscapes has led to increasing interest in connectivity and connectivity measures. Maintaining and restoring connectivity among habitat patches is recognized as an important goal for the conservation of populations.

For many species, local extinctions of fragmented populations are common, question regional survival and threat the species on a larger scale, particularly in the light of the climate change. We studied the influence of connectivity and fragmentation in pine trees by examining the correlation with the genetic structure of the populations. While most studies only explore these effects on a small scale, in this study we examine how environmental (habitat suitability, barriers, cover), population (population size, fragmentation), anthropogenic (land use change, fires) and historical factors (post-glacial recolonisation and phylogeny) influenced the present genetic diversity and differentiation in native Iberian pines across Spain.

Native populations of six species (*Pinus halepensis, P. nigra, P. pinaster, P. pinea, P. sylvestris* and *P. uncinata*) with different life histories were sampled over their distribution range in Spain and characterised for four common chloroplast microsatellite loci. We calculated genetic diversity within populations (Na, Ne, Nh, Nhe) and genetic differentiation between populations (Fst, Rst, D). We created a model where the species distribution and all the variables were rasterised to a 10 x 10 km and 50 x 50 km cell size. By assigning each variable a friction value and each variable group different weights, we quantified the variables and threats influencing the connectivity for each cell and by cost surface analysis we calculated least-cost paths between populations and correlated them to the genetic parameters.

The friction values and weights were altered to form different scenarios. The model outputs identify the factors which influence gene flow between pine populations in Spain and provide means of targeting conservation efforts.

Keywords: genetics and breeding, conservation

P6-16 Genetic variation of insular and continental natural Aleppo pine (*P. halepensis* Mill.) populations in Greece

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We investigated five natural insular and continental *P. halepensis* populations in Greece. Despite some long distance pollen transfer, insular populations are in theory genetically more isolated than continental ones, which in conjunction to restricted effective population size, may introduce stochastic events and affect the extend and structure of genetic variation.
We tested this hypothesis by sampling:
(a) a continental population,
(b) three independent populations from an insular environment of a "large" island and
(c) an insular population through range-wide population sampling from a "small" island.

A total of 162 trees were sampled from populations: Kassandra (Chalkidiki - continental), Istiaea, Limni, Kirinthos (all of Euboea island) and Zakinthos (Zakinthos island). Genetic variation was assessed based on codominant fully expressed nuclear genetic markers (isoenzymes).
Ten loci were employed: Gdh-1, G6Pd-1, Idh-1, Lap-1, Mdh-1, Mdh-4, Mdr-1, 6Pgd-1, 6Pgd-2 and Pgi-2. We employed a series of analytical approaches to investigate population genetic diversity, divergence and structure.
A series of genetic diversity parameters such as allelic richness (AR), percentage of polymorphic loci (P), effective numbers of alleles (ne), heterozygosity (H) and Shannon's diversity index (I), were estimated in order to assess within population genetic diversity. In addition, conformance to Hardy–Weinberg equilibrium was determined by means of different tests. Genetic divergence between populations was assessed by gene differentiation coefficients and the estimation of genetic distances. Population relationships were also investigated through multivariate techniques and a model-based Bayesian clustering method.
Furthermore, we estimated gene flow and investigated genetic drift and population bottlenecks. A comparative analysis of populations or population groups was used for hypothesis testing. Potential effects of forest management were also considered. Discussion focuses on the genetic diversity of the studied populations compared to the genetic diversity of the species in general and on the need for genetic conservation and proper management in order to ensure their adaptive potential.

Keywords: genetics, P. halepensis, insular - continental populations, gene conservation

pinaster
Pinus nigra
Pinus pinea
Pinus halepensis
Pinus brutia
177

P6-17 A high saturated genetic linkage map of *Pinus pinaster* based on AFLPs, ESTs, SSRs and SNPs

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Plant genomics aims to understand how genes function in plants and how plant genomes evolved. Genomic mapping is a means to understand the dissection of complex traits and to facilitate the development of comparative genomics. In the last years some saturated genetics linkage maps of *P. pinaster* have been developed using protein markers, Random Amplified Fragment Length Polymorphisms (RAPDs) (Plomion *et al*. 1995), Expressed Sequence Tags (ESTs), nuclear Single Simple Repeats (nSSR) and Amplified Fragment Length Polymorphisms (AFLPs) (Ritter *et al*. 2002). Recently the high throughput genotyping techniques based on Single Nucleotide Polymorphism (SNPs) provide hundreds of molecular markers from genes of interest easy to incorporate to genetic linkage maps.

