AAIC 2016 ASSOCIATION FOR THE ADVANCEMENT OF INDUSTRIAL CROPS

INTERNATIONAL CONFERENCE

"INDUSTRIAL CROPS: PROMOTING SUSTAINABILITY"

24-28 September, 2016

Rochester, NY

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Conference Program

Sunday, September 25

7:30 AM-6:30 PM	Niagara Falls Tour –both US and Canadian sides (Passport required)	Meet outside hotel
6:30- 7:30 PM	Registration Desk Open	Foyer-Riverview Lounge
6:30-7:30 PM	Poster Set up	Anthony (A)
6:30-7:30 PM	AAIC Board of Directors Meeting	Boardroom
7:30-9:00 PM	Welcome reception	Riverview Ballroom-Lounge

Monday, September 26

Plenary Session

Moderator: Marisol Berti

Room: C&D

8:00-10:00 AM	Registration Desk Open and Poster set up	
8:00 AM	Welcome and introduction	
8:15 AM	Keynote speaker- Jack Grushcow, Linnaeus Plant Sciences Inc., Canada	Camelina advances in breeding and market opportunities
9:00 AM	Edward Fletcher, Herbal Ingenuity	Sustainable production of herbal medicines
9:45 AM	Coffee Break	Room: Anthony (A)
10:15 AM	Charles Mullen, Sustainable Biofuels and Coproducts Eastern Regional Research Center, ARS, USDA	Guayule Pyrolisis biorefining
11:00 AM	Bus departs to Casa Larga vineyard	
11:30 AM	Vineyard tour and wine tasting- lunch	Lunch

3:00-5:00 PM	Visit to Worm Power Farm, Avon, NY	
6:00 PM	Dinner on your own	
6:30-8:30 PM	CGC meeting- David Dierig	Boardroom

Tuesday, September 27

TECHNICAL SESSIONS
Concurrent sessions

1. Oilseeds Division
Moderator: Liv Severino, EMBRAPA Algodao, Brazil
Room: C

8:00 AM	**Keynote speaker Alexandre N. Cardoso**, B.G. Laviola, Gilmar S. Santos, S.P. Favaro, M.T. Souza, L.S. Severino, Luiz C. Veras[2], Humberto U. de Souza, M.F. Braga, R Ciannella[5]	Macaw palm - a potential biomass for oil production in Brazil
8:30 AM	Elodie Gazave, E.E. Tassone, D.C. Ilut, M. Wingerson, E. Datema, H. M. A. Witsenboer, J. B. Davis, D. Grant, J.M. Dyer, M.A. Jenks, J. Brown, and M.A. Gore	Population genomic analysis reveals differential evolutionary histories and patterns of diversity across subgenomes and subpopulations of *Brassica napus* L.
8:50 AM	Federica Zanetti, C. Eynck, M. Christou, M. Krzyżaniak, M. Stolarski, D. Righini, E. Alexopoulou, E.N. Van Loo, D. Puttick, J. Tworkowski, and A. Monti	Camelina [*Camelina sativa* (L.) Crantz.]- an attractive new oil crop for Europe and Canada
9:10 AM	Marisol T. Berti, B.L. Johnson, D. Samarappuli, and R. Gesch	Integrating winter camelina [*Camelina sativa* (L.) Crantz.] into corn and soybean cropping systems
9:30 AM	Efthymia Alexopoulou	A comparison between a number of new released castor (*Ricinus communis* L.) hybrids and two native castor varieties in Greece

9:50 AM	Federica Zanetti, C. Chieco, E. Alexopoulou, A. Vecchi, and A. Monti	Bringing back castor (*Ricinus communis* L.) to Europe: a promising multipurpose crop
10:10 AM	Liv S. Severino, D.L. Auld, L.S. Vale, L.F. Marques, and O.J. Gaona-Cordoba	Castor (*Ricinus communis* L.) plants establish interplant hierarchy according to the planting density
10:30 AM	Coffee Break – Room: Anthony (A)	
11:30 AM	**Oilseeds Division meeting**	
12:00	Lunch	Room: Douglass (B)

Concurrent Session

2. Fibers and Cellulosics

Moderator: Dilpreet Bajwa, North Dakota State University

Room: D

8:00 AM	**Keynote speaker : Anil N. Netravali** Dept. of Fiber Science &Apparel design, Cornell University	Cellulose Fiber Reinforced 'Green' Composites
8:40 AM	Panjak Pandey, S.G. Bajwa, and D.S. Bajwa	Effect of UV weathering on DDGS fiber filled thermoplastic composite
9:00 AM	Cindy S. Barrera, and K. Cornish	Statistical modelling of natural rubber composites properties based on filler's characteristics
9:20 AM	D.S. Bajwa, Greg A. Holt, S.G. Bajwa, S.E. Duke, and G. McIntyre	Enhancement of termite resistance in mycelium reinforced biofiber-composites
9:40 AM	Dilpreet S. Bajwa, and E.D. Sitz	Processing and manufacture of soybean and wheat straw medium density fiberboard utilizing epoxidized sucrose soyate resin
10:00 AM	Efthymia Alexopoulou, and Tang Shouwei	The importance of bast fiber crops as feedstock for biobased products and bioenergy
10:20 AM	Coffee break	Room: Anthony

10:50 AM	Burton L. Johnson, B.K. Hanson, J. Kostuik, M.T. Berti, and P.J. Petersen	Industrial hemp (*Cannabis sativa* L.) Stand establishment and yield in North Dakota
11:10 AM	**Fiber and Cellulosics Division Meeting**	
12:00	Lunch	Douglass

Concurrent Session

3. General Crops Division
Moderator: Efthymia Alexopoulou, CRES, Greece
Room: C

1:30 PM	**Keynote speaker: Ana Luisa Fernando**	Production of industrial crops in marginal soils – Is it a sustainable option?
2:10 PM	Efthymia Alexopoulou	Switchgrass (*Panicum virgatum* L.): An ideal perennial crop for marginal lands
2:30 PM	Nicola Di Virgilio, Osvaldo Facini, Federica Rossi, and Andrea Monti	Ecosystem gas exchange of switchgrass (*Panicum virgatum* L.) in the Mediterranean area
2:50	Ana Luisa Fernando	Is it sustainable to produce *Miscanthus x giganteus* Greef et Deu in sewage sludge contaminated soils?
3:10	Coffee Break	Room: Anthony
3:30	Valerie H. Teetor, C. Schmalzel, and D.T. Ray	Planting sweet sorghum (*Sorghum bicolor* [L.] Moench) in clumps reduces lodging but not yields
3:50	Alan G. Taylor, W. Huang, M. Amirkhani, H.S. Mayton, and D. Wang	Seed technology of eastern gamagrass [*Tripsacum dactyloides*] to enhance germination and seedling survival and break dormancy
4:10 PM	**General Crops and Products Division Meeting**	
5:00-6:30	**Poster session (All divisions)- Room: Anthony**	

Concurrent session
4. Natural Rubber and Resins
Moderator: Katrina Cornish
Room: D

1:30 PM	***Keynote speaker: Howard Colvin***	Securing the future of natural rubber – an American tire and bioenergy platform from guayule (*Parthenium argentatum* Gray)
2:10 PM	M. Dorget, A. Amor, Serge Palu, and D. Pioch	European guayule (*Parthenium argentatum* Gray) market
2: 30 PM	A. Amor, C. Sanier, J.-L. Verdeil, M. Lartaud, T. Punvichai, E. Tardan, Serge Palu, and D. Pioch	Biomass imaging as a tool for addressing the challenge of multiple-product guayule (*Parthenium argentatum* Gray) biorefinery
2:50 PM	L. Brancheriau, Serge Palu, D. Pioch, N.Boutahar, E. Tardan, P. Sartre, J.M. Ebel, and E. Becourt	NIRS measurement at field level to measure rubber and resin content of guayule (*Parthenium argentatum* Gray) plants
3:10 PM	Douglas J. Hunsaker, and D.M. Elshikha	Guayule (*Parthenium argentatum* Gray) rubber production in the US desert with surface and subsurface drip irrigation and five water levels
3:30 PM	Daniel C. Ilut, P.L. Sanchez, J.M. Dyer, M.A. Jenks, and M.A. Gore	Applications of modern genomics for domestic natural rubber development: taking stock of guayule (*Parthenium argentatum* Gray) germplasm
3:50 PM	Lauren D. Johnson and M. Fraley	Panaridus update on guayule (*Parthenium argentatum* Gray) plant breeding and direct seeding
4:10 PM	Hussein Abdel-Haleem	Phenotypic characterization of guayule (*Parthenium argentatum* Gray) USDA collection under field conditions
4:30 PM	A. Pantel, S. Park, V.M.V. Cruz, D.T. Ray, W.S. Niaura, and David A. Dierig	Rate of apomixis in USDA germplasm for guayule (*Parthenium argentatum* Gray) breeding
5:00-6:00	**Poster session (All divisions) Room-Anthony**	
	Dinner on your own	

Wednesday 28 September

TECHNICAL SESSIONS

Concurrent Sessions

5. Natural Rubber and Resins
Moderator: Katrina Cornish
Room: D

8:00 AM	Colleen McMahan, U. Hathwaik, and D. Lhamo	Role of proteins and amino acids in natural rubber: guayule (*Parthenium argentatum* Gray) rubber addition studies
8:20 AM	Varun Venoor, K. Cornish, K. Koelling, and Y. Vodovotz	Bio-based composites for food packaging
8:40 AM	B.A. King, L.D. Johnson, and M. Fraley	Genetic and environmental effects on quality of guayule (*Parthenium argentatum* Gray) natural rubber
8:50 AM	***Keynote: Katrina Cornish,*** S. McNulty, N. Amstutz, and G. Bates	Progress in improving rubber yield of *Taraxacum kok-sagyz*
9:30 AM	B. Iaffaldano, Yingxiao Zhang, and K. Cornish	CRISPR/CAS9 genome editing of rubber producing dandelion *Taraxacum kok-saghyz* using agrobacterium rhizogenes without selection
9:50 AM	Muhammad Akbar Abdul Ghaffar	Increasing rubber production by post- harvest ethephon application in *Taraxacum kok-saghyz* roots
10:10 AM	Coffee break	Room: Anthony
10:30 AM	Zinan (Lily) Luo, B. Iaffaldano, X. Zhuang, M. Ma, and K. Cornish	Transcriptome analysis of *Taraxacum kok-saghyz* using RNA-seq and identification of candidate genes related to the rubber biosynthesis pathway
10:50 AM	Ming Ma, S.K. McNulty, S.E. Kopicky, Z. Luo, and K. Cornish	Quantification of natural rubber in *Taraxacum kok-saghyz* by near infrared reflectance spectroscopy

11:10 AM	Richard J. Roseberg, T.B. Silberstein, K. Cornish, S. McNulty, and N. Amstutz	Agronomic management of rubber dandelion (*Taraxacum kok-saghyz* Rodin) for root biomass and natural rubber production in Oregon
11:30 AM	David A. Ramirez-Cadavid, F. Michel Jr., and K. Cornish	*Taraxacum kok-saghyz*: an alternative source of natural rubber and other valuable bioproducts
12:00 PM	Lunch-Business Meeting	Douglass (B)
1:30 PM	**Rubber and Resins Division Meeting**	
2:00 – 3:30 PM	**Poster session and coffee (all divisions)**	

Concurrent session

6. Medicinal and Nutraceutical Plants Division
Moderator: H.Rodolfo Juliani
Room: C

8:00 AM	**Keynote speaker, Lyle E. Cracker**	Trends in research and development of the new marijuana (*Cannabis* sp.)
9:00 AM	Susana Fischer, R. Wilckens, F. Graff, L. Bustamante, J. Jara, W. Valdivia, and M. Aranda	Characterization of proteins in quinoa (*Chenopodium quinoa* Willd.) seeds from plants submitted to water stress
9:20 AM	H.Rodolfo Juliani	Headspace gas chromatography for the determination of volatile components in essential oil research
9:40 AM	Diana Jasso de Rodríguez, D.A. Carrillo-Lomelí, M.E. Rocha-Guzmán, M.R. Moreno Jiménez, R. Rodríguez-García, and J.A. Villarreal Quintanilla	Antioxidant, anti-inflammatory and apoptotic activities of two extracts of *Flourensia microphylla* in HT-29 cells in vitro
10:00 AM	Coffee Break	
10:20 AM	Diana Jasso de Rodríguez, L.C. García-Hernández, N.E. Rocha- Guzmán, M.R. Moreno-Jiménez, R. Rodríguez-García, M.L.V.	Hypoglycemic and anti-inflammatory activities of the corm extract of *Psacalium paucicapitatum*

	Díaz-Jiménez, A. Sáenz-Galindo, J.A. Villarreal-Quintanilla, and F.M. Peña-Ramos	
10:40 AM	Ramnarain Ramakrishna, D. Sarkar, and K. Shetty	Evaluation of phenolic linked anti-hyperglycemic potential of barley (*Hordeum vulgare* L.) cultivars targeting for the management of early stages Type 2 diabetes using in vitro models
11:00 AM	**Medicinal and Nutraceuticals plants Division meeting**	
12:00 PM	**Lunch-Business meeting**	Douglass
2:00 – 3:30 PM	**Poster session (all divisions)**	

Awards Banquet

6:30	Cash bar Riverview Lounge
7:00-9:00 PM	AAIC Awards Banquet-Riverview Ballroom and Lounge

Posters Presentations

Room: Anthony (A)

Fiber and Cellulosics		
1	Efthymia Alexopoulou, T. Shouwei, and Y. Papatheohari	Screening field trials for several kenaf (*Hibiscus cannabinus* L.) varieties in terms on growth and yields in Greece.
2	Defang Li	Comparison of the nutritive value of seven kenaf (*Hibiscus cannabinus* L.) varieties harvested depending on stubble height
3	Huang Siqi	Physiological response in the roots of kenaf (*Hibiscus cannabinus* L.) seedings under cadmium stress
General Crops		
4	Efthymia Alexopoulou	Comparative studies among several fiber and sweet sorghum [*Sorghum bicolor* (L.) Moench] varieties in Greece
5	E.G. Papazoglou, and Ana Luisa Fernando	Sugarbeet (*Beta vulgaris* L.) Cultivation in contaminated land for bioethanol production: a promising perspective
6	Ana Luisa Fernando, M.P. Duarte, M.D. Curt	Delaying sorghum (*Sorghum bicolor* (L.) Moench) harvest dates in the Iberian peninsula – balancing yields and effects on soil quality
7	M. Christou, and Efthymia Alexopoulou	Long term studies on giant reed (*Arundo donax* L.) in a marginal land in central Greece
Medicinal and Nutraceutical		
8	Ashish Christopher, J. Orwat, D. Sarkar, M. McFarland, and K. Shetty	Stress-induced enhancement of phenolic antioxidants in grapes (*Vitis vinifera* L.), targetting bioactive compounds for the management of early stages Type 2 diabetes
9	V. Gomes Lauriano de Souza, and Ana Luisa Fernando	Bioactivity and physical properties of chitosan films incorporated with different natural antioxidants
10	J. Bradley Morris	Production comparisons of Chinese water chestnut [*Eleocharis dulcis* (Burm. F.) Trin. Ex Hensch]

		functional corms grown in hydroponics versus flooded sand
11	Diana Jasso de Rodríguez, N.A. Gaytán-Sánchez, R. Rodríguez-García, F.D. Hernández-Castillo, M.L.V. Díaz-Jiménez, S. González-Morales, A. Sáenz-Galindo, J.A. Villarreal-Quintanilla, and F.M. Peña-Ramos	Antifungal activity of extracts of *Juglans mollis*, *Juglans microcarpa* and *Carya ovata*, against *Fusarium oxysporum* and *Alternaria alternata* in vitro
12	Rosemarie Wilckens, S. Fischer, and Ismael Obal.	Synthesis of antioxidants in sprouts of quinoa (*Chenopodium quinoa* Willd.) in response to abiotic stress
13	R. Rodríguez-García, A. Reyes-Sebastián, Jose Ángel Villarreal-Quintanilla, D. J. de Rodríguez, M.L.V. Díaz-Jiménez, H. Ramírez-Rodríguez, N.A. Ruiz-Torres and F. M. Peña-Ramos	Effect of plant extracts semi-desert in the induction of germination and seedling growth of melon
14	M.L. Flores-López, J.M. Vieira, M.A. Cerqueira, C. Rocha, Diana Jasso de Rodríguez, and A.A. Vicente	Effect of aloe vera (*Aloe barbadensis* Miller) nano-laminate coating on the shelf life parameters of tomato fruits (*Lycopersicum esculentum* Mill.)
15	H. Rodolfo Juliani, A.R. Koroch, and J.E. Simon	Essential oils of basil (*Ocimum* sp) and their associated antioxidant and antimicrobial activity
16	Diana Jasso de Rodríguez, E. de J. Salas-Méndez, R. Rodríguez-García, F.D. Hernández-Castillo, M.L.V. Díaz-Jiménez, A. Sáenz-Galindo, S. González-Morales, J.A. Villarreal-Quintanilla, and F.M. Peña-Ramos	In vitro antifungal activity of extracts of ethanol and water of leaves and stems of *Flourensia* spp. against fungi postharvest
Rubber and Resins		
17	Muhammad Akbar Abdul Ghaffar, T. Meulia, and K. Cornish	Histological study of laticifer and rubber particle ontogeny in *Taraxacum kok-saghyz* roots
18	Cécile Bessou, D. Snoeck, T. Chapuset, F. Jäger, S. Mok, I. Lewandowski, D. Pioch, S. Palu, and Y. Biard	Life cycle assessment of guayule (*Parthenium argentatum* Gray) natural rubber production in Europe
19	Thierry Chapuset, V. Anleu, D. Snoeck, and C. Nájera	Improving rubber productivity by reducing tapping frequencies in Guatemala
20	Yingxiao Zhang, B. Iaffaldano, X. Zhuang, J. Cardina, and K. Cornish	Chloroplast genome resources and molecular markers differentiate rubber dandelion *Taraxacum kok-saghyz* from weedy relatives

21	Zinan (Lily) Luo, and K. Cornish	Induction and identification of tetraploids in *Taraxacum kok-saghyz*
22		
Oilseeds		
23	Reza Keshavarz Afshar, and C. Chen	Yield and yield components of winter camelina (*Camelina sativa* L. Crantz) in response to seeding date and rate
24	Roque L. Evangelista, T.A. Isbell, R.W. Gesch, and S.C. Cermak	Processing of brassica seeds for feedstock in biofuels production
25	M. Christou, Efthymia Alexopoulou, M. Stolarski, M. Krzyżaniak, and J. Hinge	New oil crops for bioenergy and biorefinery in Europe
26	K. Pacella, Ana Luisa Fernando, F. Zanetti, and A. Monti	Growth and yield of oil crops irrigated with wastewaters – the effect of ammonium ion and nitrates
27	C.S. Nascimento, G. Molina Regalado de Oliveira, T. Rodrigues Baran, and Winthrop B. Phippen	Evaluation of the germination rate of pennycress (*Thlaspi arvense* L.) in different conditions of storage and temperature
28	E. Koukouna, E.G. Papazoglou, R.A. Babahmad, A. Ouhammou, A. Outzourhit, and Efi Alexopoulou	Life cycle assessment of biodiesel production from (*Jatropha curcas* L.)

PROGRAM ABSTRACTS

KEYNOTE SPEAKERS AND PLENARY SESSION

CAMELINA: ADVANCES IN BREEDING AND MARKET OPPORTUNITIES

Jack Grushcow

Linnaeus Plant Sciences Inc.

Camelina [*Camelina sativa* L. Crantz] is an annual oilseed crop in the Brassicaceae family that has been cultivated since 4000 BC. Recently, interest in its oil, meal and the products developed from it has increased research activity in this crop. Recently, new uses for products from camelina oil and meal, altered camelina oil composition through genetic transformation, camelina physiology and agronomic management have been published, gaining much attention and worldwide interest. Camelina is frost tolerant at seedling stage, and heat, and drought tolerant at later stages. It has a short growing period, 10 days shorter than canola (*Brassica napus* L.), few insect problems, resistant to flea beetle, blackleg, and *Alternaria* black spot, and excellent yield potential in most areas, particularly in short-season environments and marginal lands. It is a non-food crop ideal for industrial applications and requires low inputs for its cultivation. Camelina market has expanded greatly in the last five years. Although camelina first attempts to expand its cultivation where for feedstock for biofuels and jet fuel, the incorporation of camelina meal and oil in fish, chicken, pigs feed and pet food has opened great possibilities for this crop. Linnaeus Plant Sciences is the global leader in camelina crop breeding and development. The program started by accessing one of the world's largest collections of camelina germplasm. In 2013, the elite line Midas™ a high yielding, resistant variety was introduced for planting. Currently, it is the largest ongoing camelina breeding program, which also has developed best management and sustainable practices. Linnaeus has developed two very promising new camelina varieties that will greatly increase the adoption of the crop. These include a large seeded variety, 40% larger than available varieties, with no loss in oil yield and a group 2 herbicide resistant variety. The future of camelina as industrial crop for multiples uses, biofuels, feed, food, cosmetics and nutraceutical products looks promising.