We constructed a genetic linkage map for each of the parents (C14 and C15) using two F1 segregating progenies obtained by control crosses (C14xC15; C15xC14), based on AFLPs, ESTs, nSSR and SNPs. SNPs were genotyped with two Illumina bead arrays: 384 Vera Code and 1536 Golden Gate. Three genetic linkage maps for each parent were constructed: C14xC15 (106 individuals), C15xC14 (55 individuals) and a third map pooling all individuals. We used JoinMap for mapping process. Departure from homogeneity of recombination rate between female and male meiosis were tested by marker interval using a likelihood-based method. We are performing a comparative analysis of linkage groups based on SNPs, ESTs and SSRs common with those from already existing maps for the species
There was consistency of linkage groups between the three developed maps for each parent. However we found heterogeneity of recombination in male versus female meiosis for several marker pairs as reported in Plomion & O'Malley (1996). Thus, pooled map should be viewed cautiously. For pooled map 115 Framework markers (mean distance between them of 10.75 cM) and 150 accessory markers were mapped in 15 (C14) and 13 (C15) linkage groups with a LOD threshold equal to 3.

Detailed genetic maps are crucial to the understanding of genetic variation, especially for organisms without reference genome sequences. Insights into the comparative genome mapping are decisive to move towards the construction of a reliable consensus linkage map of *P. pinaster.*

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Pine and Insects Interaction

P7-01 Effect of the pine wood nematode, *Bursaphelenchus xylophilus*, on the flammability and the moisture content of *Pinus pinaster* wood

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The Pine Wood Nematode (PWN), *Bursaphelenchus xylophilus* is one of the most serious threats to pine forests worldwide. In 1999, the PWN was reported for the first time in Portugal and in Europe, south-east of Lisbon (Setúbal Peninsula), associated with dead trees of maritime pine, *Pinus pinaster Ait*. After the detection, this nematode has spread quickly to the Central Region of Portugal and in 2008 all continental Portugal was declared as affected area. More recently, in 2009, it was also detected in Spain and in Madeira Island. The migration of the nematodes through resin canals and feeding on parenchyma cells cause the formation of cavitation, plugging of tracheids, and decrease of xylem water contents. They induce quick metabolic changes in ray parenchyma cells in cavitation areas, denaturation and necrosis of parenchyma and cambial cells. The negative impact of PWN, referred in different studies, is usually related to the annual loss of pine timber and restrictions on the import of raw softwood. However, the total negative impact of this nematode is more complex and involves different environmental aspects. Pine trees after PWN infection can die in a few months, increasing the percentage of accumulated dead fuel and creating more favourable conditions for fire propagation.

The objective of this research is to understand how anatomic and biochemical changes of wood due to the presence of PWN (i.e., reduction or cessation of oleoresin flow) affect the flammability and the moisture content/relative humidity equilibrium of the *P. pinaster* wood. Therefore, diverse fuel complexes were analyzed: PWN infected fuel; non-infected fuel and fuel dead due to some other reasons. The fuel flammability was assessed from two perspectives: fuel moisture content and stage of PWN infection. The flammability was determined by cone calorimeter and the moisture content/relative humidity equilibrium using a climatic chamber.

Keywords: Diseases, Fire sciences, pine wood nematode, pine wilt disease, fire behaviour, flammability of *Pinus pinaster* wood, moisture content/relative humidity equilibrium

P7-02 Genetic analysis by ITS RFLP and sequencing of Pine Wood Nematode, *Bursaphelenchus xylophilus*, isolates from Portugal

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The Pine Wood Nematode (PWN), *Bursaphelenchus xylophilus*, the causal agent of the Pine Wilt Disease (PWD) is a native species from North America that has been carried to Japan and then spread into China, Korea and Taiwan. In 1999, the PWN was reported for the first time in Continental Portugal and in Europe associated with maritime pine, *Pinus pinaster*. More recently, in 2009, it was detected in Spain and in Madeira Island.

Bursaphelenchus xylophilus isolates from Portugal were morphologically characterised and both males and females presented the species specific morphological characters: males with spicules flattened into a disc-like structure, cucullus, at the distal end; and the females with a vulval flap and tail terminus rounded, digitated or with a mucro. These PWN isolates were analysed molecularly by PCR ITS-RFLP using six restriction endonucleases.

The restriction patterns obtained with the enzymes *Alu*I, *Hae*III, *Hinf*I, *Msp*I and *Rsa*I were identical to restriction patterns detected in PWN isolates from other parts of the world and described as specific for this species. The restriction pattern with the restriction endonuclease *Hha*I was identical to the pattern described for virulent PWN isolates.

In order to perform phylogenetic studies and to evaluate the genetic diversity of PWN isolates from Portugal and from other parts of the world, rDNA ITS regions were sequenced. All sequenced isolates were clearly identified as members of the *B. xylophilus* species and no genetic diversity was found for this genomic region between seventeen Portuguese PWN isolates (Madeira Island and Continental Portugal). Furthermore, phylogenetic analysis revealed that Portuguese PWN grouped with PWN isolates from China, Korea and some isolates from Japan. PWN isolates from USA and Canada were positioned in a different clade. Phylogenetic studies are being extended using other PWN genomic regions in order to better understand the origin and spread of this species in Portugal and worldwide.