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SUSTAINABLE PRODUCTION OF HERBAL MEDICINES

Edward Fletcher

Herbal Ingenuity

This presentation covers the current market for some of the top selling medicinal herbs and how sustainability fits into the paradigm. The presentation an discussion include the step by step answer to the questions What it will take for the market to support sustainably wild crafted herbs from both the retailer and the buyer side based on demographic studies? and How each step in the process can add value to the material which can and will affect the finished product thus affecting the market sustainability?

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GUAYULE PYROLYSIS BIOREFINING

Charles A. Mullen, and Akwasi A. Boateng

USDA-ARS, Eastern Regional Research Center, Wyndmoor, PA, USA

Guayule (*Parthenium argentatum*) is a woody desert shrub cultivated in the southwestern United States as a source of natural rubber, organic resins, and high energy biofuel feedstock from crop residues. Some 20,000 kg ha^{-1} yr^{-1} is reported to be harvested worldwide and expected to grow due to renewed interest in guayule to replace imported Hevea rubber by the multi-billion tire and rubber industry. Because only about 10% of the biomass is used as extracted latex, economical utilization of guayule requires developing value added coproducts from the residual bagasse. While many have been researching alternative uses of the bagasse, it appears its use as a feedstock for biofuels could be most beneficial given the high energy content made available by the residual plant resins. While many biomass conversion routes have been studied to produce biofuels from guayule bagasse, pyrolysis would seem to be most promising given its potential to produce hydrocarbon fuels and chemicals that could take advantage of the presence of residual resin. However, traditional fast pyrolysis bio-oils are thermally unstable due to very high concentrations of reactive oxygenates and therefore make poor fuels or intermediates for further refining. These qualities are exacerbated when traditional fast pyrolysis is applied to guayule as feedstock because the low softening temperature and high viscosity of the products complicates guayule fast pyrolysis biorefining. At ARS, we have recently developed a new pyrolysis technology called tail gas reactive pyrolysis (TGRP) that has opened up the possibilities to carry out pyrolysis of difficult-to-process biomass feedstocks. This has made guayule pyrolysis biorefining possible. Using the ARS's patent pending TGRP process, low viscosity, stable, partially deoxygenated bio-oil has been successfully produced from guayule. This bio-oil is distillable and easily hydro-treated to hydrocarbon fuels. Technoeconomic analysis (TEA) on a 200 metric ton per day pyrolysis biorefinery based on process flow sheets generated from our TGRP data gives a preliminary estimates suggesting a minimum fuel selling price of $7.50/gallon when co-located with a rubber extraction facility. This presentation will detail the above described efforts in guayule biorefnining and also our efforts in demonstrating distributed on-site biomass pyrolysis.

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ABSTRACTS

OILSEEDS DIVISION

ORAL PRESENTATIONS

CHAIR

LIV SEVERINO, EMBRAPA ALGODAO, BRAZIL

MACAW PALM (*Acrocomia aculeate*) - A POTENTIAL BIOMASS FOR OIL PRODUCTION IN BRAZIL

Alexandre N. Cardoso[1], B.G. Laviola[1], G.S. Santos[1], S. P. Favaro[1], M. T. Souza, L. S. Severino[2], L. C. Veras[2], H. U. de Souza[3], M. F. Braga[4], and R. Ciannella[5]

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According to OECD/FAO (2014), 80% of the biodiesel produced in the world is made from vegetable oils. In 2023, this percentage should be 76%, considering an expected expansion of other sources (used cooking oil and animal fat). In Brazil, bioenergy and biofuels continue to be considered sustainable alternatives to energy dependency on fossil fuels, with potential impacts on reducing emissions of greenhouse gases. It is estimated that the demand for these sources of energy will increase 50% in the next ten years (Ten Year Plan for Energy Expansion - PDE 2024). Regarding the biodiesel production chain in Brazil, soybean provides around 75% of the total oils and fats used as raw material in the production of this biofuel (NPA - National Petroleum Agency 2014). The installed capacity of the Brazilian biodiesel industry is 7.3 billion liters per year. However, the total consumption in 2015 was 3.9 billion liters, considering the mandatory addition of biodiesel to mineral diesel, currently at 7% (B7), with a planned increase to 10% by 2019. In this context, one of the bottlenecks for expansion of this chain is the diversification of raw materials, either for the installed chain of biodiesel or future demand for bio-kerosene, taking into account biomass available and suitable on a regional basis. Macaw palm or macauba (*Acrocomia aculeate* L.) is one of the most promising alternative raw materials for the production of oil for biofuels and other uses. This species is native to Central to South America. The potential yield, between 3,000 and 6,000 kg of oil per hectare, and the quality of the oil make it a suitable feedstock for biofuel production, whether for biodiesel or bio-kerosene. Considering that it is not a domesticated species, exploring its potential depends on the implementation of a breeding program with strategies to accelerate the generation of cultivars, contributing to macaw palm's domestication in the shortest time. Agricultural practices that enhance oil yield are as important as the genetic improvement of the plants. The agrosilvopastoral system, which expansion has been encouraged in Brazil, as one of the goals at the COP, would be a suitable approach for macaw palm crop. In the short term, productivity gains are possible through improvements in fruit processing, which reflect on the quality of the oil extracted both from the pulp and the nuts. The establishment of a sustainable macaw palm production chain in Brazil requires continuous and concentrated investments on research, for the development of sustainable crop systems, domestication of the species and innovations on the processing of fruits, which are all key components of a successful productive arrangement. To address those main issues, a project was designed to conduct research on the potential of macaw palm as biomass for biofuels, under the scope of the "Programme for the Development of Alternative Biofuel Crops", (http:// www.worldagroforestry.org_/alternative-biofuel-crops) launched in 2013 with support from the International Fund for Agricultural Development (IFAD), and implemented by the World Agroforestry Center (ICRAF). The project proposes the crop of macaw palm as a component of agroforestry systems, integrating food and energy production. Results include the establishment of experimental areas in a defined region, to evaluate the performance of 20 selected genotypes of macaw palm, the performance of agroforestry systems and the effect fertilization and irrigation. Studies regarding the techniques to improve the processing of macaw palm's fruits will be presented and discussed as well.

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POPULATION GENOMIC ANALYSIS REVEALS DIFFERENTIAL EVOLUTIONARY HISTORIES AND PATTERNS OF DIVERSITY ACROSS SUBGENOMES AND SUBPOPULATIONS OF *Brassica napus* L.

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The allotetraploid species *Brassica napus* L. is a global crop of major economic importance, providing canola oil (seed) and vegetables for human consumption and fodder and meal for livestock feed. Rapeseed varieties of *B. napus* produce seed oil with a high level of erucic acid used in multiple industrial applications. The non-edible oil of industrial rape has the potential to be a sustainable source of hydrotreated renewable jet (HRJ) fuel, but a significant increase in the domestic production of industrial rapeseed oil is needed. In part, this could be accomplished through the large-scale introduction of industrial rapeseed as a rotation crop in the western U.S. non-irrigated wheat production system. Such introduction across the diverse environments that constitute the wheat belt, however, necessitates the development of high yielding, locally adapted industrial rapeseed varieties that are compatible with HRJ fuel conversion processes. With this objective in mind, characterizing the genetic diversity present in the extant germplasm pool of *B. napus* is fundamental to better conserve, manage and utilize the genetic resources of this species. We used sequence-based genotyping to identify and genotype 30,881 SNPs in a diversity panel of 782 *B. napus* accessions, representing samples of winter and spring growth habits originating from 33 countries across Europe, Asia and America. We detected strong population structure broadly concordant with growth habit and geography, and identified three major genetic groups: spring (SP), winter Europe (WE), and winter Asia (WA). Subpopulation-specific polymorphism patterns suggest enriched genetic diversity within the WA group and a smaller effective breeding population for the SP group compared to WE. Interestingly, the two subgenomes of *B. napus* appear to have different geographic origins, with phylogenetic analysis placing WE and WA as basal clades for the other subpopulations in the C and A subgenomes, respectively. Finally, we identified 16 genomic regions where the patterns of diversity differed markedly from the genome-wide average, several of which are suggestive of genomic inversions. Mapping polymorphic inversions is important for breeding as no recombination, and therefore no exchange of alleles can occur between inverted segments. The results obtained in this study constitute a valuable resource for worldwide breeding efforts and the genetic dissection and prediction of complex *B. napus* traits.

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CAMELINA (*Camelina sativa*) -AN ATTRACTIVE NEW OIL CROP FOR EUROPE AND CANADA

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Camelina [*Camelina sativa* (L.) Crantz] is considered a relatively new oilseed Brassica in both Europe and North America, even though its history as a crop dates back to the Bronze Age. Almost forgotten during the worldwide expansion of oilseed rape (*Brassica napus* L.), camelina has recently received increasing interest from both the scientific community and bio-based industries around the world. The main attractive features of camelina are: drought and frost tolerance, disease and pest resistance, a unique seed oil composition with high levels of n-3 fatty acids, considerably high seed oil content, and satisfactory seed yields, in particular under low input management and in limiting environments. Within the EU project COSMOS (Camelina and crambe Oil crops as Sources of Medium-chain Oils for Specialty oleochemicals), the agronomic performance of camelina is being evaluated in a wide range of environments in Europe and, through a collaboration with Linnaeus Plant Sciences (LPS), also in Canada. A selection of improved genotypes (n=9) was tested by COSMOS partners at 4 different locations in Europe (Greece, Italy, Poland, The Netherlands) and 6 locations across Canada, covering a wide variety of soil types (from fertile clay to poor sandy) and climatic conditions (from continental cold and wet to south Mediterranean arid and continental semi-arid, with annual average precipitation ranging from less than 400 to about 800 mm). Screening trials were set up in completely randomized blocks with three or four replicates in two consecutive growing seasons (2015 and 2016) in all locations. Sowing time was optimized for each location according to the different climatic conditions. Surveyed parameters during crop development and at harvest were similar to allow for easy comparison across locations (i.e., rate of emergence, days to flowering and maturity, height at maturity, plant density at harvest, seed yield, thousand seed weight, seed oil and protein content, fatty acid profile). Camelina proved to be a highly adaptable species, reaching seed yields of ~ 1 Mg DM ha^{-1} even under the most limiting conditions (southern Greece). Growing conditions characterized by mild temperatures and adequate rainfall (Vanguard, Western Canada) resulted in seed yields of close to 2.8 Mg DM ha^{-1} in 2015. Interestingly, the length of the growing cycle varied greatly across different locations (80-110 d), but the cumulative GDD (growing degree day), values were much more stable. The performance evaluations across locations in 2015 showed that while line 13CS0787-09 reached the highest yields at the majority of sites in Europe (Italy, Greece, and Netherlands), line 13CS0787-08, which possesses up to 50% larger seed, compared to the mean of all other test entries, demonstrated high yield stability across locations in both Europe and Canada. These results suggest geographic adaptation of genotypes to some extend; however, further confirmation from the second season (2016 still ongoing) is necessary. Multi-location trials across Europe and Canada over two consecutive growing seasons serve to identify the best performing varieties in each environment which will allow defining a customized breeding program for Europe and Canada in order to establish camelina as a viable alternative in typical crop rotations.

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INTEGRATING WINTER CAMELINA (*Camelina sativa*) INTO CORN AND SOYBEAN CROPPING SYSTEMS

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The use of cover crops, common in the eastern and central Corn Belt, are uncommon in corn (*Zea mays* L.)-soybean [*Glycine max* (L.) Merr.] systems in the Upper Midwest and northern Great Plains due to the short growing season and extreme fluctuations in temperature and precipitation within and across growing seasons. Lack of winter soil cover increases soil organic matter and nutrient losses, resulting in decreased crop productivity and resiliency. For these reasons, larger amounts of agricultural inputs are required to maintain or increase yields. Therefore, there is a critical need to alter current cropping systems in our region by incorporating technologies to improve long-term productivity while enhancing ecosystem services. The project "A Novel Management Approach to Increase Productivity, Resilience, and Long-Term Sustainability in Cropping Systems in the Midwest" AFRI-NIFA-USDA 2016-69004-24784 has as one of objectives to improve land use efficiency in current cropping systems through the inclusion of winter camelina as cover/cash crops in double or relay-cropping. Our project seeks to renovate current cropping systems to improve sustainability of agricultural production. If the management of current cropping systems in the northern Upper Midwest and northern Great Plains is not improved, long-term productivity will likely decrease. Several experiments have been designed to determine the best crops' growth stage, crop's plant density, crop maturity group, and row spacing to interseed winter camelina into standing corn and soybean, in three states (ND, MN, IA). Preliminary results indicate camelina establishes well under the corn or soybean canopy at all growth stages evaluated. Rainfall or lack thereof has great influence on camelina establishment when broadcasted. When drilled at V8 stage or earlier camelina established well. Corn and soybean yields decreased only when camelina was interseeded the same sowing date as the main crop. Once established camelina covers the soil until November and after the corn and soybean crops have been harvest. In the spring, camelina starts growing as soon as the snow is goes and it is the first crop to flower. Camelina can be terminated before planting the next crop in the rotation, cover crop, or double or relay crop soybean. Camelina seed yield in relay or double cropping with soybean fluctuated between 1200-1500 kg seed ha^{-1}. Yet, there are many answered questions on camelina management. New research will allow to optimize the management of camelina interseeding system to optimize the yield of both crops while enhancing many ecosystem services.

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COMPARATIVE STUDIES AMONG SEVERAL CASTOR HYBRIS/VARIETIES IN GREECE

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Castor (*Ricinus communis* L.) is a crop indigenous to the south eastern Mediterranean Basin, Eastern Africa, and India and it is cultivated for its non-edible oilseed. Castor seed is the source of castor oil that has a variety of uses. The castor seeds contain between 40% and 60% oil that is rich in triglycerides, mainly ricinolein. In South Europe castor can be cultivated as annual spring crop sown in March to April and the growing period last 120 to 140 days. It can be inserted in the existing agricultural systems and when in a rotation scheme maize follow castor the yields of maize can be increased. In the framework of the EU project EUROBIOREF (www.eurobioref.org) castor was compared with a number of oil crops (such as cuphea, lesquerella, safflower, etc.) for a period of four years (2010-4) in central Greece. In some of these trials the castor seeds were sent by Kaiima (www.kaiima.com). In 2015 another field trial was established in central Greece. In this trial, established in the middle of April 2015, seven hybrids/genotypes were compared in three blocks following a randomized complete block design. The tested hybrids were imported from Kaiima (Kaiima 93, C1008, C854, C855, and C856), while the two genotypes were collected from the plants grown in Cephalonia island (green and red genotypes). It should be pointed out that the two local genotypes are perennial types in Greece and they can be formed in a tree shape. The final harvest for all hybrids/genotypes took place in the middle of September 2015 (19/9) and at that time the local genotypes were developed higher plants compared to the ones imported from KAIIMA (2.4 vs.1.5 m). At the same type the KAIIMA hybrids gave significantly higher number of capsules per plant compared to local genotypes (145 vs 103 capsules per plant). Moreover, higher number of immature capsules was measured for the local genotypes (17% vs 30%). Among the hybrids provided from KAIIMA the highest seed yields (as harvested) were recorded by C854 (2.78 t/ha) and the least by Kaiima 93 (2.14 t/ha). The two local genotypes that were compared with the Kaiima hybrids gave 1.40 t/ha (green genotype) and 2.20 t/ha (red genotype). It's worth mentioning that the plant residues (after the seeds removal) varied from 2 to 3 t/ha (oven-dried). It should be mentioned that the moisture content on the remaining biomass was quite high (mean moisture content 80%).

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BRINGING BACK CASTOR (*Ricinus communis* L.) TO EUROPE: A PROMISING MULTIPURPOSE CROP

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Despite massive interest by EU bio-based industry on castor (about 25% of world castor oil is currently used in EU), the domestic cultivation area is practically inexistent, and castor oil is almost 100% imported. On the other hand, castor plant is very suited to European climate and spontaneous ecotypes are often occurring in the Mediterranean basin. The domestic development of castor crop would result in very attractive opportunities. Growing castor in Europe would also allow to complementary use biomass for high-value bio-based products and not only the oil extracted from seeds. Castor typically produces a large amount of biomass (i.e., leaves), that might be profitably used to feed a castor-specific silkworm (*Samia cynthia ricini*) from which extract large quantities of textile fiber, oil and protein. A screening trial comparing four different hybrids of castor (C855, C856, Kaiima 93 and C854) was set in Bologna (Italy) and Aliartos (Greece) during spring/summer 2015. Sowing took place at the end of April in Greece and three weeks later in Italy. The plots were rainfed in northern Italy, while in Greece drip irrigation system was needed. Harvest took place manually when the majority of racemes reached full maturity (second half of September in both locations). Furthermore, two hybrids (C855 and C856), selected for contrasting earliness and morphological aspects, were sowed in big strips in Bologna, in order to use leaves as artificial diets for rearing of the wild-silk-moth. The artificial diets were prepared starting from both green (GADiet) and senescent leaves (SADiet), and the insect rearing performance was evaluated in comparison to a standard breeding on fresh leaves (FCLeaf).Castor hybrids demonstrated to be well adapted to both Mediterranean environments. The supplied irrigation in Greece caused much more vigorous plants (almost double height in Aliartos, av. value 1.64 m, than in Bologna). Seed yield was also significantly higher in Greece than in Italy (+35% on average); interestingly, the two best performing hybrids (C855 and C856) were the same in the two locations. Concerning the artificial diets, no differences emerged between the two hybrids. Even if the performance of the artificial diets were inferior compared to the fresh castor leaves, the larvae fed with artificial diets were able to complete the development until the cocoon spinning. The administration of artificial diets caused higher mortality (14.7% for SADiet and 11.5% for GADiet vs. 4.5% of FCLeaf), the general elongation of the duration of larval stage (30.3 d for SADiet and 23.8 d for GADiet vs.17 d of FCLeaf) and the lowering of the cocoon weight (0.12 g/cocoon for SADiet and 0.28 g/cocoon for GADiet vs. 0.30 g/cocoon of FCLeaf).Castor cultivation can be likely extended to the whole Mediterranean basin (under both northern and southern Mediterranean climates); shorter hybrids were more productive in both locations. The possible set up of an artificial diet to rear the silkworms based on senescent castor leaves can be an interesting and practical route, although further researches are needed to optimize this technique.

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CASTOR (*Ricinus communis*) PLANTS ESTABLISH INTERPLANT HIERARCHY ACCORDING TO THE PLANTING DENSITY

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This study was made aiming to shed light on the effect of plant density on castor (*Ricinus communis* L.) seed yield with an approach that considers individual plants rather than the plant community. The hypothesis is that castor seed yield is influenced by interplant hierarchy, which is established in response to the plant density. Three experiments were performed: i) a factorial study of six cultivars and four plant densities; ii) a study on 48 individual plants, in a temperate environment (Lubbock, TX, USA), with interplant distance varying randomly between 0.14 and 1.26 m; and iii) a study on 84 individual plants, in a tropical environment (Balsas, MA, Brazil), at stipulated plant distance varying from 0.20 to 1.09 m. In the first experiment, data was taken on seed yield components, and in the other two experiments, data was taken on seed yield and on leaf area and plant height along the cropping season. Plant hierarchy was calculated as the leaf area or plant height of a given plant dived by the average of the two neighboring plants. In the experiment of varieties vs. densities, seed yield was influenced by plant density in only one cultivar out of six, and most of the adaptation to density occurred in the number of racemes. In the temperate environment, as early as 10 days after emergence, the plant hierarchy in leaf area was correlated with the final seed yield (r= 0.36*). The hierarchy (plant height and leaf area) changed considerably along the cropping season, and the plants that dominated in leaf area and height around flowering time had higher seed yield than the plants that established domination later in the growing season. Seed yield was poorly correlated with plant density in temperate conditions. In tropical conditions, narrow plant spacing was associated with higher seed yield. However, seed yield was similar in dominating and dominated plants. The role of interplant hierarchy is more intense under high plant density. In conclusion, it was found that the response of a castor plant field to high plant density occurs with intensification of the interplant hierarchy. Measuring the effect of plant density based on the average is simplistic because under increased interplant competition each individual plant has a different response depending on its hierarchy.