Keywords: Diseases; ITS; phylogeny; Pine Wood Nematode; Portugal

P7-03 Strong Phylogeographic pattern in the pine cone weevil: the relative contributions of vicariance versus evolutionary histories of pine hosts

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While many phytophagous insects are geographically structured, local adaptation and host-plant fidelity were proved to play a significant role in genetic isolation between populations. In order to unravel the respective role of geography or host tree in shaping the population genetic structure of *Pissodes validirostris* populations, we conducted a phylogeographic study in the whole geographical and host ranges of the insect using mitochondrial and nuclear markers.

Whereas all but one species of *Pissodes* feed on the cambium and phloem of Pinaceae, *Pissodes validirostris* is the unique species feeding on the seed cones of *Pinus*. *P. validirostris* has a wide Peleartic distribution from Portugal and Scandinavia to north eastern China and has been recorded as a minor pest attacking pine species belonging to the *sylvestris* section (*Pinus sylvestris* L., *Pinus mugo* Turra, *Pinus uncinata* Mill., *Pinus nigra* Arnold and *Pinus leucodermis* Antoine), as well as mediterranean pines such as *Pinus pinaster* Aiton, *Pinus halepensis* Mill. and *Pinus pinea* L., and some North American pines that have been introduced to Europe (*Pinus contorta* Doug. Ex. Loud). The larval development of *P. validirostris* occurs fully and only in cones and seeds of *Pinus* and the whole life cycle occurs in the same host species.

In a previous taxonomic study using mitochondrial and nuclear DNA and morphometrical measures, we revealed that *P. validirostris* probably incorporates discrete taxa, or at least three independent evolutionary lineages. No haplotype was shared between the lineages, which suggest the absence of gene flow between these three groups.

The separation between the three *P. validirostris* lineages seems to be of fairly recent Pleistocene origin. Allopatric fragmentation and colonization routes from distinct refugia during the post-glacial period may explain the present structuration of *P. validirostris* populations. However, given the geographically distributed pine species, it is difficult to unequivocally statue which of the geography or the host-species is the main structuring factor.

Several factors are favourable to local adaptation of *P. validirostris* to its hosts:
1) the high number of host species with a narrow patchy range in some localities;
2) the great variability in environmental conditions within the whole geographical distribution; and
3) a low dispersal rate and the high longevity (up to 3 years) of the weevil adults.

Owing to their life-history and behaviour, one could expected that *P. validirostris* populations probably closely tracked the distribution of their hosts, and thus constitute an appropriate model to study the post-glacial expansion routes and last glacial refugia of both the insect and its associated host pines, especially *Pinus sylvestris*, *P. halepensis* and *P. pinaster*.

Keywords: Phylogeography, cone weevil, Pinus, mtDNA, local adaptation, glacial refugia

P7-04 Quaternary history of the pine processionary moth

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The pine processionary moth, _Thaumetopoea pityocampa_, belongs to a circum-Mediterranean species complex associated to pine and cedar species. In recent years, it has expanded to upper latitudes or elevations in several European countries due to increased winter temperatures. This rapid response to current climatic changes due to its cold sensitivity suggests that its past distribution is likely to have been strongly affected by Pleistocene climate changes. In general, thermophilic species have expanded during warm periods and responded to cold phases by local extinctions in northern and mountainous regions, while arctic and alpine species exhibit opposite responses. However, there is increasing evidence of more complex patterns of response, because many species have intermediate ecological requirements or habitat-generalist traits. A fragment of the mitochondrial cytochrome c oxidase subunit I gene was used to investigate the Quaternary history of the pine processionary moth, whose range is constrained by both cold winter and high summer temperatures. In Western Europe, we identified four genetic lineages that are strongly geographically structured, but surprisingly they are not isolated by the unsuitable high elevation areas of the main mountain ranges. The mountainous areas from the Betic Chain to the eastern Pyrenees (and maybe up to the Massif Central and the Alps) appear to have offered suitable environmental conditions along the slopes during the ice ages, and the current distribution reflects expansion from these bottlenecked refugial populations. _P. sylvestris_ and particularly _Pinus nigra_ are the preferred host plants and they probably persisted in all the glacial refugia of this insect. However, the different contributions of the identified refugia to post-glacial expansion might be explained by differences in host plant species richness. For example, a lineage restricted to the Pyrenean range did not contribute to the northward post-glacial colonization contrary to an Iberian lineage with a more southern origin. _P. nigra_ and _P. sylvestris_ were probably the main continuously available hosts in the eastern Pyrenees, while _P. pinaster_ was also probably present and abundant in the eastern Iberian Chain. Consequently, the Pyrenean lineage of the pine processionary moth could have been trapped elevationally by tracking mountain pines, while the eastern Iberian lineage could have expanded latitudinally by tracking thermophilic lowland pine species. Interestingly, the expansion pathway from eastern Spain to southwestern France corresponds to one of the migration routes suggested for _P. pinaster_, which would be consistent with the moth following the migration route of one of its hosts. Rather than showing that mountains acted as physical barriers to dispersal, our results suggest that topography played a major role in shaping the distribution of maternal lineages through the demographic history of its main host plants.

**Keywords:** Pine processionary moth, Black pine, Scots pine, Maritime pine, mitochondrial DNA, glacial refugia, range expansion, vertical migration, mountainous area, Western Europe

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POSTER CHAPTER

P7-05 The pinewood nematode: a major invasive pest of European pine forests

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The pinewood nematode (PWN), *Bursaphelenchus xylophilus*, is responsible for pine wilt disease (PWD), a serious disease of forest tree species, in particular among the genus *Pinus*. It has been designated as a quarantine species in Europe (Directive 77/93 EEC). The first external symptoms are the yellowing and wilting of the needles, leading to death of the tree in case of heavy attack. The nematode is native to North America, but this species is not considered as a primary pathogen of native forests in the USA and Canada. On the contrary, in countries where the PWN has been introduced, PWD has rapidly become an important disease. In Japan, *B. xylophilus* was identified as the causal agent of dramatic pine mortality in the late 1960s, and is currently the number one forest pest, with an annual loss of pine trees estimated at one million cubic meters. Asian countries other than Japan began to report the presence of the PWN in the mid- to late-1980s. In 1999, the PWN was reported for the first time in Europe, in declining maritime pine (*P. pinaster*) in the Setubal region of Portugal. Although a national phytosanitary strategy of eradication was implemented by the Portuguese authorities, new outbreaks have been reported since 2008 in the Iberian Peninsula (centre of Portugal, and centre and North of Spain) and in Madeira Island.

The tree species that are the most susceptible to PWN are mainly *Pinus* spp., although the host list also includes species of *Abies*, *Chamaecyparis*, *Cedrus*, *Larix*, *Picea* and *Pseudotsuga*. In particular, the European species *P. pinaster*, *P. sylvestris* and *P. nigra* are known to be killed by the PWN as mature trees in the field. Very recently, the EU collaborative project REPHRAME (KBBE.2010.1.4-09) has been launched, its objectives being the development of improved methods for detection, control and eradication of PWN in support of EU Plant Health policy. Although an Asian origin is suspected for the first introduction in Portugal, the invasion routes of the PWN in Europe remain largely unknown. In the framework of REPHRAME, we will use a set of microsatellite markers identified from the nematode genome to locally characterise the populations and their genetic relationships, based on direct field sampling but also on retrospective analysis of the variability in the existing distribution of PWN in Portugal and Spain. These studies will help solve basic questions such as the comparison of the different introduction and dissemination scenarios for the PWN European populations.

Keywords: Bursaphelenchus xylophilus, invasive species, microsatellites, pathway analysis, pine wilt disease, *Pinus* spp.

P7-06 Phenotypic plasticity of maritime pine to insect herbivory

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Plants are able to recognize the biotic damage caused by insects or other plant enemies, and quickly react activating a suit of plastic responses that strongly enhance plant resistance (i.e. reducing further damage) and/or tolerance (i.e. reducing the impact of damage on plant fitness). During the last decades large progress has been made to understand the molecular mechanisms involved in the recognition, triggering and signalling of plant induced responses. We now know that plastic responses to herbivory are much more complicated, variable and widespread than usually assumed. They include a wide range of physiological and morphological changes, from the simple increase of the concentration of existing chemical defences or the production of new physical or chemical barriers, to other much more complex mechanisms that even involve other members of the ecosystem. Plants are able, for example, to detect alarm messages emitted by neighbouring damaged plants, and prepare their physiological machinery accordingly to the increased risk of damage. The volatile organic compounds emitted by damaged plants can also serve as cues for herbivory enemies that can help the plant by reducing herbivore populations within complex and exciting tritrophic interactions. The presence of mychorrizas and other microorganisms of the rizhosphere may also play key roles modulating the efficiency of the induced responses. Most of these fascinating responses, which constitute a kind of plant immune system, have been demonstrated only in annual model plants, but we still know little about defensive induced responses in long-lived plant species such as pines. Pines are large, long-lived plants that are particularly exposed to herbivory. Because they have to fight against many types of different herbivores that may exert highly variable pressures during their long-life span and, at the same time, keep growing and reproducing, defensive strategies based on plastic responses may be even more effective in these species.