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ABSTRACTS

FIBERS AND CELLULOSIC CROPS DIVISION

ORAL PRESENTATIONS

CHAIR

DILPREET BAJWA, NORTH DAKOTA STATE UNIVERSITY

CELLULOSE FIBER REINFORCED 'GREEN' COMPOSITES

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Fiber reinforced plastics (composites) have been replacing metals in many applications. Most of the current composites are made using fibers and resins that are derived from non-sustainable petroleum. They have excellent mechanical properties and low density resulting in high specific properties. However, they tend to be non-degradable, non-recyclable and in most cases non-reusable. As a result, most of them end up in landfills at the end of their useful life. Green composites made using fibers and resins derived from plants on the other hand are fully sustainable and can be composted, eliminating need for landfills. While the research to develop 100% plant based fully green composites began only 25-30 years ago, significant progress has been made to date. Plant fiber reinforced green composites with properties similar or better than wood can be found in many applications from automobile parts to housing and from furniture to packaging. The technology has advanced to a stage where Advanced Green Composites with high strength, high stiffness and toughness comparable to Kevlar® based composites can now be made using cellulosic fibers. This talk will present an overview of the research progress made in the field of green composites and present some future directions.

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EFFECT OF UV WEATHERING ON DDGS FIBER FILLED THERMOPLASTIC COMPOSITE

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Distiller's Dried Grain with Solubles (DDGS) is a major co-product of corn ethanol production through dry grind fermentation. The corn ethanol plants in the US produced 39 million tons of DDGS in 2015. Due to the nutritive value of DDGS, it has mainly been used as a feed. But with increased production of ethanol, it is imperative to develop new value-added applications for DDGS, which will bring additional revenues to the refineries. The objective of this study was to evaluate the effects of ultraviolet (UV) weathering on fiber fraction of DDGS as a filler in high density polyethylene (HDPE) composites. The grain hull fibers from DDGS and corn and oak fibers (as control treatment) were grinded in a Wiley mill (Model 4, Thomas Scientific, NJ, USA), and further particle sized to 30-60 mesh (0.250 mm-0.595 mm) using a ro-tap shaker (W.S. Tyler® Ro-Tap® 8in Sieve Shaker, 230V/50Hz, USA). Six different composite formulations were designed with different combinations of the fibers and HDPE polymer (Petrothene LB 010000, Equistar Chemicals, TX, USA). The mixture was compounded and extruded into 102 cm × 1 cm profiles with a twin extruder to manufacture composite samples. The samples were tested for different physico-mechanical properties such as water absorption (ASTM D1037-12), specific gravity (ASTM D6111-13a), flexural (ASTM D7264-15), compression (ASTM D6108-13) and impact (ASTM D256-10) properties. To study the degradation effect by UV light, all the samples were exposed to UV in a QUV weatherometer (Q-LAB, OH, USA) for 2000 h. After finishing the weathering of samples, the same set of tests were performed on UV exposed samples to understand the effect of UV weathering on composite properties. The DDGS fiber composites absorbed the least moisture of 4.47% of all the samples tested for 18 days for their water absorption capacities. Also, the flexural results from the UV weathered samples showed that the DDGS fiber based composites were able to retain 70% of stiffness of the unweathered DDGS based samples. DDGS fiber can be used as an economically alternative material as filler to wood fiber in thermoplastic composite materials.

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STATISTICAL MODELLING OF NATURAL RUBBER COMPOSITES PROPERTIES BASED ON FILLER'S CHARACTERISTICS

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The reinforcement of rubber by fillers has been of great interest for decades. However, most of the research has focused on carbon black and silica. These studies have identified morphological and physicochemical characteristics of the filler, namely, particle structure, specific surface area and surface energy as the primary factors influencing the reinforcement of natural rubber by fillers. Yet, there is still a lack of practical models to predict resulting mechanical properties of rubber composites, particularly for non-conventional fillers. The objective of this study was to develop data-driven models to predict tensile properties of natural rubber composites containing different low cost, waste-derived fillers. Two statistical models, additive and multiplicative, were developed based on filler's characteristics and experimental data from previous studies using multiple linear regression analysis. Principal component analysis was used to evaluate the correlation among explanatory variables. New independent explanatory variables were developed, to replace the correlated variables. The results were simplified models that described the relationships between the parameters associated to the waste-derived filler characteristics and various composites mechanical properties (tensile strength, 300% modulus and ultimate elongation). Agro-industrial byproducts such as lignocellulosic materials are generated in large quantities and could potentially serve as alternative, more sustainable filler sources for polymer composites. Although, the accurate prediction of the effect of these types of filler over the composite final properties involves very complex mechanisms, these models can facilitate the screening of a wide variety of these materials while minimizing extensive laboratory work.

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ENHANCEMENT OF TERMITE RESISTANCE IN MYCELIUM REINFORCED BIOFIBER-COMPOSITES

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The demand for eco-friendly sustainable packaging materials with minimum environmental impact and ecological footprint has been growing for the last several decades. According to U.S. Environmental Protection Agency 2012 data, only 2.8 million tons (8.8 %) of the total 32 million tons of plastics waste generated in the U.S. was recycled. From an ecological standpoint, synthetic plastics are essentially inert due to low chemical reactivity, and cause major pollution to environment and ecosystem. There is a growing interest for biodegradable or compostable packaging materials. Bio-composite materials discussed in this study refers to a fully biodegradable composite product made from 100% bio-derived substrates, such as fungus mycelium and ligno-cellulosic fibers, as reinforcement. The composite material is a patented technology, developed by Ecovative Design LLC (Green Island, NY). Since the biocomposite material is derived from cellulose, it is prone to termite attack. Therefore, the objective of the study was to identify natural and safe termiticide that can be applied to mycelium-based biocomposites to improve their resistance to biological attack. In this research mycelium reinforced bio-composite boards manufactured from kenaf (*Hibiscus cannabinus* L.), hemp (*Cannabis sativa* L.) and corn fibers at two different densities, and reinforced by three different strains of fungi were evaluated for termite resistance. Four termiticides namely cedar oil, vetiver oil, borax, and guayule (*Parthenium argentatum* L.) resin were manually applied on the composite material surface. The treated boards were evaluated for termite resistance in accordance with ASTM D3345-01. Three replications of each sample material, were individually placed in specimen bottles and exposed to 1 g (approximately 100 count) of termites for 90 days. At the end of the test, the termite mortality rate, sample weight loss and surface characteristics of samples were recorded. The results showed significant interaction between different types of termiticides, nature of cellulosic fiber, and fungus strain. Borax treatment was least effective as termiticide. Kenaf and hemp samples treated with guayule oil showed maximum resistance to termites, followed by vetiver oil. Overall the weight loss for treated and untreated samples ranged between 17.4%-33.7%, and 19.9% -55.8% respectively. The findings of this study show that natural oils and resin can be used as surface treatment on mycelium based biofiber-composite materials to improve their termite resistance.

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PROCESSING AND MANUFACTURE OF SOYBEAN AND WHEAT STRAW MEDIUM DENSITY FIBERBOARD UTILIZING EPOXIDIZED SUCROSE SOYATE RESIN

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Supplementing wood fiber supply with other lignocellulosic materials and identifying formaldehyde-free resin binders are issues that are at the forefront of the fiberboard industry. Soybean straw [*Glycine max (*L.) merr.] and wheat (*Triticum aestivum* L.) straw show promise as annually renewable alternatives to traditional wood fiber sources. Epoxidized sucrose esters of fatty acids or epoxidized sucrose soyate (when produced from soybean oil) have shown versatility as a thermosetting resin and as a formaldehyde-free binder that could be adapted for use in the fiberboard industry. The objective of this study is to evaluate the physical and mechanical properties of medium density fiberboard using wheat and soy straw while using binder systems containing methylene diphenyl diisocyanate (MDI) and epoxidized sucrose soyate (ESS) resins. Additionally, the study investigated various factors affecting the milling of wheat and soy straw fibers, with the fines content and the viable fraction of fibers from hammer milling being the responses of interest. Several spectroscopy and mechanical tests were conducted in order to evaluate any interactions between MDI and ESS and to characterize their properties. Previously milled soy and wheat straw fibers were conditioned to 10 wt% moisture until pressing was performed using a Carver lab hot press. Boards were made using either only wheat or soy straw and four resin binder systems at a 4 wt% loading with the target density of the boards being 640 kg/m^3. Boards made with wheat straw and MDI resin acted as the control. Board properties were tested using the methodology outlined in ASTM D1037 as a guideline. Hammer milling of wheat and soy straw was also conducted with the fiber moisture content, milling speed, and screen size being varied to see the effect on fines generation and the resultant viable fiber fraction produced. ESS was successfully blended with MDI resin with minimal changes to board properties. However, no significant chemical reaction between the two resins was observed. Boards made from soy straw showed similar properties to that of the control boards, with the only significant variance being a superior screw withdrawal resistance and water resistance for the wheat boards. Optimal levels for minimizing fines generation and maximizing the viable fraction for soy and wheat straw were identified. Medium density fiberboard can be produced from wheat or soy straw with minimal changes in properties. Boards made with ESS and MDI blends can also be produced with minimal changes to properties, but further evaluations of resin blends are warranted. Varying the fiber moisture content, milling speed, and screen size in hammer milling of straw produces significant effects for fines generation and the resultant viable fraction and can produce significant performance improvements and cost reduction at an industrial level.

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THE IMPORTANCE OF BAST FIBER CROPS AS FEEDSTOCK FOR BIOBASED PRODUCTS AND BIOENERGY

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Fiber crops are valuable feedstock for biobased products (textile industry, eco-friendly building materials, particleboards, insulation boards, cosmetics, medicine, bio-polymers, agro-chemicals, etc.) and bioenergy. In the light of a strong renewed interest in fiber crops and sustainable biobased production chains as well as the relevant research activity on fiber crops carried out from Europe and China a project entitled FIBRA (www.fibrafp7.net) was established in 2012. FIBRA project was a sound link between EU and China that will lead to a wider stakeholders' participation, while providing a long term vision on future and common research activities between EU and the Republic of China. In FIBRA project emphasis is being given in two categories of fiber crops the *bast fiber crops* (flax, hemp, kenaf, ramie, nettle, and jute) as a fiber group of crops for both Europe and China. The area of *fiber flax* cultivation in Europe is around 80,000 ha, while in China has been reduced a lot and not exceed 10,000 ha. The straw yields varied from 0.9 to 7 t/ha, while the seeds yields from 390 to 930 kg/ha. The achieved yields of flax in Europe came up to 70% of the potential fiber and seed yields. In Poland had been found that the best crops before flax in rotation are cereals, especially oats. The *area of hemp cultivation* is quite smaller compared to fiber flax and at world level is around 80,000 ha and almost 25% of the total area is found in Europe. It is a crop with a rapid grow and in 100 days can reach a height of 4 m and its moderate yields can be 10 t/ha. Its consumption of fertilizers or irrigation is modest and hemp crops suppress weeds and some soil-borne diseases and at the end of its cultivation the soil condition is healthier and improved. It is considered a good forecrop for cereals cultivation. Hemp absorbs heavy metals such as Cd, Pb, Zn, Cu, contribute to the recultivation of contaminated soils. It could be a plant for recultivation. It is considered that has relative resistance to periodic water shortage. *Jute* is considered a quite important fiber crop next to cotton. Jute represents the 70% of the global production of bast fiber crops. China is the third largest area of jute cultivation in the world. There are some elite jute varieties planted in China, such as Meifeng No.4, Jute 179, Fuhuangma No.3, Zhonghuangma No.1, No.2, and Fujute 1, 2, 3 and Yueyuan No.5. The average raw fiber yield of new elite varieties can reach 7500 kg/ha, while the fine fiber yield can reach 4000 kg/ha. *Ramie* is commonly known as China grass that can be harvested from 3 to 6 times a year. Ramie is one of the strongest natural fibers and it is strong even when wet. Like linen, it will break if folded repeatedly in the same place. The dry weight of raw stem fiber ranges from 3.4 to 4.5 t/ha/year. With yields 4.5 t/ha/year dry raw fiber 1.6 t/ha/year of dry non-de-gummed fiber can be obtained. The area of cultivation *kenaf* is much smaller compared to the above mentioned crops. It reached its highest cultivation area in China in 1980's. The last years high yielding varieties have been developed (H328 and H386) with up to 7,500 kg fiber/ha (30 ton dry stalk/ha). Because the crop hosts the root-knot nematodes crops that are sensitive to these should be avoid following kenaf cultivation such as cotton and peanut.

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INDUSTRIAL HEMP (*Cannabis sativa* L.) STAND ESTABLISHMENT AND YIELD IN NORTH DAKOTA

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Seed quality aspects, germination and vigor, often interact with soil properties and weather to influence live seed emergence and initial crop stand establishment. Industrial hemp can exhibit varying stand establishment with seedling mortality ranging from 20 to 50% under average conditions and approaching 100% under poor stand establishment conditions. Studies at Langdon, ND, in the 2015 and 2016 seasons evaluated 15 industrial hemp varieties from Canada, France, and Australia, for germination, live-seed emergence, seedling mortality, stand density, flowering, plant height, seed oil content, seed weight, THC tissue content, and grain, biomass, and fiber yield. In 2015, seedling mortality ranged from 48 to 82% when sown on May 27 under average conditions. Seedling mortality from June 5 seedings, in 2015, ranged from 91 to 97% and were greatly influenced by heavy rains after seeding, which caused soil crusting. Reseeding on June 16 resulted in reduced seedling mortality values from 48 to 56% for the same varieties. Industrial hemp seedling mortality for nine varieties ranged from 39 to 58% and 64 to 72% from May 24 and June 20 seedings, respectively, in 2016, where later seedings received high rainfall that caused excessively wet soil conditions. Resulting industrial hemp plant densities were approximately 30 to 50% of ideal stands and their influence on yield was not clear, since comparative normal stands were not present. Seed vigor and plant density studies are needed in the near future to provide producers with information to achieve optimum stands and yield performance.

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ABSTRACTS

GENERAL CROPS DIVISION

ORAL PRESENTATIONS

CHAIR

EFTHYMIA ALEXOPOULOU, CRES, GREECE

PRODUCTION OF INDUSTRIAL CROPS IN MARGINAL SOILS – IS IT A SUSTAINABLE OPTION?

Ana Luisa Fernando

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An increasing global awareness that the supply and security of petroleum-based materials is diminishing, coupled with environmental concerns related to climate change, water availability, and soil degradation, has increased demand for more renewable, diversified, and sustainable systems, of which biomass resources are one of the pillars. Yet, the demand for biomasses may increase sharply, thus increasing the risk of conflicts on land use due to competition for food and feed. Hence, segregating the growth of dedicated biomass crops on marginal land is an option to overcome these conflicts. Therefore, the objective of this work was to determine if producing industrial crops on marginal soils as feedstock for bioenergy and biomaterials, could reduce greenhouse gas (GHG) emissions without depleting soil nutrients, water supplies, or negatively impacting biological and landscape diversity. Investigated crops include perennial grasses, such as *Miscanthus* (*Miscanthus* × *giganteus* Greef et Deu) or giant reed (*Arundo donax* L.) and annual crops, such as kenaf (*Hibiscus cannabinus* L.), sorghum (*Sorghum bicolor* (L.) Moench) or rapeseed (*Brassica napus* L.). Effects of cultivating these grasses on the biodiversity, soil quality and erosion, the use of water and landscape, as well as effects on GHG emissions, acidifying emissions and eutrophication emissions were evaluated and opportunities and constraints associated with its cultivation on marginal soils were assessed. Life Cycle Assessment (LCA) and Environmental Impact Assessment (EIA) protocols were used in the evaluation. Results indicate that sustainability of industrial crops production in marginal soils depends on the productivity. The productivity loss diminishes the energy, and the greenhouse savings but the presence of vegetation may contribute to improve the quality of soil and waters and the biological and landscape diversity. Perennial crops present and added advantage towards annual crops, in terms of erodibility potential, disturbance of soil properties, hydrological impacts and biological and landscape diversity due to less tillage and high biomass production. However, a higher land area is demanded to produce the same amount of biomass feedstock and the quality of the biomass may limit its use.

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SWITCHGRASS: AN IDEAL PERENNIAL CROP FOR MARGINAL LANDS

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Perennial grasses considered as ideal feedstock for both bioenergy and biobased products. The main reasons that make perennial grasses attractive feedstock for biomass production are: their high biomass yields, the high contents of lignin, cellulose and hemicellulose polysaccharides and their positive social and environmental benefits. Perennial grasses are also not seen as competing for agricultural land because they can be grown on marginal or degraded lands where intensive agricultural practices harm the environment and where the economic returns to the farmer's labour and capital are not sustainable. Switchgrass (*Panicum virgatum* L.) is a perennial grass that has the advantage to establish by seeds and can be cultivated successfully in most climatic areas of Europe due to the fact that there are appropriate varieties for both cold and hot areas. It is being used in America for soil erosion control, fodder and recently for energy purposes as a biomass crop for ethanol production. Its yields vary from 8 to 25 t/ha depending on the site and the variety. In European context, the crop has been investigated in the projects FAIR-CT97-3701 (www.switchgrass.nl) and ENK6-CT2001-00524 (www.cres.gr/bioenergy_chains), while recently it has been included in the projects OPTIMA (www.optimafp7.eu).In Greece in the view of the Switchgrass project two trials have been established. The purpose of these trials were: a) to evaluate the crops yields under marginal fields for long term, b) to evaluate the effect of nitrogen fertilisation rates on biomass productive of the crops, c) to evaluate a series of switchgrass varieties (10 in total; lowland and upland ones). During all growing periods (1998-2015), a series of measurements were carried out including canopy height, number of tillers per square meter, number of tillers per plant and number of leaves per tiller. At the end of each growing season a final harvest took place (4 m^2 per plot) after a killing frost in order to determine the fresh and dry matter yields and yields components.The biomass yields were maximized in the second growing period and the mean dry matter yields were 19.99 t/ha. In the third growing period the yields were reduced and were 15.48 t/ha. This reduction was continued in the fourth year but from the year 4 until the year 14 the recorded dry matter yields were remained more or less the same. The dry matter yields varied from 12 to 14 t/ha. It should be pointed out that in all years the lowlands varieties gave significant higher biomass yields compared to the upland ones. At the same time the stems of the lowland varieties were quite resistant to lodging, while in the plots of the upland varieties lodging problems were recorded at the end of the summer after a heavy rain.In the first years no significant effect of nitrogen fertilization on growth and yields were recorded. In the year 5 some differences were recorded. From the year 6 until the year 14 the mean dry yields in the plots that received zero nitrogen fertilization rate was around 10t/ha, while in the plots that received 75 kg N/ha was 13.5 t/ha and in the plots with 150 kg N/ha was 15.8 t/ha. It should be pointed out that in the 15th growing period a sharp decline of switchgrass yields were recorded in both field trials and the fields looked quite old.

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ECOSYSTEM GAS EXCHANGE OF SWITCHGRASS IN THE MEDITERRANEAN AREA

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Switchgrass (*Panicum virgatum* L.) is a fast-growing perennial grass, that has gained importance as a feedstock for biofuel production in substitution of fossil fuels to reduce atmospheric greenhouse gases (GHGs) emissions. Life cycle assessment of switchgrass evidenced a considerable larger GHGs savings potential by e.g. ethanol-switchgrass compared to corn, soybean, alfalfa, and fossil fuels. GHG reduction potential is also linked to the ability to sequester carbon, as result of the balance between assimilation and emission, respectively representing photosynthesis and respiration, which in an open field is the result of plant and soil interaction (agro-ecosystem). While aboveground CO_2 fixation of a crop can be easily estimated, respiration and belowground biomass are difficult to measure, especially at a large field scale. Although switchgrass is generally recognized to be able to sequester significant amounts of soil carbon, literature lack of information on measured carbon storage potentials of switchgrass, and more generally perennial grasses, in the Mediterranean area, and especially at ecosystem level. Moreover, studies conducted on different environments than Mediterranean show very variable results. Therefore, in the present study we used the eddy covariance tower to monitor in a nearly continuous mode the exchange rate of CO_2 between the atmosphere and plant canopy in a 5-ha rainfed switchgrass located in the Po Valley, North Italy, for three consecutive years. After three years of cultivation, switchgrass ecosystem adsorbed 170.82 Mg CO_2/ha (gross primary production), of which 70.75 Mg CO_2/ha (net ecosystem exchange) fixed by the ecosystem and 18.27 Mg CO_2/ha in the soil. The aboveground biomass increased from 6.9 to 15.8 Mg/ha from the first to the third year. The accomplishment of the production of high quantities of biomass to support the development of the bio based economy should also be addressed by minimizing water competition with food crops, thus considering the water use efficiency (WUE) a crucial trait when selecting most appropriate biomass crops. The eddy covariance tower also gave the possibility to monitor water fluxes between the atmosphere and the plant canopy. Switchgrass ecosystem showed a considerable water use efficiency (WUE): about 82 m^3 of water were used to fix a Mg of CO_2, corresponding to 6.9 mg of fixed CO_2 each gram of H_2O. From 55% to 59% of annual precipitation was used. Even if during the establishment year both carbon fixation and water use efficiency were lower, the field resulted to behave as C sink during all years. Large scale conversion of land with switchgrass would not have negative effect for local water balance in the investigated area under North Mediterranean conditions and will ensure net biomass fixation. Long-term monitoring is required to define how long switchgrass cultivation will act as sink of C, also considering the removal of harvested biomass from the field.This work was funded by the FP7 OPTIMA project “Optimization of Perennial Grasses for Biomass production (Grant Agreement 289642)”.