In this communication we summarize recent results on the plastic responses of maritime pine (*Pinus pinaster* Ait.) to real or simulated herbivory. As expected, maritime pine seedlings strongly react to insect herbivory, increasing the concentration of chemical defences (resin and phenolics) and modifying the profile of both resin terpenes in plant tissues and volatile terpenes emitted from the needles, changes that may be involved in plant-plant or plant-animal communication. The responses can be extremely strong and fast, with up to 3-fold increase of the resin content in the stems within just 48 hours of insect feeding.

The induced responses of pines trees are not restricted to the site of injury; instead, they can be detected further away, especially in those tissues more relevant for plant fitness (e.g. primary meristematic tissues). Induced plastic responses also involve permanent anatomic changes such as the formation of new traumatic resin ducts that helps improving plant protection systemically. Responses to herbivory do not only include changes related to secondary metabolism but also relevant changes in carbon and nutrient allocation within the plant, as well as alterations of primary and secondary growth patterns. For example, after application of methyl jasmonate, a phytohormone involved in signalling insect damage and triggering induced responses, we found a huge increase in the biomass of the fine root fraction and significant shifts in nutrient allocation from roots to shoots. Both increased nutrient acquisition and nutrient reallocation will likely help to reduce the impact of the damage on pine fitness, and thus are interpreted as "induced tolerance" responses.

All these plastic responses show different levels of genetic control within the studied populations, and are modulated by abiotic environmental conditions, such as nutrient availability, offering a fascinating scenario to study the relevance of pine defensive strategies within the evolutionary ecology of Mediterranean pines.

Conservation

P8-01 New Relict Endangered Populations of *Pinus sylvestris* in Turkey

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Pinus sylvestris L. is one of the largest distributed tree species in the World. It is also an important tree species in Turkey, 1,239,578 ha (OGM, 2006). New relict populations of *P. sylvestris* at a significant distance from the main distributions are recently recorded at three close locations (Bogazgoren, Koylu, and Kuluncak) in Malatya region, Eastern Turkey (Yılmaz *et al.*, 2009).

This occurrence represents one of the most southern distribution of the species. *P. sylvestris* trees in Malatya region have mostly bulky trunks, spreading crowns, and thick branches. The maximum tree heights are about 10-12 m. Young *P. sylvestris* seedlings in the region have been growing very slowly and apical control has been disappeared in some of the seedlings. Surprisingly, unusual forms of *P. sylvestris* trees in which a couple of individuals originating from one stump is commonly observed in these populations due to hot and dry stressing conditions for the species (Yılmaz *et al.*, 2009). The percentage of sound seeds (44.1%) and the number of seeds per cone (25.5) in the region was significantly lower than those of larger populations of *P. sylvestris* in Turkey (Boydak, 1977; Yılmaz and Yüksel, 2010).

Boğazgören population has very limited number (forty three) individuals. Köylü population is also very small, about 2 ha. Both populations are under the threat of disappearance due to the damages of insects, Wild boars (*Sus scrofa*), and erosion. In Kuluncak population, *P. sylvestris* trees are scattered in about 50 ha and under the threat of suppressing effect of better adapted native Oak trees. Therefore, Oak tree population and growth conditions should be controlled regularly in order to sustain this *P. sylvestris* relict population. Both Boğazgören and Koylu populations should be fenced and protected from the animal damage.

These three populations should be taken under the long-term conservation program.

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Keywords: *Pinus sylvestris,* Scotch pine, Relict population

P8-02 Stand structure and spatial relationships between trees, shrubs and regeneration dynamics in a Stone pine forest (*Pinus pinea* L.) in central Italy

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In Italy Stone pine forests (*Pinus pinea* L.) have traditionally been cultivated for the production of both wood and pine nuts. To accomplish these objectives forest management generally prescribes even-aged stands and the clear cutting system with artificial regeneration.

In the last decades pine forests have become even more important for their social and cultural role, as well as for landscape conservation, especially those included within protected areas along coastal districts. Thus it is important to investigate whether the classic silvicultural system is the most appropriate to achieve the current public needs or if there is a need to shift to more sustainable and close-to-nature silvicultural methods. Despite the relevance of this topic, few studies have focused on natural regeneration of Stone pine forests and their management as uneven-aged systems.

This work has been carried out in the Pineta Granducale di Alberese, an historical coastal Stone pine forest included within the Maremma Natural Park (Tuscany, central Italy) and in a Natura 2000 site. Forest structure consists of a composite of even-aged and uneven-aged stands, the latter with a vertical structure comprising two or multiple strata and presence of natural regeneration of pine. Underbrush is composed by Mediterranean shrubs such as cistus, rosemary, lentisk and juniper.

The aims of our study are:
1) to characterize the forest structure of even-aged and uneven-aged Stone pine stands;
2) to describe the spatial pattern and dynamics of pine recruitment and its relationship with adult trees and shrubs, and
3) to discuss uneven-aged management system for coastal Stone pine forests in Italy.

Fieldworks have been carried out in experimental plots laid out in even-aged stands, in two storied stands and in uneven-aged stands with multi strata vertical structure. In each plot, the x,y coordinates and the species of all trees with a height greater than 20 cm have been recorded. For each tree with a diameter at breast height (dbh) greater than 2.5 cm the dbh, height, crown length and crown projection have been measured. For trees with a dbh less than 2.5 cm the tree height and the distance between the tree and closest shrub have been collected. In addition, the location, mean height and species composition of the Mediterranean shrubs have been recorded. The data has been processed using quantitative structural indexes and spatial statistical analyses.

The results are finally discussed and forest management guidelines based on uneven-aged silvicultural system as alternative option for management of coastal Stone pine forests are presented.

Keywords: Stand dynamics and forest management, Conservation.

P8-03 The black pine of the Maghreb *Pinus nigra* Arn. subsp. *mauretanica* (Maire & Peyerimhoff) Heywood

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The aim of this work is to bring a sum useful information on the black pine of the Maghreb (*Pinus nigra* subsp. *mauretanica*), which is an extremely rare species, of very high biogenetic and patrimonial value. In spite of legal protection and a privileged localization within a biosphere reserve, it is unfortunately seriously threatened (especially by fires). Its situation in the Maghreb, and more particularly in Algeria, is very worrisome, as gives evidence of catastrophic fire of August 2000, which destroyed a big part of Tikjda forest at southern Djurdjura, where the black pine is present in only one locality with approximately one hectare. An integral reserve was settled on the area where the most number of trees (450-470) remain, but, the results of *in situ* protection have been limited. This "state of the knowledge" identifies many gaps in our knowledge of biology and demographic structure of this pine and the factors which govern its evolutionary dynamics and block its development.
 So, the objective of this note is to provide certain data on habitat and auto-ecology of the black pine, its exact distribution in the Djurdjura mountain and its syntaxonomical value (*Junipero hemisphaericae-Cedretum atlanticae* ass. nova p*inetosum mauretanicae* subass. nova), which will allow to compensate partially these gaps.
Finally, to improve conservation measures of this world biogenetic heritage, it is necessary to direct the researches in the global frame of biological conservation (case of narrow population and consanguinity problem). We know that the scarcity of populations and the narrowness of their distribution areas make them particularly exposed to genetic accidents, environmental or demographic risk, which at any time can eliminate them. But, we can expect considering the "umbrella species" concept, the still viable population of black pine on the northwest edge of Tigounatine, could benefit from the coverage of its sympatric congener, the Atlas cedar, as long as possible.

Keywords: Black pine, Djurdjura, residual species, protected area, phytosociology, fires

POSTER CHAPTER

P8-04 *Pinus uncinata Ramond* ex DC: Conservation and proposal of management at its southwestern limit of distribution (Castillo de Vinuesa, Soria, Spain)

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The mountain pine (*Pinus uncinata*) constitutes the dominant tree species at the timberline of the centre and southwest of Alpes and the Central Pyrenees reaching to 2,700 m of altitude. This species reaches its south-western limit of distribution in the Iberian System (Castillo de Vinuesa, Soria, Spain), where it survive a relict and endangered forest stand of 66 ha

This small and isolated population from the Pyrenees presents noticeable conservation problems. Firstly, gene flow with other Iberian populations is not possible due to its isolated situation. Secondly, a high possibility of genetic erosion of *Pinus uncinata* may result from hybridization with *Pinus sylvestris*. Finally, plant regeneration from seeds is scarce (REF). Its survival in this area seems to be quite difficult. Moreover, bioclimate modelling estimations for *Pinus uncinata* in this area forecast a great reduce of suitable area for the species in the territory (Benito Garzon *et al*., 2008).

Therefore, this population needs special attention to evaluate its likely disappearance under future global warming pressure.

In order to preserve this natural area, it has been proposed a new kind of protected area named "Microrreserva de Flora" (protected reserve of flora less than 200 ha) (López Díez *et al*., 2010).

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Keywords: Conservation; Climate change impact

Short field visit

Typical landscape with calcareous steeps and mixed oak / pine forest of Luberon Natural Park (Photo ONF)

Combining fire hazard mitigation and wildlife habitat improvement in a mixed oak-pine forest

Luberon Natural Regional Park

1 - Short description of the area

Name	Luberon Natural Park
Municipality	(i) Les Taillades, (ii) Cheval Blanc
Département (county)	Vaucluse (84)
Ecosystem type	(i) Mixed *Pinus halepensis, Quercus ilex* forest and (ii) Mediterranean garrigue
Management authority	(i) Les Taillades Municipality forest, (ii) Petit Luberon State Forest (Office National des Forêts, State Forest Service).
Protection status	Natural Regional Park

2 - Ecological characteristics

The field tour will visit the emblematic cultural and natural landscapes of the Luberon Natural Park. It is a limestone mountain formation emerging between the Durance River and Calavon plains, 35 km from Avignon. The topography consists of a rough relief creating a landscape mosaic of high patrimonial value spreading between 110 m and 720 m asl. The dominant vegetation types on the State forest area is Holm oak (*Quercus ilex*) coppice forests and pure or mixed (with Holm oak) Aleppo pine (*Pinus halepensis*) forests. Shrublands is also widely spread consisting mainly of xerophilous garrigues of Kermes oak (*Quercus coccifera*) with aromatic plants intermixed with grassland communities.