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IS IT SUSTAINABLE TO PRODUCE *MISCANTHUS* X *GIGANTEUS* GREEF ET DEU IN SEWAGE SLUDGE CONTAMINATED SOILS?

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The use of biomass as feedstock for energy and biomaterials has been promoted as an opportunity to sustain energy security, contributing to the rural development. According to the European Commission, increasing the use of biomass in the EU can help diversify Europe's energy supply and create growth and jobs. *Miscanthus* x *giganteus* Greef et Deu is a lignocellulose rhizomatous crop being considered as a viable substitute to non-renewable energy sources. Yet, as the risk of conflicts on land use due to competition for food and feed, is increasing, segregating the growth of dedicated energy crops on marginal land is an option to overcome these conflicts. Therefore, the aim of this study was to evaluate the environmental sustainability of *Miscanthus* x *giganteus* Greef et Deu production in sewage sludge contaminated soils, in Portugal. In this work, *Miscanthus* was cultivated in pilot fields with different levels of contamination: 50, 100 and 200 Mg (sludge)/ha, corresponding to half, the value and twice, the maximum deposition of sludge allowable by the European law. Results from non-contaminated fields were also used as control. Combustion of the biomass in a small CHP plant was the process considered as the end use of *Miscanthus*, once it is largely implemented, industrially and commercially. No significant differences were observed among the yields of *Miscanthus* obtained in contaminated and non-contaminated soils. Effectively, results from the pilot field studies showed that no phytotoxicity was observed, and the yields obtained were even higher in the fields with sludge then in the fields without sludge. Therefore, the energy balance and the greenhouse savings were similar or even higher than in the control pots. Moreover, the presence of vegetation contributed to improve the quality of soil and waters and the biological and landscape diversity. Nevertheless, biomass obtained from contaminated soils presented a higher ash and nitrogen content, which can be detrimental for the exploitation of the biomass. However, balancing benefits and constraints of the production of *Miscanthus* in sewage sludge contaminated soils showed that it represents an opportunity to produce sustainable biomass in a resource constrained World.

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PLANTING SWEET SORGHUM [*Sorghum bicolor* (L.) Moench] IN CLUMPS REDUCES LODGING BUT NOT YIELDS

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Since the rise of the biofuel industry, sweet sorghum [*Sorghum bicolor* (L.) Moench] has been an attractive crop due to the high yields of fermentable juice as well as fibrous biomass, with lower requirements than other crops and high water use efficiency. Previous work has shown that stalks planted closer together in regular rows are thinner, weigh less, and yield less juice than ones planted further apart, probably due to competition for light. However, some crops grown in hills or clumps benefit from conservation of soil moisture and mutual shading, especially in marginal climates. This study examined the effects of planting sweet sorghum in clumps compared to regular rows. Four varieties (Cowley, Hodo, M81E, and Mer74-2) were sown on May 26, 2015 in a split-plot design, with arrangement (hill or normal) as main plot and variety as sub-plot, with four replications. Normal rows were planted with a tractor-driven grain drill at 18 seeds m^{-1}. Hills were hand-planted as a cluster of three to five seed every 0.5 m. Each variety was harvested 30 days after half of the plants were flowering (172 to 176 days after planting). A 3.05 m section from one harvest row (out of four-row plots) was cut at the soil line and weighed. A subsample of ten plants was weighed with and without leaves and panicles separately. Stem diameters were measured before the stalks were passed through a roller mill and juice collected and weighed. Juice samples were analyzed by HPLC with a refractive index detector. Stems in the hills were significantly greater than those in the regular rows. Weights of the subsamples and juice were also significantly higher in the hills. However, field weight showed no significant difference between treatments. Plants in normal rows were smaller but there were more of them per area than in the hills. There were no differences in number of leaves, but the overall weight was significantly different. Further investigation revealed that this was due to leaf width and area, but not length. Overall rate of lodging was significantly lower in the hills (11.2% versus 59.4%), indicating that stalks in clumps might offer each other support, or that thicker ones are less susceptible to lodging. Growing small grains in clumps has been shown to improve yields, partly due to conservation of soil moisture: the effects of wind are reduced and transpiration rates are lower, which is especially important under dryland conditions. In the case of sweet sorghum grown in Arizona, greater water use efficiency and leaf area appear to be two advantages of planting in clumps, yielding thicker, sturdier stalks with more juice.

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SEED TECHNOLOGY OF EASTERN GAMAGRASS [*Tripsacum dactyloides*] TO ENHANCE GERMINATION AND SEEDLING SURVIVAL AND BREAK DORMANCY

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Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a US native perennial warm-season grass that commonly has low seed germination. Previous research has shown that seed dormancy and low germination rates of eastern gamagrass are attributed to tissues surrounding the embryo. Thus, mechanical seed treatments that break the integrity of the cupule and pericarp may reduce seed dormancy and improve germination. Cold moist stratification (pre-chilling) is the most effective and therefore the commonly recommended treatment for breaking dormancy of perennial warm-season grasses. However, drying after stratification may induce dormancy, termed dormancy reversion. Combinations of mechanical seed treatments following post-drying of stratified seed may have the potential to reduce or eliminate dormancy reversion. Fungicide seed treatments have been widely used to protect seeds from fungal infections and improve germination, seedling growth and survival. Severe internal fungal contamination of eastern gamagrass seed is routinely observed in laboratory germination tests. Conventional seed treatments may reduce the incidence of both seed-borne pathogens and non-pathogenic contaminants, but these seed treatments may also induce phytotoxicity. Novel fungicidal seed treatments are needed to eradicate internal pathogens and not injure the germinating seedlings. This study was conducted to develop technologies to break seed dormancy and enhance germination and seedling survival of eastern gamagrass. Germination tests for all seed treatments were carried out at an alternating temperature of 20/30 °C (16/8 hours). Intact cupules and non-scarified caryopses of selected seed lots of 'Pete' and 'Meadowcrest' all had a percentage of dormant seeds. A method of physically removing the caryopsis from the cupule and then scarifying the caryopsis was previously described in the literature and termed scarified caryopsis (SC). Our lab developed a one-step method of just grinding the top of the seed, termed cupulated caryopsis top removal (CCTR). CCTR breaks the integrity of both the cupule and pericarp and germination test results were comparable for CCTR with SC treatments in breaking dormancy. Moreover, the SC method was time consuming and tedious, while CCTR was rapid and has potential for large-scale commercial use. Additionally stratification for 8 and 12 weeks completely broke dormancy of two seed lots tested. Post-drying following stratification caused dormancy reversion; however, reversion was overcome by CCTR treatment. Four weeks of post-storage following post-drying did not adversely affect germination. The fungicide seed treatment using captan or thiram significantly ($P < 0.01$) reduced germination of CCTR treatments, which was attributed to phytotoxicity of the seed treatments. Pyraclostrobin and fluxapyroxad seed treatments had the best control of fungal seed contaminants and final percentage germination when applied singly or in combination. The fungicide combination of pyraclostrobin and fluxapyroxad also resulted in the highest percentage seedling survival in germination tests.

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ABSTRACTS

RUBBER AND RESINS DIVISION

ORAL PRESENTATIONS

CHAIR

KATRINA CORNISH, THE OHIO STATE UNIVERSITY

SECURING THE FUTURE OF NATURAL RUBBER-AN AMERICAN TIRE AND BIOENERGY PLATFORM FROM GUAYULE

Howard Colvin

Cooper Tire & Rubber Company

In 2011, a team was formed under a government grant consisting of members from industry, government and academia with the objectives of defining the guayule (*Parthenium argentatum* Gray) genome, developing genetic tools to leverage the genome, improving guayule agriculture, developing guayule rubber isolation technology and exploring the feasibility of developing a concept tire with the rubber components made of guayule or guayule derived rubber. An overarching element of this effort would be a study evaluating the three pillars of sustainability to determine the impact of guayule production on communities where it would be grown, processed and used. This Cooper-led program was funded in 2012 and work is expected to be completed in 2017. This paper provides an overview of the progress made to date and next steps to complete the work.

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EUROPEAN GUAYULE MARKET

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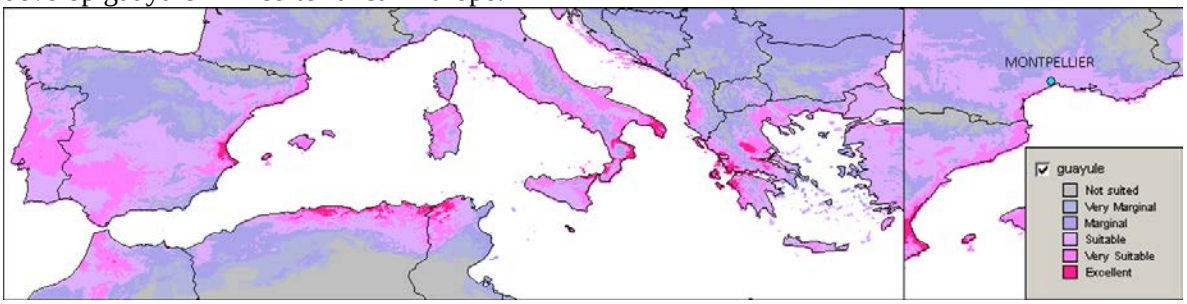
Some companies are involved in guayule market or research since years or decades (YULEX, PANARIDUS, ENERGYENE, BRIDGESTONE, COOPERTIRES, PIRELLI, VERSALIS). Each company has its own strategy: focusing on high value non allergenic latex, producing end-products (tires, gloves) rather than to sale raw-material (latex and / or rubber), valorizing all the guayule (*Parthenium argentatum* Gray) co-products (latex, rubber, resin, bagasse…), increasing agricultural yield…..Some European research projects (EU-PEARLS) allowed to build a European guayule (but also Kazakh dandelion) knowledge, partnership and intellectual property especially on water extraction process. VERSALIS, an Italian company, is involved on sustainable polymer production, bio sourced monomer (for PLA synthesis) and bio polymers like guayule rubber. A key point for developing a sustainable guayule production chain would be boosted by an integrated approach for valorizing the whole bush, not only the rubber part, according to the bio refinery concept which requires a dedicated integrated process. CIRAD / CTTM patented process is the starting point of a European guayule natural rubber commodity chain for profitable and sustainable market. We will give some detail concerning CIRAD / CTTM strategy to help to develop guayule in Mediterranean Europe.



Suitable climatic areas for guayule cultivation in the Mediterranean region

Involvement of the Bio-Based Industry with Private and Public Partnership (BBI-PPP) is needed. The aim of several EU partners involved in a European Innovation Partnership (EIP) commitment is to support any project to recognize Guayule rubber as a critical raw material. Guayule field extension and access to a processing plant is needed at this stage in Europe. Demand for guayule latex and rubber is real, but for potential investors profitability has to be demonstrated at a semi-pilot scale before commercialization and substitution of 10% of the total NR import from Asia to be achieved by 2025.

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BIOMASS IMAGING AS A TOOL FOR ADDRESSING THE CHALLENGE OF MULTIPLE-PRODUCT GUAYULE BIOREFINERY

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R & D on guayule (*Parthenium argentatum* Gray) (G) has been driven for a century for securing rubber production (or polyisoprene, PI), a strategic feedstock for tire and glove industry. Sustainable development of G needs an efficient valorization of compounds in bark, wood, leaves, bringing an opportunity to apply the biorefinery concept. However to our knowledge there is no large scale G multiple-product chain. Bulk rubber can be extracted with solvent processes, or a latex can be obtained with an aqueous process enabling to feed tire and glove industry. Solvent processes use ground dry biomass which can be stored prior to extraction, whereas the aqueous process is based on grinding fresh biomass. These processes were set in Mexico and the United States were G is cultivated. G is now being acclimated in Southern Europe; CIRAD and CTTM are optimizing wet grinding steps for high quality latex production (patent application) towards an integrated "green" biorefinery. The chemical composition of EU G biomass (PI 8 %dw, resin 10%dw; total ~2 t/ha) confirms it as a suitable feedstock for producing a range of compounds (PI, terpenes, wax), but their extraction with water (for avoiding harmful solvents) brings a real challenge. Indeed while in hevea, rubber is located in laticifer ducts, G stores it inside cells, but resin is in ducts. To better understand biomass cellular structure and to map in situ biochemical compounds compartmentation and to study the effect of biomass processing on rubber, waxes and reisn extraction, we combined several imaging technologies (ie wide field or bright field, epifluorescence, multiphoton and real time microscopy). Our imaging approach allowed (i) to provide an accurate 3D description of secondary metabolites cellular compartmentation, and (ii) to describe the in situ dynamics of polyisoprene particles and understand the aqueous extraction process; for example flocculation or coagulation phenomena due to thermal effect upon grinding on the Brownian motion of particles within the cell. It is necessary to deal with conflicting goals: difficult release of PI particles in water (a non-solvent here); physiological, physicochemical stability of multi-phased systems; chemical constraints (degradation). By understanding the behavior of rubber particles under various thermal, chemical and physicochemical conditions, and dealing with the complex structure of biomass it was possible to monitor the extraction process. In a first step, the process (10kg/batch pilot) extracts up to 80% of high Mw rubber; resin is recovered in a second step with supercritical CO_2. Taken together, our results shows that imaging technologies open new routes for biomass processing to develop an integrated green biorefinery.

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NIRS MEASUREMENT AT FIELD LEVEL TO MEASURE RUBBER AND RESIN CONTENT OF GUAYULE PLANTS

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Natural rubber increasing worldwide demand and the effects of climatic changes emphasize the interest in developing guayule rubber as a commodity such as *Hevea* rubber from Asian plantations. Guayule (*Parthenium argentatum* Gray) will contribute to sustainable development in Mediterranean and southern countries where CIRAD operates its research activities. During the European EU-PEARLS project CIRAD has already worked on NIRS (Near infrared spectroscopy) laboratory measurement of guayule powder from dried branches, to measure water, rubber and resin content). The method is working well, but still time consuming. A new research development on NIRS aims at developing an even simpler and quicker method of resins and rubber contents by NIRS measurement on living guayule plants in the field, during their growth. The purpose is enabling (i) to monitor the evolution of biomass chemical composition over the whole cropping period, and (ii) to estimate harvest date. Indeed guayule type of reproduction leads to differing plants. Encouraging preliminary results about this new method developed in the experimental fields in Montpellier (France) are reported. This direct and simple method which is being experimented will provide a tool for a more efficient genetic selection, as a large number of analyses are needed in order to determine best lines.

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GUAYULE (*Parthenium argentatum* Gray) RUBBER PRODUCTION IN THE US DESERT WITH SURFACE AND SUBSURFACE DRIP IRRIGATION AND FIVE WATER LEVELS.

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Commercial production of guayule (*Parthenium argentatum* Gray) for natural rubber (NR) is expected to increase in the southwestern United States (US), inspired by US tire companies and others seeking domestic supplies to offset world-wide NR demands. One of the most important factors in commercializing guayule in arid desert regions is improving irrigation management to obtain economic rubber yields with judicious water use. Previous irrigation research conducted three or more decades ago provided insights on managing irrigation for guayule, however, several important inconsistencies in those earlier studies were never reconciled. Moreover, the improved guayule germplasms developed since then have not been studied in the context of yield responses to variable irrigation, particularly for subsurface drip irrigation (SDI). With an objective to expand existing guayule irrigation management knowledge, two irrigation field studies were conducted simultaneously on nearby, 1.4-ha fields in Maricopa, AZ: one using SDI, the other with the more common level-furrow, surface irrigation (SI) method. In October 2012, studies were initiated by transplanting guayule seedlings of Yulex-B, a line also under limited production in the area. The seedlings were spaced at 0.36-m, along 1.02-m wide x 100-m long rows. Each field consisted of 15 plots, five irrigation treatment levels and three replicates. In April 2013, irrigation treatments were imposed in a randomized complete block design using irrigation amounts of 40, 60, 80, 100 and 120% for the SI field and 25, 50, 75, 100 and 125% for the SDI field. Irrigations were given to all plots when ≈60-65% and ≈30-35% of measured available soil water of the root zone remained for the 100% treatments for the SI and SDI fields, respectively. Final plant harvests of 2 rows x 100 m for plots occurred in March 2015, after 29 months of growth. Destructive samplings of plants were also made 8 times prior to final harvest. Harvest measurements included dry biomass (DB) weights, and rubber and resin contents. Other field data included irrigation and soil water contents measurements. Total applied water, TWA, (which included all irrigation plus rainfall over 29 months) varied from 980 to 1950 mm/year for the SI study and from 860 to 2030 mm/year for the SDI. Final dry biomass (DB) increased significantly with irrigation water level, whereas highest rubber content occurred for the driest irrigation levels for both studies. The maximum DB achieved under SDI with 2030 mm/year of TWA was over twice the maximum attained with surface irrigation for similar TWA (1950 mm/year). For surface irrigation, final rubber yield (RY) varied from 1220 to 1680 kg/ha but mean RY was not significantly different for the three wettest treatments. For SDI, RY varied from 1350 to 3440 kg/ha and mean RY was significantly greater at the highest irrigation level than all other treatments. Based on these results, about 1500-1600 mm/year of TWA is recommended when using surface irrigation, although irrigation frequency should be maintained at regular 12-day intervals during summer months. This practice should attain near-maximum RY potential under SI but should also achieve high water use productivity (RY per unit TWA). However, with the much more frequent irrigation capability using SDI, the aim should be about 2000 mm/year of TWA. This practice should achieve significantly high RY without sacrificing high water use productivity.

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APPLICATIONS OF MODERN GENOMICS FOR DOMESTIC NATURAL RUBBER DEVELOPMENT: TAKING STOCK OF GUAYULE GERMPLASM

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Guayule (*Parthenium argentatum* A. Gray) is a perennial woody shrub native to the North American Chihuahuan Desert that holds promise as a sustainable source of natural rubber and hypoallergenic latex. However, development of high rubber yielding cultivars has met with only partial success, in large part due to a combination of limited genetic diversity in the source of germplasm, extensive polyploidy variation within and among the available guayule accessions, and a complex mode of reproduction that is characterized by sporophytic self-incompatibility in diploid plants and facultative apomixis (diplospory type) in polyploid plants. In order to assist the improvement of guayule for commercial-scale production, we evaluated 412 plant samples from 66 accessions of guayule and allied species which represent a complete sampling of the extant guayule public breeding stocks maintained by the National Arid Land Plant Genetic Resources Unit (NALPGRU) at Parlier, CA. We used flow cytometry to estimate ploidy levels and genotyping-by-sequencing (GBS) to simultaneously identify and genotype tens of thousands of single-nucleotide polymorphism (SNP) markers across all samples. Phylogenetic and population genetics analysis indicated that, in general, the genetic relationships among guayule plants are consistent with a history of focused breeding selections from only two distinct rounds of sampling from the same wild population. The only two diploid guayule accessions available appear genetically indistinguishable, indicating a single source of diploid guayule germplasm in this collection. We identified previously unknown multi-species hybrids in this collection, as well as aneuploidy and ploidy level variation within accessions, and selected a subset of accessions as a preliminary guayule diversity panel for this collection. The results of this study will lay the foundation for genomics-assisted breeding in guayule and provide a valuable resource for the development of a domestic natural rubber industry.This work was funded and supported by the USDA-ARS and USDA-NIFA/DOE Biomass Research and Development Initiative (BRDI) Grant No. 2012-10006

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PANARIDUS UPDATE ON GUAYULE PLANT BREEDING AND DIRECT SEEDING

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Guayule continues to show promise as a potential alternative source of natural rubber. Economic viability depends on highly productive shrub production on farm. Both genetic advancement and improved cultural practices are essential. Current practices for establishing the crop are not as cost effective and timely as desired. Commercialization will be greatly facilitated by successful, time efficient, low risk methods to direct seed guayule. Data will be presented showing plant breeding updates. Older public germplasm will be compared with initial PVP lines, as well as with new experimental lines. In addition, further methods and data will be presented on our proprietary direct seed procedure. We have successfully direct seeded guayule over four years and two locations. Our data suggests that direct seeded guayule produces significantly more biomass and rubber per hectare compared to transplanted guayule of the same age. Pictures and data will be presented showing biomass and rubber production in conventional (transplant) plots as compared to direct seeded plots at various levels of thinning.

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PHENOTYPIC CHARACTERIZATION OF GUAYULE USDA COLLECTION UNDER FIELD CONDITIONS

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Among the more than 2000 plant species that synthesize natural rubber (NR), only rubber tree (*Hevea brasiliensis* Muell. Arg.) and guayule (*Parthenium argentatum* A. Gray) are growing on commercial scale. Because of changes in NR demand, vulnerability of its prices, and the threats of rubber tree diseases and natural disasters, guayule is sustainable, domestic and alternative NR source as well resource for latex, resins, and biofuels. Guayule is a potential new crop for arid-lands and low input regions of southwestern USA. The USDA guayule collection containing 56 accessions of improved breeding materials and wild types collected from North Mexican and Southern Texas deserts, and are maintained at the National Arid Land Plant Genetic Resources Unit (NALPGRU) at Parlier, CA. Phenotypic characterization of guayule collection is required to accelerate guayule breeding and germplasm improvement. To phenotype USDA guayule collection, the accessions were grown in replicated field trial at Maricopa, AZ under two irrigation regimes, 100% and 50% field capacity. Morphological traits including plant height, canopy volume and perimeter, main branches number, stem thickness and leaf traits were measured. Initial results indicated the variations in growth vigor among guayule accessions under favorable growth conditions (100% field capacity). The growth vigor of guayule accessions were suppressed in response to drought stress (50% field capacity) compare to those grown under favorable conditions. These phenotypic variations among guayule accessions as well their variable response to the environmental stresses will lead to identifying parental candidates to be used in guayule breeding programs to increase the genetic gains of traits related to growth vigor, and consequently enhance rubber and latex yield and production.

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RATE OF APOMIXIS IN USDA GERMPLASM FOR GUAYULE BREEDING

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Genetic improvement of guayule (*Parthenium argentatum* Gray) has been a research focus of public institutions for many years and is currently a priority for Bridgestone. Polyploidy was well studied during the Emergency Rubber Project in the 1940's by counting chromosomes in root-tips or pollen mother cells, with appropriate stains. New research technologies and equipment allow us to advance our knowledge in a way that was previously too labor-intensive to be practical. An example of this is the use of a desk-top ploidy analyzer (flow cytometry) that is a fast and easy technique used to measure embryo and endosperm ploidy. Breeding guayule is complicated by facultative apomixis in polyploid collections. The USDA National Plant Germplasm System (NPGS) contains 51accessions of guayule (*P. argentatum*) plus accessions that are interspecific hybrids. All except 2 diploid guayule collections reproduce by apomixis; the two diploid accessions reproduce sexually. Guayule polyploids range from triploids ($2n = 3x = 54$) to octaploids ($2n = 8x = 144$). The objective of this study was to estimate the rate of apomixis, as well as whether or not there was meiotic reduction in the megaspore mother cell, and whether or not there was fertilization to form an embryo. We examined leaf tissue of maternal plants and 100 progeny seeds from these plants to estimate their rate of apomixis. The seed provided additional insight due to the ploidy levels in two different seed structures (embryo and endosperm). Results from this study indicated that off-type progeny (seed) would not have been identified if only leaf samples were used, resulting in an over-estimate of the rate of apomixis for the accession. Segregation in triploids is an example of this. In a number of cases we were not able to conclude which of the four potential reproductive classes of seed resulted from: (1) reduction + fertilization; (2) reduction + no fertilization; (3) no reduction + fertilization; and (4) no reduction + no fertilization. We speculate that perhaps the earlier assumptions of: (1) embryo sac development and (2) normal meiosis in the male (pollen) are not always the case. However, further tests with controlled crosses need to be done to test this hypothesis. These results will help guide our breeding program and better utilize plants resulting from reduction and/or fertilization causing new recombinations. The technique will also help to better characterize our new breeding lines and the expected amount of variation from generation to generation.

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ROLE OF PROTEINS AND AMINO ACIDS IN NATURAL RUBBER: GUAYULE RUBBER ADDITION STUDIES

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Natural rubber (NR) is a critical agricultural material vital to United States industry, medicine, and defense, yet the country is dependent on imports to meet domestic needs. Guayule (*Parthenium argentatum*), a woody desert shrub indigenous to the US, is under development as a renewed agricultural crop in the semi-arid southwestern US. Guayule natural rubber (GNR) may be used to replace *Hevea* NR, or in place of petroleum-based rubber, but substitution must take into consideration differences in physical and chemical properties. In natural rubbers those differences are usually attributed to non-rubber constituents, typically proteins and lipids, depending on the plant species and post-harvest processing. NR from *Hevea* typically contains high levels of proteins that contribute to the outstanding properties which render *Hevea* NR uniquely suited for the most demanding rubber applications (eg aircraft tires). In contrast, guayule natural rubber is low in proteins, thus deprived of some attributes of *Hevea*. Addition of amino acids and proteins to guayule could potentially improve performance, and thereby widen the range of applications for use. In this study, low protein guayule NR latex was blended with a series of commercially-available proteins and amino acids varying in chemical structure to study the impact of specific interactions that may be formed in the blends. Addition of amino acids reduced bulk viscosity, improved thermo-oxidative stability, and impacted cure rate, but did not largely impact mechanical properties. Protein addition also reduced bulk viscosity and improved thermo-oxidative stability. Effects on vulcanization and mechanical properties in compounds were surprisingly influenced by the choice of antioxidants used. Gel, green strength, mechanical properties, and at times crystallinity of guayule rubber could be improved with added protein, but not to levels observed for *Hevea*, even when *Hevea* proteins were used. Our studies confirm that commercial proteins and amino acids from natural sources may be considered as a new class of biobased rubber compounding chemicals. Moreover, the data provide insights as to the mechanisms of non-rubber constituents' interaction with polymers in natural rubber compositions. FTIR evidence supports that protein-polymer interactions are composed of hydrogen bonds, hydrophobic interactions, and covalent interactions including disulfide bonds, which occur at different stages in natural rubber synthesis, extraction, stabilization, and processing.

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BIO-BASED COMPOSITES FOR FOOD PACKAGING

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Increased use of bio-based polymers and rubbers could help decrease our dependency on fossil fuel feedstocks. PHBV (Poly (3-hydroxybutyrate-co-3-hydroxyvalerate)) is a semi-crystalline polymer that meets this sustainability goal by being bio-derived and biodegradable. The brittle nature of PHBV, and its relatively high water permeation and transmission rates make it unsuitable for packaging application. In addition, PHBV has poor thermal properties above 160ºC, thus limiting its packaging application. It has been previously demonstrated that improved bioplastic properties (increased softness and flexibility) can be achieved by blending natural high viscosity rubber (gel) extracted from natural rubber, with thermoplastic (PHBV or PLA). These blended materials proved suitable for making TV trays and blown films. The preliminary objective of this work was to manufacture peroxide cured high viscosity natural rubber matched to that of natural rubber gel so that the bioplastic rubber blend could be scaled up to commercially-meaningful volumes. Organic peroxide cured natural rubber was developed to achieve properties (increased viscosity) comparable to that of high viscosity rubber (gel). A new organic peroxide cure system was sourced, which is completely consumed during an initial heating step and so can be used to induce controlled and complete crosslinking. Organic peroxide cured matched viscosity Hevea rubber (MVNR) was found to have a higher than Hevea gel. Therefore, new blends of PHBV with MVNR were developed, and characterized for thermal properties and water vapor transmission rates of these blends with 2, 5, 10, 15, and 25 % by weight of MVNR.

GENETIC AND ENVIRONMENTAL EFECTS ON QUALITY OF GUAYULE NATURAL RUBBER

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Guayule continues to show promise as a potential alternative source of natural rubber. Guayule natural rubber (GNR) quality is strongly influenced by molecular weight of the rubber. GNR molecular weight can be controlled to some extent by the extraction process, but the rubber in the guayule feedstock must have an acceptable molecular weight in order to produce high quality GNR. Data will be presented on the role of genetics and environment on the molecular weight of GNR prior to extraction. This will include studies in the living plants, as well as effects of storage.

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PROGRESS IN IMPROVING RUBBER YIELD OF *Taraxacum kok-sagyz*

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Taraxacum kok-saghyz faces many domestication and agronomic challenges. A multi-faceted approach is required to maximize the rate of improvement. An overview of current findings will be presented, including germplasm improvements, and effects of density, planting dates, and overwintering.

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CRISPR/CAS9 GENOME EDITING OF RUBBER PRODUCING DANDELION *TARAXACUM KOK-SAGHYZ* USING AGROBACTERIUM RHIZOGENES WITHOUT SELECTION

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CRISPR/Cas9 (clustered regularly interspaced short palindromic repeats/CRISPR associated protein 9) is a highly accessible genome editing tool. Here we demonstrate its potential for use in *Taraxacum* species. *Taraxacum kok-saghyz* (TK, Kazak Dandelion) is notable for its ability to produce high molecular weight rubber in its roots and promise as an alternative source of natural rubber. In order to accelerate the domestication of TK, we have established a simple strategy to deploy CRISPR/Cas9 in this species. A critical gene encoding*: fructan 1-fructosyltransferase* (*1-FFT*), implicated in inulin biosynthesis was selected as the target, as inulin is an expected antagonist of rubber production. TK plantlets were inoculated with *Agrobacterium rhizogenes* harboring a plasmid encoding a Cas9 and sgRNA (single guide RNA) targeting TK *1-FFT*. We were able to rapidly induce hairy roots harboring knockout alleles without the selection of stable, herbicide or antibiotic resistant transformants. Mutagenesis was affirmed by observing a loss of restriction sites within *1-FFT*, followed by sequencing. Of 11 hairy root samples tested, 10 showed the presence of genome editing, with mutation rates as high as 88.9%, suggesting a high efficiency mutagenesis induced by CRISPR/Cas9 via *A. rhizogenes*-mediated transformation. Whole TK plants were regenerated from hairy roots harboring knockout alleles. The regenerated plants were confirmed to contain knockout alleles with mutation rates as high as 80.0%. TK plants with edited genomes were obtained within 10 weeks. By omitting a selection step, it was possible to generate edited TK plants lacking stably transformed CRISPR elements, which may potentially reduce off-target mutagenesis. Application of high efficiency CRISPR/Cas9 genome editing will facilitate the domestication and commercialization of TK as a rubber producing crop, and may accelerate basic research on the regulation of rubber biosynthesis.

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INCREASING RUBBER PRODUCTION BY POST-HARVEST ETHEPHON APPLICATION IN *TARAXACUM KOK-SAGHYZ* ROOTS

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In Hevea rubber production, ethephon (ET) has been used to prolong latex flow for improved yield. The same methods may prove effective in other rubber-producing plants such as *Taraxacum kok-saghyz* (TK). The objectives of this study are to evaluate post-harvest ET application on TK rubber production and to gain a better understanding of its laticifer composition and rubber particle ontogeny due to ET use. Harvested roots of one year old TK plants grown in raised beds were submerged in ET solution with and without environmental stimuli, i.e. cold temperature induction. Rubber and latex analytes were measured using latex quantification (LQ) and Accelerated Solvent Extraction (ASE), respectively, to determine total rubber per plant. Changes in the roots, laticifers and rubber particles were observed by microscopy. The 1% ET solution at ambient temperature increased root rubber concentration 1.6x after nine days, over the control. Also, cellular changes in the cytoplasm and production of morphologically distinct rubber particles were observed in ET treated roots compared to the control roots. ET application at ambient temperature appeared to stimulate the rate of cytoplasmic senescence and was further evaluated as a processing aid. In this evaluation, 1% ET pretreatment was combined with rubber processing by the PENRA III method that uses commercially-available enzymes to increase yield and purity of extracted TK rubber. The combined method yielded more than twice the rubber obtained by PENRA III alone. Further analysis of the sugar extracted in a processing step before rubber extraction revealed that inulin levels were high in control roots, as expected, with little free fructose. However, inulin levels were low in ET treated roots while fructose levels were high. This effect could be caused by the ET-induced senescence described previously in our microscopy observations and perhaps some hydrolysis could have been caused by the acidic ET solution. These results and observations indicate that post-harvest ET application has a direct effect on rubber biosynthesis. ET also changed root composition, partly by inducing senescence, and rendered them more processable which directly led to higher rubber yield using the PENRA III process. Adaptation of these methods to a larger scale should effectively increase post-harvest TK rubber production and final yield.

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TRANSCRIPTOME ANALYSIS OF *TARAXACUM KOK-SAGHYZ* USING RNA-SEQ AND IDENTIFICATION OF CANDIDATE GENES RELATED TO THE RUBBER BIOSYNTHESIS PATHWAY

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Taraxacum kok-saghyz (TK) is a potential alternative for natural rubber production due to its high molecular weight rubber, short life cycle, and diverse environmental adaptation. However, its inability to compete with weeds (e.g. *Taraxacum officinale*) results in low rubber production per acre. In order to improve rubber yield, breeding efforts are necessary. Until now, only limited breeding efforts have been carried out due to TK's self-incompatibility. The need to grow TK to maturity for accurate rubber yield estimation makes it an ideal crop for marker-assisted selection (MAS), a strategy integrating molecular genetics with traditional breeding efforts in attempt to select for desirable phenotypic traits, such as high rubber, in a short timeframe. Limited genomic resources currently available for this species make it difficult to implement MAS. Here, we present a comprehensive transcriptome dataset as well as identify putative markers tightly linked to quantitative trait loci (QTL) controlling rubber biosynthesis for further genomic studies and molecular breeding efforts (e.g. MAS) in this species. In order to lay a foundation for MAS, RNA-Seq was used to detect sequence variants (e.g. single nucleotide polymorphisms, SNP). A total of 55,532 contigs with lengths over 200 bp were assembled using *de novo* assembly. When comparing our transcriptome sequence dataset with the publically available *Taraxacum kok-saghyz* root (TKR) EST database, 4,233 out of 6,966 (60.8%) unigenes in their database were covered by our transcriptome dataset (47,090 unigenes). All the enzymes in the terpenoid backbone biosynthesis pathway (potentially implicated in rubber biosynthesis pathway) were assigned by 102 contigs via KEGG pathway analysis in Blast2GO, while none of the enzymes in the MEP pathway (one branch) were assigned in the TKR EST database, suggesting an improvement and enrichment in relevant genes for TK. A total of 16,891 SNPs were detected between three high rubber and three low rubber plants. Of those 16,891 SNPs, 77 SNPs of 18 genes were involved in the terpenoid biosynthesis pathway. Forty-two SNPs were finally selected and converted to functional SNP markers using KASP (Kompetitive Allele Specific PCR) technology. These SNPs were then used for validation in an F1 population with 84 individuals. As a result, a total of 37 out of 42 SNP markers (88.1%) were polymorphic, 1 was monomorphic (2.38%) and 4 (9.52%) were counted as failed reactions. A marker-trait association analysis identified 2 SNP markers (SNP1113, SNP1245) that were significantly related to rubber content. Both of them were located in the gene encoding 4-diphosphocytidyl-2-C-methyl-D-erythritol kinase in the MEP pathway, suggesting a potential linkage between SNP markers and quantitative trait loci (QTL) controlling rubber production. To conclude, we have established significant genomic resource for TK, providing a comprehensive transcriptomic reference. The power of RNA-Seq to detect SNPs was validated. A large set of SNP markers, including the ones putatively related to rubber biosynthesis, were identified, providing a solid foundation for further MAS.

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QUANTIFICATION OF NATURAL RUBBER IN *TARAXACUM KOK-SAGHYZ* BY NEAR INFARED REFLECTANCE SPECTROSCOPY

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Taraxacum kok-saghyz (TK), is an herbaceous perennial that produces high molecular weight rubber within its root, which is a potential rubber resource for industry use. In order to accelerate the TK breeding process, rapid methods to quantify natural rubber are needed. Near Infrared Reflectance (NIR) spectroscopy is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from about 700 nm to 2500 nm), and is based on molecular overtones and combination vibrations. When a sufficient number of samples have been collected to represent all the available variation and the samples have been analyzed by the reference method, a mathematical model can be constructed that describes the relationship between specific spectral features and the sample characteristic of interest. Thereafter, a researcher may quickly predict that same characteristic in a new target sample by applying the chemometric model to the spectrum of the new sample. NIR is a rapid, cost-effective, non-destructive, accurate and efficient analytical method. A NIR quantification prediction model for TK roots was generated using 290 dried and finely ground TK root samples. NIR data were collected with an Analytical Spectral Devices (ASD) Field Spec 3 using IndicoPro. The spectral files were converted to a GRAMS SPC file format with the equation Absorbance=log(1/Reflectance). The rubber contents of the ground samples were determined by ASE. The NIR predictive model was developed by pairing the accelerated solvent extraction (ASE) data with the spectral data by GRAM IQ. About one fifth of the scans (61) were removed from 290 to generate a validation set. Finally, we created a rubber prediction model (r^2 =0.88, standard error of cross validation = 8.3 mg rubber/g dry root). A ratio of performance to deviation of 2.9 was calculated for the model, meaning that the model qualifies as a useful prediction tool. The model reduces sample processing time and the cost of accelerated solvent extractions, so improves the speed of phenotyping and TK breeding. As the NIR reveals higher rubber plants from breeding and selection, some rubber values fall near or above the limits of the model. Such high samples are then also analyzed using ASE and the model regenerated to extend its accuracy over the higher range. This iterative process is ongoing and the original model has been significantly extended. Also, a modification of the method was developed which allows very small samples (<0.2 g) to be accurately scanned because a single sample cannot cover the bottom of the collection plate. In order to scan the small samples with our model, we covered the parts of the MugLite and the plate with black plastic so that there was a small hole the light could pass through, and the hole in the plate matched the hole on the light. However, the NIR model still requires dry ground roots. Therefore, the next step is to attempt to create a new NIR model with fresh roots, or perhaps rosettes, to further accelerate the breeding process.

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AGRONOMIC MANAGEMENT OF RUBBER DANDELION (*Taraxacum kok-saghyz* Rodin) FOR ROOT BIOMASS AND NATURAL RUBBER PRODUCTION IN OREGON

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Natural rubber (NR) has superior performance characteristics in many industrial applications compared to synthetic rubber made from petroleum. Use of NR is required in many high-performance applications, such as aircraft tires. The primary current source of NR is the Brazilian rubber tree (*Hevea brasiliensis* Willd. Muell.-Arg.). Over 90% of the world's NR exports are controlled by five countries in SE Asia. The roots of rubber dandelion (*Taraxacum kok-Saghyz* Rodin), (TKS), also historically known as Russian dandelion, contain significant quantities of NR that is nearly identical to that from the rubber tree. Research during WWII and since 2006 in Ohio, Oregon, and other locations suggest that with plant breeding and improved agronomic management, competitive rubber yields can be achieved from TKS grown in temperate climates. Despite this potential, agronomic management of this plant as a crop is not well understood, resulting in widely varying germination, crop growth, root biomass yield, and rubber content when grown in test plots in Ohio, Oregon and Ontario. The objective of this research was to measure TKS growth and yield under varying agronomic conditions under field conditions in Oregon. Four main field experiments were started in 2014 using TKS transplants. Up to four seed types (accessions) were used to create randomized complete block factorial designs for each experiment. An irrigation study included four irrigation rates and two accessions. A plant density study included four plant densities ranging from 108,000 to 861,000 plants/hectare and four TKS accessions. A time series harvest date study included two accessions harvested on three harvest dates. A fertilizer study included a single accession and four fertilizer treatments (two rates of phosphorus, potassium, and sulfur, with and without nitrogen). For the four studies, roots were dug in fall of 2015 and biomass yield and rubber content were measured. Root inulin content also was measured in some cases. Root biomass yield per plant was only slightly affected by increasing density for the four TKS accessions, such that per-hectare yields generally increased in proportion to the plant density for the ranges in this study, suggesting that optimum plant densities are even greater. TKS planted at higher density or accessions with greater above-ground vegetation closed canopy sooner and competed better with weeds than those with less above-ground vegetation or planted at lower density. Delaying harvest from July to August or October (of the second growing season) resulted in greater root biomass yield and greater inulin content, but lower root rubber content. TKS plants receiving less irrigation were under more moisture stress and the above-ground vegetative growth was noticeably less. Effects of moisture stress on root biomass yield and rubber content will be discussed, as will the effects of the fertilizer treatments. Rubber dandelion has good potential as a source of natural rubber grown in temperate climates, but improved management using improved cultivars will be necessary to facilitate a viable domestic NR industry using TKS.