3 - Excursion area history /context

The Luberon Regional Natural Park was create in 1977. It covers 185 000 ha and 170,000 inhabitants are living in this area. The Petit Luberon State Forest is totally included in the Natural Park and covers 3,310 ha. During the last 90 years, the total area burnt by wildfires was more than two times the State Forest area (7,316 ha). Forest fire risk is increased by dry stormy winds (Mistral) and steep terrain.

In the Luberon Natural Park, fuel management has been implemented in the last decades following two main options, respectively isolation by fuel breaks and area-wide fuel modification. Several surface fuel management techniques have been used, mechanical clearing being the most common, whereas prescribed burning and controlled grazing are increasingly developed.

Sheep grazing has always been a traditional practice in that part of France. Rural abandonment resulted in a decrease of the grazing pressure in grasslands, shrub lands and forest areas leading to fine fuel accumulation. Recent studies have shown the possible renewal of active rangeland management in south eastern France, with the clear objective of wildfire mitigation. Beylier et *al.* (2006) showed the successful contribution of sheep grazing to fuel control on both a fuel break network and neighbouring areas in the Luberon Natural Park. Renewal of rangeland management combines new establishment of livestock farmers in fire prone areas, together with consolidation of existing animal farming.

Fuel control by cheep grazing on a strategic fuel break (Photo ONF).

Prescribed burning under Aleppo pine stand in Luberon Natural Park (Photo C Mestre, INRA)

Prescribed burning was first introduced in 1992 as a technique for completing fuel management to decrease wildfire hazards. As more experience has been gained, the objectives have broadened including landscape management and wildlife habitat improvement

*Pinus brutia plantation
(Photo INRA)*

4 - Points of interest and discussion during the excursion

The visit will focus on the protection of the Petit Luberon State Forest located in the western part of the Luberon forest area (21,365 ha). Last large wildfires in 1989 and 1991 have led to a renewal of the local fire prevention management plan. It includes a complete fuel-break network with equipments limiting fire ignition at the wildland urban interface located at the bottom hill of the Luberon massif (stop 1 in Les Taillades Municipality pine and oak forest), fuel-breaks along the main access roads to secure fire-fighters transit (stop 2 In Cheval Blanc Municipality forest, mainly Aleppo pines) and several strategic fuel-breaks to limit total area burnt on the Luberon plateau (stop 3 in Petit Luberon State Forest). The fuel-breaks are managed by the State Forest Service combining clearing treatments, grazing and prescribed burning (stop 4) to control the build up of fuel loads as well as tree layer thinning when present. Vegetation management under *Pinus brutia* plantation and *Pinus halepensis* natural regeneration will be also presented.

The visit will be organized through presentations of Jean-Luc DUPUY, Eric RIGOLOT, Jean-Charles VALETTE (INRA) and Lionel KMIEC (ONF)

Medpine 4 field trip

08:30 Bus departure from Porte de l'Oule

11:00 Visit of the Font-Blanche long-term research site

The Font-Blanche site is part of a Mediterranean forest growing on a limestone plateau at an elevation of 420 m. It has an annual rainfall of 720 mm and a mean annual temperature of 13.5 °C. Soil depth is in the range of 10-40 cm.

Location: The forest is a Departmental Domain of Bouches du Rhône (CG13) and is located 5 40' 45" E, 43° 14' 27" N at Roquefort La Bédoule (South-East France).

Vegetation: It is a mixture of *Pinus halepensis* (Aleppo pine) and *Quercus ilex* (hoalm oak). Pines occupy the dominant strata about 13.5m high and oaks form a lower strata reaching about 6.5m. Understory vegetation consists mainly of *Quercus coccifera* shrubs. Leaf Area Index is 2.5 to 2.7 m^2 m^{-2} and basal area is 21.3 m^2 ha^{-1}. Mean DBH is 22.7 cm for pines, and 8.2 cm for oaks.

Objectives: This experimental site is aimed at monitoring the carbon and water fluxes from the plant to the ecosystem, as well as studying the various processes involved in the carbon and water cycles, with a particular emphasis to drought effects. Measurements are also designed to provide data to parameterize and test models.