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TARAXACUM KOK-SAGHYZ(TK): AN ALTERNATIVE SOURCE OF NATURAL RUBBER AND OTHER VALUABLE BIOPRODUCTS

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Taraxacum kok-saghyz (TK) is a rubber-producing dandelion being developed as an alternative to the traditional source of natural rubber (NR), the para rubber tree (*Hevea brasiliensis*), which is mainly grown in Asian-Pacific countries. One of the major challenges to the development of an economical and sustainable NR supply from TK roots is the large quantity of byproducts that are the result of separating and purifying NR. These include the non-rubber parts of the roots and the leaves which must also be separated and transformed into products and/or raw materials of value to different commercial sectors. In order to commercialize TK as a bioproduct and bioenergy feedstock, a complete assessment of the composition of TK roots and the amounts of potential NR and co-products that could be produced from this crop is needed. In this study, a compositional analysis of field harvested TK roots was conducted to identify components of the roots that may have commercial value and to inform the design and development of processes for the recovery of NR and other valuable co-products from TK roots. In order to generate a representative compositional analysis, a 3 kg subsample was taken from a batch of 188 kg of dry roots harvested from a field planting in Ohio in 2014. The harvested roots were dried, then chopped and flattened into 2 cm pieces and thoroughly mixed before subsampling. Wet chemistry methods were employed to identify and quantify TK components. Results showed that the compositional analysis had a greater than 95% mass closure. Hot water extractives were the primary component accounting for accounting 60% of the root dry mass. Sugars were the greatest water soluble component accounting for 32% of the root dry mass. Among these, inulin, a valuable food thickener and sweetener, was found in high concentration, 17% of the dry root mass. Hexane extractives (NR) and acetone extractives (mainly fatty acids, sterols, and triglycerides) represented 4.5% and 2% of the dry TK root, respectively. Lignocellulosic fractions of the TK root constituted 25.7% of the dry root mass. This consisted of acid insoluble organic matter (9.4%), cellulose (8.7%), hemicellulose (6.6%), and pectin 3.3%. Protein was another important constituent of the root accounting for 15.4% of the dry root mass, the majority of which (10% of the root mass) was soluble in hot water. This study indicates that TK roots are a potential source of not only NR but also of products of importance including inulin, cellulose, hemicellulose, proteins and lignin. The production of TK rubber could diversify the sources of NR and reduce the world's dependence on the traditional limited sources.

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ABSTRACTS

MEDICINAL AND NUTRACEUTICAL CROPS DIVISION

ORAL PRESENTATIONS

CHAIR

TRENDS IN RESEARCH AND DEVELOPMENT OF THE NEW MARIJUANA (*CANNABIS SP*.)

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For the past several decades, the United States banned the use of the plant commonly known as marijuana with laws enforced by local, state, and federal officials. Marijuana (*Cannabis sp.*) was considered to be a health hazard that needed to be forcibly removed from society, even though a number of individuals were using the plant material for medicinal and recreational purposes without ill effects. Within the recent past, however, many U.S. citizens rejected the no marijuana policy, recognizing the plant as generally safe for use. Beginning in 2001, a legal challenge to the U.S. Drug Enforcement Agency was initiated to grow marijuana for testing whether the plant or the plant extract could improve patient health and/or relieve patient pain. While this legal challenge ultimately failed, the following few years brought political pressure on elected state officials to change the law. When asked in a 2015 survey if marijuana should be legalized, 58% answered yes, contrasting the 34% that supported legalizing the plant in 2001 and the 11% that supported the legalizing the plant in 1969. As scientists and medical doctors begin to access the potential medicinal properties of marijuana, a new perspective on possible health benefits of the plant constituents, such as cannabidiol (CBD) become important. Early research suggests that this marijuana sourced cannabinoid has inhibitory activity against several cancers and brain tumors. Other research suggests that cannabidiol has anti-inflammatory activity that could treat arthritis and autoimmune disorders. These new test programs suggest several positive benefits can be expected from the new marijuana. To support this hypothesis, a scientific literature on medicinal and aromatic plants was surveyed over the past 15 years to determine the research focus within medicinal and aromatic plants over time. An examination of five databases that index journal articles, Agricola, CAB Abstracts, Google Scholar, PubMed, and Web of Science were searched to monitor literature terms associated with medicinal and aromatic plant materials. The objective of this presentation is to provide an overview on the current legal status of Marihuana use in the US, highlight the current trends on the research of the new marihuana and provide insights on the development of marihuana as an industrial/medicinal crop.

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CHARACTERIZATION OF PROTEINS IN QUINOA (*Chenopodium quinoa* Willd.) SEEDS FROM PLANTS SUBMITTED TO WATER STRESS

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The demand for healthy foods with high functional value has encouraged the search for alternatives to enhance the beneficial characteristics of food through multidisciplinary research. Studies on the interaction between genotype, the environment and crop management have shown that the interaction has effects on the content of secondary metabolites in the plants and on their productive organs. Special attention has been given in recent years to the study of quinoa (*Chenopodium quinoa* Willd.) due to its high nutritional value. Quinoa has high protein content conferred by the composition of amino acids contained in its seeds. Quinoa seeds also synthesize various bioactive substances like polyphenols, carotenoids, dietary fiber and oleic acid, which have gained importance because of the benefits they have on human health. The objective of this study was to determine the effect of water on the chemical composition, protein content and electrophoretic pattern (albumin, globulin, and residual protein) of quinoa seeds. The seeds used in this study came from a trial conducted under controlled irrigation (95, 40, and 20% water available) during the stage of grain filling, applied on a quinoa crop corresponding to the variety Regalona and ecotypes B080 and AG 2010. Protein content, concentration of saponins and electrophoretic pattern (albumin, globulin and residuals of proteins (%) were determined in both washed and unwashed seeds prior to analysis. The experiment was conducted in a completely randomized design with 3 replicates per irrigation treatment. Determination of protein and saponin contents obtained prior to an analysis of the assumptions of normality of errors and homogeneity of variance were subjected to analysis of variance (ANOVA) and a test of comparison of means (Tukey's test) at 5% significance level using the SAS statistical program and LMS test. The results obtained in polyacrylamide gels were evaluated as presence (+) or absence (-) of protein bands upon determination of their molecular weight by comparison with the proteins reference. The results show no significant differences ($P > 0.05$) between washed and unwashed seeds in terms of protein content. This might indicate that although irrigation was deficient for some treatments, the plant was able to produce seeds with the same protein concentration. However, seed protein fractions decreased significantly when seeds were washed before the analysis. Washed and unwashed seeds reached average values of 11.7 and 26.4 mg mL of albumins, 15.3 and 31.9 mg mL of globulin and 23.7 mL and 8.0 mg of protein residuals, respectively. Saponin concentration was similar in both washed and unwashed seeds, ranging from 0.11 to 0.16% regardless of the amount of water applied during cultivation.

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HEADSPACE GAS CHROMATOGRAPHY FOR THE DETERMINATION OF VOLATILE COMPONENTS IN ESSENTIAL OIL RESEARCH

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Essential oils are receiving increased attention by the scientific community and industry due to their multifunctional properties. One of the challenges is to find proper methods to extract and analyze essential oils found in small amounts. Headspace gas chromatography and mass spectrometry can provide the mean of extracting and analyzing volatiles components usually found in low concentrations. The objective of this work is to provide examples on the use of Headspace Gas Chromatography/Mass Spectrometry (HS/GC/MS) to drive the process of product development in the area of essential oils with potential applications in the field of industrial crops and products. Specifically, to use Headspace to compare the chemical composition of essential oils in different parts of the plant, in different wild varieties or in crosses as part of breeding programs. A Shimadzu static headspace system linked to a gas chromatograph/Mass Spectrometer (HS/GC/MS, GC2010 Plus/TQ8040) was used in this study. In spices such as Liberian Non-timber Forest Products, like in *Xylopia aethiopica* HS was used to evaluate the chemical diversity of essential oils in small amounts of samples coming from different parts of the plant to identify new products. In *Piper guineense,* to assess the variation of essential oils in wild populations to select those lines with best aroma profiles. In basil (*Ocimum sp.*), HS was used to select those crosses with best aroma profiles. HS can be used as a fast way to extract and analyze essential oils as compared to more traditional and time consuming extraction techniques such as hydro-distillation. HS was found to be suitable for the analysis of essential oils to assist in the process of developing new products and new plant varieties. The presentation will highlight the use of HS/GC/MS as a technique to evaluate chemical diversity and drive the process of selection of new plant derived products.

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ANTIOXIDANT, ANTI-INFLAMMATORY AND APOPTOTIC ACTIVITIES OF TWO EXTRACTS OF *FLOURENSIA MICROPHYLLA* IN HT-29 CELLS IN VITRO

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In Mexico, colon cancer has the third place on incidence in man and women. Inflammation plays an important role in the development and progression of cancer, because of its deregulation, as chronic inflammation, being the inflammatory bowel disease an important risk factor for the development of cancer. Recently it has been an increased interest in the research of natural products and their antioxidants compounds, these chemical compounds have been linked to the treatment of different diseases such as cancer and inflammation. Mexico has an extensive variety of semi desert plants that has been studied because of their high content of polyphenols. *Flourensia microphylla* has been studied by its antifungal activity, with a lack of reports on additional biological activities. The aim of this research was to explore the antioxidant, anti-inflammatory and apoptotic effects from two extracts: ethanol and acetone 70% on colon cancer HT-29 cells. The total phenols content in the extracts of *F. microphylla* were determined by Folin-Ciocalteu method, obtaining as results 1276.1 ± 1.17 and 856.16 ± 0.96 mg/100 mg sample for the ethanol and acetone 70% extracts, respectively. The Antioxidant activity of extracts showed different results for the three methods of analysis: In DPPH ethanol extract, showed a percent inhibition of 57.9%, and acetone-70% inhibited by 68.57%; in the ORAC assay, extracts of ethanol and acetone-70%, obtained 117.19 and 138.19 concentrations of Trolox mEq / 100 mg sample, respectively; in the NO test they were obtained an IC_{50} of 0.015 and 0.007 for ethanol and acetone-70%, respectively. For the biological assays it was used HT-29 cells at 90% confluence. Cell viability was evaluated, and treatments for obtaining protein are applied, and then performing the assay membrane apoptosis in human cells. Inflammation markers were measured by Western blotting. Apoptosis assay was performed by human cells apoptosis microarrays kit. As for the inflammation assay it was observed that Acetone 70% extract activated the cytokine to inhibit IL-8. In the apoptosis assay, ethanol extract activated the necessary pathways to reach apoptosis. According to these results, acetone 70% was found to act as a potent anti-inflammatory extract, decreasing pro-inflammatory cytokine; while the ethanolic extract exhibitied apoptotic activity, suggesting possible uses as natural anticancer agent.

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HYPOGLYCEMIC AND ANTI-INFLAMMATORY ACTIVITIES OF THE CORM EXTRACT OF *PSACALIUM PAUCICAPITATUM*

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Diabetes is the disease responsible for about 1.5 million people death. According to WHO estimates, diabetes it will be the seventh leading cause of death by 2030. Inflammation is the process of response to tissue injury, characterized by pain, swelling, redness and warmth in the affected area. *P. Paucicapitatum* (sweet potato deer) is an endemic plant of Oaxaca, used in traditional medicine to treat diabetes, wound healing and gastric ulcers. Nowadays there are no scientific reports on the chemical composition and biological application of this species. The objective of this study was to evaluate the hypoglycemic and anti-inflammatory activities of the aqueous extract of the corm of *P. paucicapitatum*. Corms were collected in Ixtlan de Juarez, Oaxaca, an infusion with a 1000 ppm concentration was prepared, and hypoglycemic activity in C57BL / 6 mice was evaluated. The mice were divided into 3 groups of 8 mice: healthy control (T1), obese control (T2), and obese+infusion (T3). The T2 and T3 were fed with a diet high in saturated fat and fructose. In T3, the infusion was administered daily intra-gastrically with a cannula (200 ul) for 14 weeks. The anti-inflammatory activity was evaluated by measuring the concentration of cell protein, obtained from cultures in HT-29 cells, the protein concentration was determined using the assay kit Bio-Rad Bradford in treatment 3. *P. paucicapitatum* extract showed hypoglycemic activity, significantly decreasing blood glucose levels in 62.22% of the cases, up to 98 days of starting treatment. The effect can be attributed to fructo-oligosacharides, kestose, nystose and fructofuranosilnistose, identified in the corm infusion. The extract also showed anti-inflammatory activity, showing that this species can be a source of hypoglycemic and anti-inflammatory bioactive compounds, which can be the basis for the development of new botanical products for controlling the disease.

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EVALUATION OF PHENOLIC LINKED ANTI-HYPERGLYCEMIC POTENTIAL OF BARLEY (*HORDEUM VULGARE* L.) CULTIVARS TARGETTING FOR THE MANAGEMENT OF EARLY STAGES TYPE 2 DIABETES USING *IN VITRO* MODELS

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Cereal grains such as barley (*Hordeum vulgare* L.) are rich in phenolic antioxidants. Utilizing these plant-based foods as functional ingredients for potential dietary management of chronic oxidative stress-linked diseases, especially early stages Type 2 Diabetes Mellitus (T2DM) has merit. Our goal is to gain better knowledge of application of phenolic metabolites from malting barley cultivars targeting for dietary management of early stage T2DM. Therefore, the primary objective of this study was to screen and evaluate various malting barley cultivars for phenolic antioxidant-linked anti-hyperglycemic properties using *in vitro* assay models. Whole kernels of 12 malting barley cultivars were milled and three different extracts (cold water, hot water, & 12% ethanol) were investigated. The content of total soluble phenolics (TSP) in the extracts was measured using Folin-Ciocalteau method, while their antioxidant capacity was determined based on their ability to reduce ABTS [2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid] and DPPH [2,2-diphenyl-1-picrylhydrazyl] free radicals. Further, potential of barley extracts to inhibit key enzymes involved in glucose metabolism such as α-amylase and α-glucosidase was determined through *in vitro* assay models. The TSP content ranged between 0.441 and 0.634 mg/g GAE on a dry weight basis across cultivars and extraction types, with hot water extracts showing the highest TSP content. Ethanol extracts of barley cultivars exhibited the highest antioxidant capacity, followed by cold water and hot water extracts. Among cultivars, Pinnacle was found to have the highest antioxidant activity (86 - 100% ABTS inhibition; 30 - 58% DPPH inhibition), followed by Celebration (75 - 100% ABTS inhibition; 26 - 48% DPPH inhibition) and Lacey (80 - 100% ABTS inhibition; 29 - 46% DPPH inhibition). For enzyme inhibition, cold water and 12% ethanol extracts of most barley cultivars were found to have considerably high α-amylase inhibitory activity. Cultivars Innovation (85%) and Pinnacle (98%) showed high α-amylase inhibition in cold water and 12% ethanol extracts respectively compared to other cultivars. Hot water and cold water extracts were found to have a moderate capacity to inhibit the activity of α-glucosidase, while ethanol extracts demonstrated very low inhibitory potential. The cultivars that showed the highest levels of α-glucosidase inhibition were Lacey (41%), Tradition (38%) and Black Barley (38%) among hot water extracts; and Black Barley (40%), Genesis (38%) and Quest (37%) among cold water extracts. Significant dose dependence was observed in the α-glucosidase inhibitory potential of barley extracts. In this study, all barley cultivars showed high phenolic content, high antioxidant potential, high α-amylase, and moderate α-glucosidase inhibitory activity. Thus from this study screened barley cultivars with high phenolic bioactive-linked functionalities in relation to anti-hyperglycemic potentials can be targeted either as a food ingredients or as nutraceuticals for the dietary management of early stages T2DM and associated macro- and micro-vascular complications.

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ABSTRACTS

POSTER PRESENTATIONS

FIBER AND CELLULOSICS

COMPARISON OF THE NUTRITIVE VALUE OF SEVEN KENAF (*HIBISCUS CANNABINUS*) VARIETIES HARVESTED DEPENDING ON STUBBLE HEIGHT

B. Jie, Defang Li, A.G. Chen, J. J. Li, S.Q. Huang, H.J. Tang, H. Li, and Y. Deng

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Protein feed shortage is one of the most important factors that limit the development of animal husbandry in China, especially South China. Kenaf (*Hibiscus cannabinus*) can be used as a high-quality protein feed for livestock's. This study aimed to evaluate the yield and quality characters of seven kenaf varieties by harvesting on the basis of stubble height and high nutritive value. This study was performed in two parts: first, a reasonable stubble height was selected, and then kenaf varieties were harvested when they reached the selected stubble height and then their nutritive value was determined. The results showed that 90 cm stubble height was the most appropriate for harvesting crop and also this stubble height improved their biomass content and nutritive value. The dry matter accumulation of the whole plants, crude protein content, and crude fiber of the kenaf varieties ranged from 15,359.31 kg/ha to 18,502.18 kg/ha, 8.99% to 16.23%, and 16.71% to 37.43%, respectively. The nutritive value of the seven kenaf varieties was the same during the first two harvests, but was slightly different during the third harvest because of the cold climate during this harvest time. SZHP35 variety had the highest nutritive value with highest dry matter accumulation (18,502.18 kg/ha) and crude protein yield (2,027 kg/ha), and 4A-4B had higher leaf proportion and yield and significantly higher crude protein ($P < 0.05$) than the other varieties. Correspondence analysis results suggested that 4A-4B was closely related to leaf yield and crude protein content, and SZHP35 was closely related to high yield. Our findings suggested that 4A-4B could be used as a forage material in South China; further studies are warranted to determine the optimum stubble height that might yield the best nutritive value.

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PHYSIOLOGICAL RESPONSE IN THE ROOTS OF KENAF (*Hibiscus cannabinus* L.) SEEDINGS UNDER CADMIUM STRESS

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Kenaf (*Hibiscus cannabinus* L.; Family: Malvaceae), is multipurpose crop, one of the potential alternatives of natural fiber for biocomposite materials. Salicylic acid (SA) as a signal molecule mediates many biotic and environmental stress-induced physiological responses in plants. In this study, we investigated the role of SA in regulating Cadium-induced oxidative stress in the roots of kenaf. Kenaf plants pretreated with 0.2 mM SA for 12 h and subsequently exposed to 100 μM Cd^{2+} for 24 h displayed attenuated toxicity to the root. The SA promoted root growth was correlated with decreased lipid peroxidation in root cells. The ameliorating effect of SA was confirmed by the histochemical staining for the detection of loss of membrane integrity in Cd-treated roots. We show that treatment with 0.2 mM SA increased the activity of NADH oxidase, ascorbate peroxidase (APX) and peroxidase (POD) in the roots exposed Cd. However, a slightly decreased superoxide dismutase (SOD) activity was observed in SA + Cd-treated roots when compared to those of Cd treatment alone. The accumulation of ascorbate (ASC), glutathione (GSH) and proline are also measured in the roots of kenaf, we found that roots treated with SA in the presence of Cd accumulated more ASC, GSH and proline than the one treated with Cd only. These findings reflect the possible role of SA as a potential inhibitor of cadmium toxicity in kenaf.

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ABSTRACTS

POSTER PRESENTATIONS

GENERAL CROPS

SUGARBEET (*BETA VULGARIS* L.) CULTIVATION IN CONTAMINATED LAND FOR BIOETHANOL PRODUCTION: A PROMISING PERSPECTIVE

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A growing global concern nowadays is energy supply due to the inevitable depletion of fossil fuel. Ethanol is a renewable fuel source that can be produced by fermentation of sugar from sugar and starch-containing crops. Sugar beet (*Beta vulgaris* L.) is a commercially important plant species since it covers the 30% of the world's sugar production, while at the same time it has been proved to be a good feedstock for bioethanol production. The possibility to cultivate sugar beets for energy purposes in heavy metal contaminated areas seems to be an interesting approach combining the energy production with the soil rehabilitation and this is the scope of this work. Namely this study investigates the effects of heavy metals on growth and bioaccumulation potential of sugar beet plants, as an indication of the capacity of that crop to be irrigated with industrial wastewater or to be cultivated in polluted sites that cannot be used for food production. A greenhouse experiment was carried out using two groups of 12 pots each, filled with surface soil artificially contaminated by cadmium or by nickel aqueous solutions respectively. In the first group the pots were spiked with 500 ml aqueous solutions of $Cd(NO_3)_2$ $4H_2O$, with total amounts of: $Cd_{0.5}$: 0.5 g $Cd(NO_3)_2$, Cd_5: 5.0 g $Cd(NO_3)_2$, Cd_{10}: 10.0 g $Cd(NO_3)_2$ and Cd_0-control: only distilled water. In the second group the pots were spiked with 500 ml aqueous solutions of $Ni(NO_3)_2 \cdot 4H_2O$, with total amounts of: $Ni_{1.0}$: 1.0 g Ni $(NO_3)_2$, Ni_{10}: 10.0 g $Ni(NO_3)_2$, Ni_{20}: 20.0 g $Ni(NO_3)_2$ and Ni_0-control: only distilled water. The pots within each group were arranged according to the completely randomized design, with three replicates. At the end of the experiment, the DTPA extractable soil metal concentration ranged widely; for cadmium from 10.7 mg kg^{-1} ($Cd_{0.5}$) to 225.8 mg kg^{-1}(Cd_{10}) and for Ni from 4.1 mg kg^{-1} ($Ni_{1.0}$) to 75.4 mg kg^{-1} (Ni_{20}). In Cd treatment, plant growth remained unaffected. Plant height and fresh and dry weights of the aerial sugar beet biomass did not differ significantly among treated and control plants. In the beets the average concentration of Cd increased with the level of contamination with a maximum of 14.3 mg kg^{-1} (Cd_{10}) of dry weight. In Ni treatment, plant growth was negatively affected by the treatments. The low treated plants ($Ni_{1.0}$) remain unaffected, but all measured morphological parameters were significantly reduced in Ni_{10} and totally inhibited in Ni_{20}, where the plants were completely dried. The beet average Ni concentration also increased with the level of contamination, up to 45.9 mg kg^{-1} (Ni_{10}). In both experiments, leaves presented a significant higher accumulation than beets. Although accumulation of Cd and Ni by sugar beet was well below the criterion used to classify this species as a hyperaccumulator, it still remains unclear if the biofermentation process will be affected by the metals concentration in the biomass.

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WIDENING THE HARVEST TIME FRAME OF SORGHUM [*Sorghum bicolor* (L.) MOENCH]IN THE IBERIAN PENINSULA – YIELDS AND SOIL QUALITY IN VARIETAL TRIALS

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Sorghum [*Sorghum bicolor* (L.) Moench] is a promising feedstock for the production of biofuels, due to its high biomass and sugar, cellulose and hemicellulose yields. Yet, the harvest window for sorghum is a critical issue for the carbohydrates processing: harvesting in a short period reduces the sugar loss but is limited to the capacity of the mill; furthermore, the time of harvest is dependent on sorghum variety. Multi-varietal sorghum crops and delaying the harvest may improve the handling efficiency of bioethanol mills by prolonging the processing period and, additionally, the senescent leaves and the longer crop permanence in the soil may contribute to improve the soil quality. Therefore, the performance of a number of sweet and fiber sorghum varieties was investigated in the Iberian Peninsula to analyze the effects of delayed harvesting on the changes in stem yield and composition and the related end use quality for bioethanol, along with litter production and composition. Field trials were conducted during three years at two experimental sites in the Iberian Peninsula, Lisbon (Subtropical-Mediterranean climate) and Madrid (Continental-Mediterranean climate). The above-ground standing biomass (stalks, leaves and panicles with seeds) at the end of the vegetation period were harvested, as well as litter (mainly fallen leaves) at different dates. Fresh and dry matter stem yields were determined at the different harvest dates and biomass was characterized in terms of sugar; a selection of samples were analysed for their content in ash, cellulose, hemicellulose, nitrogen and phosphorus content. Litter was also quantified in terms of fresh and dried matter at the different harvest dates and it was characterized in terms of ash, nitrogen and phosphorus content. Results evidenced the interaction climate-variety on the yields and the possible harvest time window of the site. Thus, the warmer climate conditions in Lisbon allowed delaying the harvest up to December. There, delaying the harvest from early October to middle November slightly increased the stems and soluble sugar yields. Delaying the harvest to December decreased the yields (stems and sugar) and the sugar content but the cellulose and hemicellulose content remained constant. However, the December harvest, in terms of soil erosion control, provides added benefits due to the longer crop permanence in the soil. In terms of increment of nutrients (N, P) and organic carbon in the soil, delaying the harvest to November resulted in an added benefit, but from November to December, the benefit remained similar. A normalization and weighting procedure is being applied to the data, in order to aggregate the effects of the delayed harvest, and to provide hints to increase the sustainability of sorghum production in the Iberian Peninsula.

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LONG-TERM GROWTH AND YIELD PERFORMANCE OF GIANT REED (*Arundo donax* L.) GROWN IN MARGINAL LAND UNDER LOW INPUTS

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Giant reed (*Arundo donax* L.) was grown for 13 subsequent years in a 0.3 ha marginal field in central Greece, established in 2002. The experimental design was a split plot design and the factors studied were three irrigation and three nitrogen fertilization levels, in three replications. The three irrigation (I) and nitrogen fertilization (N) levels were: I_0: non-irrigated, I_1: 50% of I_2, I_2: fully irrigated, N_0: 0 kg N/ha, N_1: 40 kg N/ha and N_2: 120 kg N/ha. Rhizomes were planted in rows 1.5 m apart and at 0.7 m within the row. Meteorological data were collected and evaluated during the growing periods. At the final harvest every year growth and yield characteristics were measured, like height of the shoots, plantation density (as shoots per plant and shoots per square meter), number of leaves, basal shoot diameter, fresh and dry matter yields and yield components, moisture content. The plants exceeded 5 m height from Year 5 onwards for all irrigation rates, apart from I_0, where plants remained stable at 4m. In the last year plant height decreased to almost 3 m. Over 8 stems per s.m were produced after Year 4 until Year 10. Mean yields of 12 t DM ha^{-1} were achieved from Years 4 to 10. Thereafter, yields dropped to 10 t DM ha^{-1}. A further decrease of yields was noticed in the 13^{th} year of the trial. Non-irrigated plots kept stable yields of ~8 t DM ha^{-1}. Stem fraction was 88-90% of total dry matter. All irrigation rates affected significantly growth and yields during the plant's lifespan while the effect of nitrogen fertilisation was occasional and significant only in N_0 rate. Rain-fed giant reed grown in marginal fields showed a rapid growth stage until the fourth year, when yields reached the ceiling yields of 10 t DM ha^{-1}. Then yields slightly decreased until the ninth year. Thereafter yields were stable at 8 t DM ha^{-1}. In contrast, the fully irrigated plants reached 24 t DM ha^{-1} in Year 5 while from Year 3 to Year 10 the yields overpassed the 15 t DM ha^{-1}. Thus, in conclusion, giant reed is a very productive crop in the long run, able to produce considerable yields even when grown under low inputs in marginal lands.

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ABSTRACTS

POSTER PRESENTATIONS

MEDICINAL AND NUTRACEUTICAL PLANTS

STRESS-INDUCED ENHANCEMENT OF PHENOLIC ANTIOXIDANTS IN GRAPES (*Vitis vinifera* L.), TARGETTING BIOACTIVE COMPOUNDS FOR THE MANAGEMENT OF EARLY STAGES TYPE 2 DIABETES

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Fruits and fruit derived products such as beverages are an excellent source of dietary antioxidants with health relevant phenolic profiles. These phenolic bioactives can be targeted for the dietary management of oxidative stress-linked chronic diseases, such as early stages type 2 diabetes. Metabolic innovations to improve the biosynthesis of phenolic antioxidants in fruits during pre-harvest stages include the mild induction of abiotic stresses through ozone or chemical treatments. This strategy offers excellent scope to improve phenolic antioxidant-linked functionalities in popular fruits for human health benefits. Therefore the major aim of this study was to enhance phenolic antioxidant-linked functionalities in grapes (*Vitis vinifera* L.) through pre-harvest ozone and chemical treatments, with the goal of improving bioactives that can be targeted for post-prandial glucose management through diet for human health. In this study, nine grape cultivars were treated with ozone and chemicals (six rounds of single formulated spray combinations of insecticides and fungicides) in the field, following this cold water extracts of grape fruits were evaluated for total soluble phenol content, total antioxidant activity, α-amylase, and α-glucosidase inhibitory activity, using *in vitro* assay models. The results were compared to untreated grapes which were included as controls. In general, all red grape cultivars and one white grape cultivar (Vignole) showed high total soluble phenolic content (0.8 – 1.8 mg/G F.W.) and high total antioxidant activity (85-95% DPPH inhibition) when compared with other white grape cultivars. Ozone treatment significantly enhanced phenolic antioxidant–linked functionality in Vignole and Frontenac grape cultivars with 40-50% increase in total soluble phenolic content, while the chemical treatments enhanced total phenolic content and antioxidant activity in de Chanac and Foch grape cultivars. High α-amylase inhibitory activities with significant dose responses were found in all grape cultivars with Vignole exhibiting the highest α-amylase inhibitory activity at one-fifth of dilution (88%). Similar to α-amylase inhibition, Vignole also showed high α-glucosidase inhibitory activity (99%) at one-fifth of dilution, and had positive correlation with total soluble phenolic content. Overall high α-glucosidase inhibitory activity was observed across all grape cultivars. In this study, Vignole, St Croix, Frontenac, De Chanac, and Foch grape cultivars showed high phenolic-linked bioactive functionalities and have the potential to be targeted as part of dietary management of early stages of type 2 diabetes. The abiotic ozone stress and chemical-induced stimulation of phenolic bioactives was not uniform across all grape cultivars as some cultivars performed better compared to others (depending on the choice of cultivar and its interaction with specific ozone or chemical treatment). Therefore the findings suggest that genotypic differences along with phenotypic characteristics play a significant role in determining base phenolic antioxidant profiles, and this will affect their potential for bioactive enrichment in grapes.

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BIOACTIVITY AND PHYSICAL PROPERTIES OF CHITOSAN FILMS INCORPORATED WITH DIFFERENT NATURAL ANTIOXIDANTS

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Natural antioxidants, extracted from plants, are an alternative to the chemical compounds used as preservatives by the food industry due to their antioxidant and antimicrobial activity. Thus, the aim of this work was to develop an active packaging based on chitosan, a natural biopolymer, by incorporating different natural antioxidants (five essential oils and seven hydro alcoholic extracts). The tested essential oils were thyme, rosemary, ginger, tea tree and sage. Hydro alcoholic extracts were obtained from green and black tea (from Azores Island), ginger, kenaf leaves, marjoram, rosemary and sage plants by double extraction with ethanol 70% assisted with sonication. To evaluate the bioactivity of the films, several physical properties were measured and a migration assay was carried out at 37 ± 2 °C using ethanol 95 % v/v as fat simulant. Total phenolic content and antioxidant activity were monitored in the simulant during 10 days by Folin-Ciocalteu method and DPPH and ABTS assays, respectively. Chitosan films without incorporation of antioxidants were also tested as control. Colour and optical properties (transparency and opacity) were also evaluated in the films along with the determination of the solubility and swelling index in water. All the films with essential oil or hydro alcoholic extracts demonstrated good bioactivity and showed remarkable light barrier, especially on the lower wavelength (UV light), demonstrating an extra protection against oxidation process. Films with ginger or rosemary oils, and green or black tea extract presented the highest antioxidant activity measured in the simulant. In order to clarify the mechanism associated with the packaging activity, an identification of the phenols migrating to the simulant is being carried out. Results obtained from this study indicate that the films tested have shown potential to be used by the food packaging industry as an alternative tool to preserve food from the oxidation processes, although further research is demanded to evaluate the behaviour of these novel materials in direct contact with food matrices.

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PRODUCTION COMPARISONS OF CHINESE WATER CHESTNUT [*ELEOCHARIS DULCIS* (BURM. F.) TRIN. EX HENSCH] FUNCTIONAL CORMS GROWN IN HYDROPONICS VERSUS FLOODED SAND

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Chinese water chestnut [*Eleocharis dulcis* (Burm. f.) Trin. ex Hensch.] corms are used as a canned or raw vegetable worldwide and may have potential use as a functional vegetable for human health uses. The accessions in the USDA, ARS, Plant Genetic Resources Conservation Unit do not produce very many or healthy corms when grown in plastic pots containing flooded sand in Griffin, GA. The objectives of this study were to 1) compare Chinese water chestnut corm production in flooded sand versus a drip irrigating hydroponic system for maximizing high quality corm production, 2) estimate variability for corm production among 5 Chinese water chestnut accessions, and 3) use cluster analysis for grouping accessions into phenotypes. Five Chinese water chestnut accessions were planted in a drip irrigated hydroponic system and in plastic pots containing flooded sand inside a greenhouse at Griffin, GA during 2013 and 2014. One mature corm per accession was planted in buckets containing perlite within the hydroponic system and in plastic pots containing flooded sand during the spring and summer of 2013 and 2014, respectively. After approximately 210 days, the number of corms were harvested, counted and weighed. Significantly more corms per accession (ranging from 102 – 241) and weights (ranging from 429 – 476 g) were produced in the drip irrigated hydroponic system when compared to the flooded sand method where corm numbers per accession ranged from 47 – 49 weighing 77 – 224 g for all accessions during both years. Individual accession effects were detected for both live number and weight of corms when the drip irrigated produced corms was compared to those grown in flooded sand. Principal component analysis indicated that both principal components were correlated the same for corm production traits. Cluster analysis grouped all accessions into well-defined phenotypes based on corm production. Drip irrigated hydroponics was successful in maximizing corm production for regeneration.

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ANTIFUNGAL ACTIVITY OF EXTRACTS OF *JUGLANS MOLLIS*, *JUGLANS MICROCARPA* AND *CARYA OVATA*, AGAINST *FUSARIUM OXYSPORUM* AND *ALTERNARIA ALTERNATA IN VITRO*

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The nogalillos, wild species found in northern Mexico, belong to the family *Juglandaceae*; are trees, sometimes shrubs, aromatic and resinous, 6 to 15 meters high, which produce a fruit walnut-shaped reddish-brown, spherical, and covered by a fleshy or fibrous source of tannins and coloring wrap. There is little scientific information about the chemical and biological composition of this species, specially their content of flavonoids and coumarins, for which it has been used as a medicinal plant against fungi and bacteria, such as; *Botrytis* sp., *Colletotrichum* sp., *Mycobacterium tuberculosis*. The aim of this study was to evaluate *in vitro* antifungal activity of ethanol and aqueous extracts of leaves and stems, *Juglans mollis* Engelm, *Juglans microcarpa* Berl and Carya *ovata* Mill (Nogalillos) against *Fusarium oxysporum* and *Alternaria alternata*. The plants were collected in the region South of the State of Coahuila, the ethanol and aqueous extracts were prepared with the leaves and stems separately. The fungi were isolated from infected tomato fruits and sown in the middle Potato Dextrose-Agar (PDA). Bioassays were conducted by agar dilution technique. Bioassays were performed by the agar dilution technique. The concentrations of the extracts of leaves and stems in ethanol and water were 50, 500, 1000, 2000, 3000, 4000 and 5000 ppm, and absolute control and chemical control. Inhibition was measured by mycelial growth compared with controls and evaluated with a completely randomized design with 4 replications. The results were evaluated with analysis of variance, mean comparison test by Tukey (P = 0.05). Probit analysis was applied to calculate the concentration of plant extracts resulting in a 50% and 90% inhibition of visible growth of the pathogen when compared to the control sets (MIC_{50} and MIC_{90}). The results showed that ethanol extracts of leaves and stems of *J. microcarpa*, inhibited by 76 % and 97 % to 5000 ppm *F. oxysporum* respectively, while ethanol extracts of leaves and stems of *Carya ovata*, inhibited 69 % and 70 % to 5000 ppm *F oxysporum*, respectively.

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SYNTHESIS OF ANTIOXIDANTS IN SPROUTS OF QUINOA (*Chenopodium quinoa Willd*.) IN RESPONSE TO ABIOTIC STRESS

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Quinoa is recognized as one of the most interesting pseudo-cereal due to the nutritional composition of the whole plant, especially the phytochemicals contain in its grains. It tolerates drought (100 to 200 mm water requirements), low temperatures and soil salinity (200 mM NaCl). In Chile, quinoa is grown mainly in the altiplano, interior areas of the north, La Serena, Alto Bio Bio in the Bio Bio Region, and coastal areas from the O'Higgins Region to Araucania Region. Grain yield reaches 3000 kg ha^{-1} in Chillán (Bio Bio Region).There is evidence that quinoa has been consumed for thousands of years and served in many different ways including sprouts in salads. Recent studies have shown that edible sprouts have higher nutritional value than matured plants. For instance, broccoli (*Brassica oleracea* L. var *italica*) seeds treated with a sucrose solution result in sprouts with an increased amount of antioxidants. In general, NaCl, sucrose and glucose modify the osmotic potential of the imbibition solution, causing an osmotic stress that increases the amount of antioxidants, anthocyanins and polyphenols in sprouts during germination. Light also increases the concentration of antioxidants. Studies have reported that Chickpea seeds (*Cicer arietinum*) exposed to blue light during germination show a higher content of extractable polyphenols than seeds submitted to green light, while yellow light results in an increased content of beta-carotene. The total antioxidant capacity (TAC) of germinated seeds of quinoa is high, reaching values between 92 and 116.9 mmol Trolox kg^{-1} dry weight. The aim of this study was to evaluate the changes in the total polyphenol content of quinoa seedlings ('sprouts') in response to the applications of sodium chloride and sucrose, and to the exposure to different light conditions during germination. Two trials were carried out using quinoa seeds (*Chenopodium quinoa* Willd), ecotype B080, which were washed in order to reduce saponin content. In both trials, seeds were imbibed and germinated. In trial 1, seeds were soaked in a sodium chloride and a sucrose solution (0. 75 and 150 mM) in darkness, while seeds in trial 2 were soaked on a disc with distilled water and exposed to white, blue and yellow lights. The experiments were conducted using a completely randomized design with 3 replications in trials 1 and 2, respectively. The parameters evaluated were germination percentage (GP), vigor index (VI), fresh weight (FW) of sprouts and concentration of total polyphenols (TP), which was determined by the Folin-Ciocalteu method. Data were submitted to analysis of variance (ANOVA) and significant differences were determined by LSD test (P = 0.05). The results showed that sodium chloride had higher effects ($P \leq 0.05$) on GP, VI and FW compared to sucrose. No effects were observed in the TP content of sprouts ($P > 0.05$) due to the stress caused by sodium chloride or sucrose. Similarly, light radiations had no effects ($P > 0.05$) on GP, VI, GR, FW and TP content. It can be concluded that the stress caused by sodium chloride, sucrose or different types of light radiation (white, blue and yellow) do not increase TP content in sprouts of quinoa ecotype B080.

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EFFECT OF PLANT EXTRACTS SEMI-DESERT IN THE INDUCTION OF GERMINATION AND SEEDLING GROWTH OF MELON

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In semiarid regions of northern Mexico there is a large number and variety of wild plants that grow under extreme climatic conditions. Brassinosteroids are a new class of plant hormones, in addition of auxins, gibberellins, cytokinins, abscisic acid and ethylene, presenting important biological effects on plant development. The objectives of this research were to study the chemical composition of 22 plants growing in the semi-desert of northern Mexico, and identify chemical compounds which by their nature can act as inducers of growth and evaluate the biological activity of the compounds identified in the induction of melon seed germination and seedling growth. The leaves of the plants were collected in different wild sites of Coahuila and Nuevo Leon. The leaves extracts were prepared using methanol as solvent, and analyzed by gas chromatograph coupled to mass spectrometry (GC-MS). The biological activities of the extracts were evaluated in melon seed. The design was a completely randomized with 3 repetitions. Data were analyzed by analysis of variance (ANOVA), and mean test by the method of Tukey (P= 0.05), using the R language program.The results showed that in 9 plants collected, were identified compounds with steroidal chemical structure like to brasionoesteroids that can be use as inducers of germination and seedling growth of melon. Studies showed that plant extract yields vary from 10.42% (*Yucca filifera*) to 32.33% (*Rhus muelleri*).

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EFFECT OF *ALOE VERA* (*Aloe barbadensis* Miller) NANO-LAMINATE COATING ON THE SHELF LIFE PARAMETERS OF TOMATO FRUITS (*Lycopersicum esculentum* Mill)

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Tomato fruits (*Lycopersicon esculentum* Mill.) are the second most important vegetable crop in the world after potato, with an annual production of around 163.4 million tons of fresh weight. Being a climacteric fruit, its ripening is accompanied by an increase in respiration rate and ethylene production (EP), thus having a relatively short postharvest shelf life (SF). The major limiting factors in the storage of tomato are the respiration and transpiration along with microbial contamination, and thus the control of these factors is primordial to extend its SF. The use of low temperature storage is effective in delaying and/or reducing EP, but tomato is sensitive to chilling injury. Also, the use of postharvest pesticides and sanitizers are the most frequently used methods to reduce pathogens levels in fruits; however, their application leads to fruit pesticide residues representing a serious problem to human health. The application of edible coatings represents an alternative for extending postharvest life of fruits and recently, some works suggested that this approach can improve functionality when they are used at the nanoscale. In this context, nano-laminate coatings composed by the alternate deposition of biopolymers have been designed in order to combine their bioactivity and barrier properties, and they have shown an enhanced efficiency and better gas exchange when compared with conventional coatings. It has also been shown their ability to incorporate bioactive compounds with a controlled release of the active agent and thus prolonging their bioactivity during storage time. Recently, *Aloe vera* (*Aloe barbadensis* Miller) liquid fraction has evidenced potential antioxidant and antifungal properties against fungi of economic importance. Therefore, in this study the effectiveness of nano-laminate coatings constructed by alternate deposition of a total of five nano layers of sodium alginate (Alg) and chitosan (CH) (Alg-CH-Alg-CH-Alg) with and without *Aloe vera* liquid fraction (NL-Av and NL, respectively) was evaluated on the SF parameters of tomato fruits and compared with uncoated tomato fruit. The evaluations were conducted under two conditions: cold storage (11°C and 90% relative humidity, RH) and room temperature (20°C/85% RH), used to simulate the distribution and consumption chain of tomato fruits. The application of nano-laminate coatings was effective to control the maturation process in both storage conditions, since a reduction in the gas transfer rate was shown in the coated tomato fruits. In addition, NL-Av showed to have better protection properties against moisture loss and improved control of gas transfer rate, together with restricted EP. Microbial spoilage was reduced during both storage conditions, impacting the quality of tomato fruits.The use of NL-Av is thus an attractive postharvest alternative to extend the quality of tomato fruits during storage.