Measurements: They include meteorology, eddy covariance, vegetative and reproductive phenology, growth, soil respiration, sap flow, soil moisture, water stress, wood hydraulic properties, litter bags, …
Observations started in 2007.
In addition, plots were set up to study the effects of 30% rainfall exclusion, and 30% additional irrigation.

The research group: The site is managed by INRA – URFM, but measurements are conducted by a multidisciplinary team involving scientists from INRA, Cemagref, CEREGE, CNRS-CEFE, and IMEP collaborating closely in the research federation ECCOREV.

Networks: The site is part of the network of French Observatory on Long Term Environmental Research "F-ORE-T" (http://www2.gip-ecofor.org/f-ore-t/fontBlanche.php), and ICOS Europe, (Integrated Carbon Observation Research). Font-Blanche participates to continental water budget estimation in HyMeX (HYdrological cycle in the Mediterranean EXperiment).
The visit will be organized through presentations of Roland HUC and Guillaume SIMIONI (INRA), Michel VENNETIER (Cemagref), Frédéric GUIBAL (IMEP), Lionel CHEVALIER (Conseil Général des Bouches-du-Rhône), Jérôme ORGEAS (Mayor of Roquefort-la-Bédoule)

13:00 Picnic at Fontblanche

14:30 Visit of the Ceyreste Aleppo-butia pine provenance trial

A two-site comparative trial with 12 *P. halepensis*, 12 *P. brutia* and 3 P*. eldarica* provenances was planted in south-eastern France in 1976 (Ceyreste, 450 m. asl), and 1978 (Vitrolles, 200 m asl) within the international FAO network (FAO/SCM/CRFM/4bis). Both sites are located in the thermo-Mediterranean coastal environment and exhibit a strong water stress. The Vitrolles plantation was unfortunately destroyed by a forest fire in 2004.

The variability of adaptation was estimated by provenance growth and survival. Results confirm the highest susceptibility of some Aleppo pine to frost as compared to *P. brutia*. At Ceyreste, on calcareous sandstone, most of P. brutia provenances grew faster than *P. halepensis* provenances. At Vitrolles on compact limestone (drier conditions) the best growing provenances belong to *P. halepensis*. A clear species x site interaction was observed confirming the different ecological optima of the two species. However provenance ranking within species remains almost stable.

The field trip will also offer the opportunity to visit an arboretum planted in 1976 and 1977 (1,4 ha). Most angiosperm species except some *Eucalyptus* did not survive. Among conifers, Cypress species and pines from the Aleppo-brutia complex exhibit the highest survival rates and the best growth.

The visit will be organized though presentations of Christian PICHOT and Roland HUC (INRA) and Cédric MAZAURIC (ONF)

16:20 Bus departure to Cassis

17:00 Vineyard visit and wine tasting at Domaine de Fontcreuse - Cassis

18:15 Visit of the historical parts of the Cassis village and of its harbour

19:30 Dinner in Cassis city

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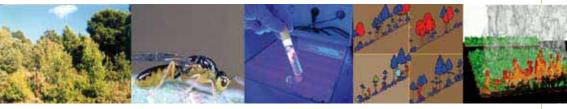|	
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FRENCH NATIONAL INSTITUTE FOR AGRICULTURAL RESEARCH

INRA conducts mission-oriented research, which seeks to meet the major challenges of our society in terms of food and nutrition, sustainable agriculture and the environment. It is organized in 14 research divisions located in 19 regional centers. The Forest, Grassland and Freshwater Ecology (EFPA) research division is represented in 11 regional centers, developing research on continental ecosystems. Within the Provence Alpes Côte d'Azur (PACA) regional center, research units are organized in three joint programs, including one on Adaptation to Global Change (ACG), which combines expertise in biology, environmental sciences as well as human and social sciences.

The research unit Ecology of the Mediterranean Forests (URFM) is a multi-disciplinary research group devoted to the study and modeling of functional and evolutionary dynamics of complex forest ecosystems in the context of global change, focusing on the Mediterranean forest as an experimental system. The applied goal of URFM is to develop sustainable management tools for a variety of end-users at local, national and regional scale. We integrate and combine three majors fields of research:

- population biology and evolution studies analyze the genetic diversity, spatial dynamics and adaptive dynamics processes of tree and insect populations;
- functional ecology and community dynamics studies integrate growth, dynamic and physiological models (water uptake and carbon balance) in mixed forests;
- physics and fire ecology are combined in a mechanistic approach of fire dynamics and fire behavior.

To lead all the research projects, URFM research group, the EFPA division and INRA in general develop partnerships with the European and international community, the socio-economic world, the public authorities and the society at large.

To have more information on the Institute, the divisions and units involved in environmental issues, the partnerships, you can visit the following web sites:

http://www.international.inra.fr/
http://www.inra.fr/efpa/
http://www.avignon.inra.fr/acg
http://www.avignon.inra.fr/URFM