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ESSENTIAL OILS OF BASIL (*Ocimum sp*.) AND THEIR ASSOCIATED ANTIOXIDANT AND ANTIMICROBIAL ACTIVITY

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Basil (*Ocimum basilicum*, Lamiaceae) essential oils are complex mixtures that can include over a hundred chemical constituents. However, only a few of these components are found in high relative concentrations, such as citral, 1,8-cineole, linalool, methyl chavicol, eugenol, methyl eugenol and methyl cinnamate and it is the blend or ratio of all the constituents that together provide the basis of the herbs aroma. The major types of basil in which the traditional sweet basil reside, are rich in linalool and methyl chavicol with varying amounts of each component, from low levels of linalool to high levels of methyl chavicol and vice versa. Additional chemotypes also contain linalool and eugenol in varying amounts, methyl chavicol and/or methyl eugenol, and linalool and methyl cinnamate. Oils from aromatic plants have been known since antiquity to possess biological activity, mainly antibacterial, antifungal and antioxidant properties. In this study we are evaluating the chemical diversity of selected *Ocimun* species, including green and purple varieties, to relate the variability of their composition with the antioxidant and antimicrobial activities of their main essential oils and their main purified standards. The essential oil profile of all basils (*Ocimum* spp.) showed remarkable differences in the chemical composition of the monoterpenes and phenylpropanoids. Essential oil content varied significantly between the varieties and lines. The highest oil content was observed in Italian Large Leaf (1.7%) and cinnamon basil (1.4%). The highest radical scavenging activity was associated with the linalool-eugenol chemotypes, with the highest activity observed in those with highest content of eugenol, sweet basil and Osmin Purple essential oils. The oils from selected basils showed different antimicrobial activities. All the oils tested inhibited 100 % of the growth of yeast. Sweet basil exhibited the strongest activity against *E. coli* and *S. aureus*. The results show that the essential oils of basil have a number of additional attributes and applications in addition to their aroma and flavor impact.

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IN VITRO ANTIFUNGAL ACTIVITY OF EXTRACTS OF ETHANOL AND WATER OF LEAVES AND STEMS OF *FLOURENSIA* SPP. AGAINST FUNGI POSTHARVEST

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During post-harvest practices fruits and vegetables are usually affected by the incidence of diseases caused mainly by fungi. *Fusarium oxysporum* and *Rhizopus stolonifer* cause losses up to 40% of the total harvest. Different techniques have been implemented to extend the shelf life of products, including chemical treatment, however, can cause resistance of pathogens and affect the environment and human health. There are natural alternatives to control pathogens. The extracts of *Flourensia cernua, F. microphylla*, and *F. retinophylla* have reported antifungal activities. The aim of this work study was to evaluate the *in vitro* inhibitory activity of leaves and stems ethanolic and aqueous extracts, of *Flourensia cernua, F. microphylla* and *F. retinophylla*, against *Fusarium oxysporum* and *Rhizopus stolonifer*, fungi that cause diseases of postharvest fruits of commercial interest. The plants were collected in the semiarid region south of the State of Coahuila, the ethanol and aqueous extracts were prepared with the leaves and stems separately. The fungi were isolated from infected tomato fruits and cultured in the middle Potato Dextrose-Agar (PDA). Bioassays were conducted by agar dilution technique and performed by the agar dilution technique. The concentrations of the extracts of leaves and stems in ethanol and water were 50, 500, 1000, 2000, 3000, 4000 and 5000 ppm with absolute and chemical controls. The experiment was established under a completely randomized design in factorial arrangement with four replications. Data analysis was performed by analysis of variance and mean comparison of Tukey test (P=0.05). Probit analysis was applied to calcúlate the concentration of plant extracts resulting in a 50% and 90% inhibition of visible growth of the pathogen when compared to the control sets (MIC_{50} and MIC_{90}). The following analysis of the extracts (in triplicate) were carried out: Proximate analysis of total content of phenols and flavonoids, antioxidant activity. Extracts were submitted to chemical composition by GC-MS and infrared analysis. The results showed that ethanol extracts of leaves and stems of *F. cer*nua inhibited by 100% to 4000 ppm *F. oxysporum*, while ethanol extracts of leaves and stems of *F. microphylla*, inhibited 93.62% and 90.25% to 5000 ppm *F oxysporum*, respectively. Besides ethanol extracts of leaves and stems of *F. cernua*, inhibited 100% to 3000 ppm *R. stolonifer*.

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ABSTRACTS

POSTER PRESENTATIONS

RUBBER AND RESINS

HISTOLOGICAL STUDY OF LATICIFER AND RUBBER PARTICLE ONTOGENY IN *Taraxacum kok-saghyz* ROOTS

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Taraxacum kok-saghyz (TK) is being developed as a commercial crop in the US and Europe as an alternative to *Hevea brasiliensis*, the tree that produces industrial rubber. Both *Hevea* and TK contain pipe-like multi-nucleate vessels called laticifers which produce latex. As a potential new rubber crop, understanding laticifer origin and rubber particle ontogeny in TK will be useful in manipulating rubber production and yield. Thus, the objectives of this study are to gain a histological understanding of TK laticifer development and the ontogeny of rubber particles by characterizing the morphology and development of rubber-producing cells at both the seedling stage and in mature TK plants. Different microscopy methods were used to obtain high image resolution, and detailed analysis of early laticifer development and rubber particle ontogeny. The microscopic observations on the seedlings showed that rubber particles were produced before laticifers, as early as eight days after germination, beginning at the cotyledonary collar areas. Laticifers were first observed 14 days after germination in the cotyledonary collar area at the pericycle and outside of the primary phloem group. In mature TK, high laticifer numbers were recorded near the plant crown and the numbers decreased toward the root tip. Conversely, the laticifer density was highest when the root diameter was small. The rubber particles, which are spherical or ovoid, were not as easily identified in seedlings as they were in mature TK plants. However, these particles began to appear 10 days after germination. The mature plants exhibited similar rubber particle morphology to *H. brasiliensis* and *Parthenium argentatum* (guayule). In addition, laticifer plastids, membranous organelles found in the cytoplasm of laticifer cells, produced some of the rubber particles while other rubber particles were formed independent of this plastid. Also, two distinct rubber particle morphologies are found in TK. Rubber particles developed in the cytoplasm (plastidic rubber) are irregularly shaped prior to moving inside the vacuole. Once in the vacuole, the outer layer of the rubber particle becomes smooth (vesicular rubber). In conclusion, these findings have provided us with useful information on laticifer and rubber particle ontogeny that we can use further in studying and explaining the *de novo* site of rubber particles as well as to predict rubber production in TK roots.

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LIFE CYCLE ASSESSMENT OF GUAYULE NATURAL RUBBER PRODUCTION IN EUROPE

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Guayule natural rubber may offer an interesting alternative to synthetic or Hevea natural rubbers. It presents unique properties beneficial in both heavy tire and non-allergenic medical furniture productions. In temperate regions, guayule is the sole potential source of natural rubber, as Hevea rubber can only be produced in tropical countries. Nowadays, commercial productions of guayule only exist in the USA but recent studies within the EU-PEARLS project framework have proven the technical and economic feasibility of guayule growth and rubber extraction in the European context. In order to further assess the overall feasibility of guayule rubber development in Europe, there is a need to also investigate the environmental impacts or benefits of such a natural rubber source compared to synthetic rubber. We conducted a comprehensive analysis of guayule natural rubber environmental impacts (1 kg of crude rubber) using Life Cycle Assessment, ILCD 2011 midpoint+ Simapro 8.2 and ecoinvent 3.2, Allocation, Recycled content. We included in the system analysis, all background processes from input production and transportation to the field up to the crude rubber extraction at the mill gate (Figure 1). Data for the field cultivation were taken from 3 field experiments carried out in France and Spain. We also compared the impacts of guayule natural rubber with those of a synthetic rubber provided in the Ecoinvent database, Synthetic rubber (RER) production, Allocation, Recycled content. The LCA results will be presented.

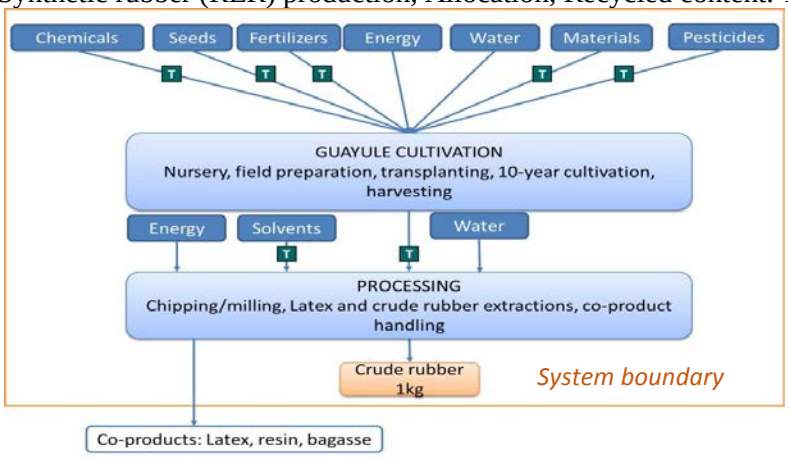

Figure 1: LCA system boundary of guayule rubber. T: transport

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IMPROVING RUBBER PRODUCTIVITY BY REDUCING TAPPING FREQUENCIES IN GUATEMALA

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Hevea brasiliensis , perennial crop, can be exploited on cycles from 30 to 40 years. It has a particular system of harvesting, the tapping, which consists in removing a thin layer of bark of 1.5 to 2.0 mm depth, so that the latex can be expelled. This operation is repeated regularly at intervals of 1 to 5 days. This interval determines the frequency of tapping. The improvement of productivity and profitability can be done either by increasing the yield per tree, or by reducing the labor. The productivity per tree depends on the clone genetic potential, its behavior in a given environment and its reaction to the tapping frequency. The tapper's productivity will depend on the number of trees tapped per tapper and the quantity of latex the tree will produce after each tapping. This last parameter can evolve with the tapping frequency.

In Guatemala, a study was conducted on the reduction of the tapping frequencies (tapping every 4, 5, 6 or 7 days) combined with stimulant (ethephon, 2.5% a.i) applications frequencies, varying from 8 to 14 applications a year. The results show that the yields per tree per year ($g.t^{-1}.y^{-1}$) decreases with the tapping frequency whereas the yield per tapping ($g.t^{-1}.t^{-1}$) increases when the frequency of tapping is reduced.

The economic impact of the reduction of tapping frequency is presented with various assumptions of rubber price.

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CHLOROPLAST GENOME RESOURCES AND MOLECULAR MARKERS DIFFERENTIATE RUBBER DANDELION SPECIES FROM WEEDY RELATIVES

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Rubber dandelion (*Taraxacum kok-saghyz*, TK) is being developed as a domestic source of natural rubber to meet increasing global demand. However, the domestication of TK is complicated by its colocation with two weedy dandelion species, *Taraxacum brevicorniculatum* (TB) and the common dandelion (*Taraxacum officinale*, TO). TB is often present as a seed contaminant within TK accessions, while TO is a pandemic weed, which may have the potential to hybridize with TK. To discriminate these species at the molecular level, and facilitate gene flow studies between the potential rubber crop, TK, and its weedy relative, TO, we generated genomic and marker resources for these three dandelion species. Complete chloroplast genome sequences of TK (151,338 bp), TO (151,299 bp), and TB (151,282 bp) were obtained using the Illumina GAII and MiSeq platforms. Chloroplast sequences were analyzed and annotated for all the three species. Phylogenetic analysis within Asteraceae showed that TK has a closer genetic distance to TB than to TO and *Taraxacum* species were most closely related to lettuce (*Lactuca sativa*). By sequencing multiple genotypes for each species and testing variants using gel-based methods, four chloroplast Single Nucleotide Polymorphism (SNP) variants were found to be fixed between TK and TO in large populations. Additionally, Expressed Sequence Tag (EST) resources developed for TO and TK permitted the identification of five nuclear species-specific SNP markers. The availability of chloroplast genomes of these three dandelion species, as well as chloroplast and nuclear molecular markers, will provide a powerful genetic resource for germplasm differentiation and purification, and the study of potential gene flow among *Taraxacum* species.

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INDUCTION AND DENTIFICATION OF TETRAPLOIDS IN TARAXACUM KOK-SAGHYZ

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Taraxacum kok-saghyz (TK), also called "Buckeye Gold", is an alternative rubber resource, which has received considerable attention, as the production of natural rubber, currently harvested from *Hevea brasiliensis*, faces serious challenges such as potential shortages of supply and pathogen threats. Additionally, TK's high molecular weight rubber, short life cycle and adaptation to diverse environments make it a potentially ideal rubber-producing crop. However, as a new crop, TK has not been fully domesticated and rubber yield is highly variable. Its inability to compete with weeds (e.g. *Taraxacum officinale*) results in low rubber production per acre. In order to improve rubber yield, breeding efforts are necessary. However, only limited breeding efforts have been carried out due to its self- incompatibility and the need to grow plants to maturity before high rubber yield genotypes can be accurately identified. One strategy to accelerate breeding is autopolyploid induction, which could increase plant size and the biosynthesis of chemical secondary products in plants such as rubber. In this study, colchicine was used to induce tetraploids. Flow cytometry was used to identify successfully induced tetraploids. To date, 17 tetraploids have been induced from over 6000 treated seeds. The optimal induction treatment was 0.2% colchicine for 48h treatment. Comparisons will be made between tetraploids and diploids to determine if root rubber yield will be increased in tetraploids and if this results from either or both increased rubber concentration and increased root size. Other morphological effects on stomata size, leaf width, leaf dimension and leaf index will also be explored. Seed production by tetraploids will be tested in crosses, and their potential assessed for TK crop improvement.

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VARIATION IN CUTICULAR WAXES IN GUAYULE LEAVES UNDER DROUGHT STRESS CONDITIONS

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Guayule (*Parthenium argentatum* A. Gray) is a shrub native to the southwestern United States which can be used to produce domestic natural rubber, latex and biofuels. The wax content of plants help it to survive biotic and abiotic stresses. To study the variation in wax content in guayule, six guayule lines (including cultivars and wild accessions) were grown in three replicates each under greenhouse conditions. The experiments were planted in a complete randomized design (CRD), side by side with two different irrigation levels; well-irrigated and dry treatments. Cuticular waxes were extracted with Chloroform and quantified using Gas Chromatography-Mass mass Spectrometer. Results showed the variation in total wax content among the studied lines within each water stress treatment and well between treatments for each line. For example lines AZ5, CAL3, and R1103 increased wax content under drought, CAL7 and N566 produced less wax while line 11693 showed no significate difference in total wax content. Wax analyses determined five classes of Guayule cuticular wax; those being fatty acids (FAs), alkanes (Alk) alcohols (Alc), wax esters (WEs), and a group of unknowns. Among these classes wax esters were the most abundant. These results suggest that wax content could have a role in resistance to abiotic stress (drought tolerance) in guayule.

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ABSTRACTS

POSTER PRESENTATIONS

OILSEEDS

YIELD AND YIELD COMPONENTS OF WINTER CAMELINA (*Camelina sativa* L. Crantz) IN RESPONSE TO SEEDING DATE AND RATE

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Camelina has shown desirable characteristics as a low-input bioenergy crop for dryland cropping systems in the U.S. Northern Greta Plains (NGP). Less attention has been given to winter type camelina compared to spring camelina. Nevertheless, if timely planted and properly managed, winter camelina can fulfil its sensitive growth stages, e.g. inflorescence emergence, flowering, and grain setting in a more favorable environmental condition (wetter and cooler) compared with spring camelina. A field experiment was conducted during 2015-2016 in Sidney, Montana, to evaluate the effect of seeding date (Sep 15, Sep 29, Oct 13) and seeding rate (5.6, 8.4, and 11.2 kg ha^{-1}) on seed yield, yield components, and oil concentration of two camelina cultivars (Joelle and Bison).

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PROCESSING OF BRASSICA SEEDS FOR FEEDSTOCK IN BIOFUELS PRODUCTION

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Several Brassica species are currently being evaluated to develop regionalized production systems based on their suitability to the environment and with the prevailing practices of growing commodity food crops like wheat, corn, and soybeans. This integrated approach to farming will provide high quality oil feedstock for biofuel and simultaneously improve the rural economy. Aside from their agronomic differences, these Brassica species produce seed with varying oil content and fatty acid composition. *Brassica napus* (Invigor L130) and *B. juncea* (Oasis) seeds contain around 46% oil with oleic acid (C18:1) as their main fatty acid. *Brassica carinata* (AAC A110) and *B. napus* (Gem) seed also have 46% oil with 40 and 46% erucic acid (C22:1), respectively. *Brassica juncea* (Pacific Gold) seeds have 40% oil with the same amounts (~20%) of oleic, linoleic (C18:2) and erucic acids. *Camelina sativa* (Joelle) oil contains 57% polyunsaturated fatty acids of which 63% is linolenic acid (C18:3). *Thlaspi arvense* oil (32-36%) also contains 60% monounsaturated fatty acids (MUFA) of which 78% are ≥ 20 carbons. *Sinapis alba* (Tilney) seeds have the lowest oil content (27%) but also the highest MUFA (69%) of which 84% are oleic and erucic acids.The oils were extracted from whole seeds either by cold pressing, full (with seed cooking) pressing, or pre-pressing followed by solvent extraction. Cold pressing seeds with 46% oil content resulted in press cakes with about 20% oil content. Seeds with < 40% oil contents resulted in cakes with < 5% residual oil when full-pressed. However, full-pressing seeds with oil content > 45% had press cakes with 11 to 14% oil contents. Tilney seed, processed by prepressing and then extracted with solvent, had its oil reduced to 0.5%. The oil yields from cold-pressed and full-pressed seeds may be improved by double pressing to an oil content of ≤ 8% or down to 0.5% with solvent extraction. The filtered oils were acid-degummed by pretreating with citric acid, chemically-refined using NaOH, and then bleached with activated clay. The phospholipids content, measured as phosphorus (P), in the crude oils (< 140 ppm P) were effectively reduced by acid-degumming and further lowered below detection level (< 5 ppm P) after bleaching. The crude oil of *T. arvense* had the highest sulfur (S) content (144 ppm) followed by Pacific Gold (54 ppm) and the rest were ≤ 20 ppm. The reduction in S content varied with each cultivar. *Thlaspi arvense* (56 ppm), *B. juncea* (Pacific Gold) (11 ppm), and *B. carinata* (10 ppm), had the highest remaining S after bleaching. The extent of oil refining needed for feedstock oils will depend on the type of fuel to be produced and the conversion technology involved.

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NEW OIL CROPS FOR BIOENERGY AND BIOREFINERY IN EUROPE

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Most of the existing biorefinery concepts use a limited number of raw materials (usually straw or wood). The EU-funded EuroBioRef project will develop a high integrated and diversified concept applying multi-feedstocks, multi-technologies, and multi-processes that will enable flexible biorefinery facilities to produce multi high added-value bio-products. Several non-food oil crops and lignocellulosics are the new potential resources. In this particular work, focus is given on the non-food oil crops: castor seed, crambe, cuphea, lesquerella, lunaria and safflower. The purpose of this work is to explore the viability of the selected crops and crop rotations, their adaptability to the climate conditions and agrizones, as well as the management and logistic components (tillage, irrigation, harvest time, available equipment, etc.) so as to finally propose dynamic farm-tailored cropping systems and rotations. All crops were grown for three years (2010/2011, 2011/2012 and 2012/2013) in field trials along with rapeseed and sunflower for comparison reasons. The oil crops were sown in Greece and Poland that represent the Mediterranean and Continental environmental zones respectively. In addition, castor was studied in Madagascar. In Greece, the field trials with the winter crops (lunaria, safflower, rapeseed) were sown in October, and harvested until July, while spring crops (crambe, castor seed and sunflower) have been established in April and harvested until October every growing season. Rapeseed and sunflower were sown as reference crops for the winter and spring non-food oil crops respectively. In Poland crambe, lunaria, safflower and camelina were tested as spring crops along with rapeseed as reference. Several crop rotation schemes have been examined in each location. Information on the harvesting (time & equipment) and storage operations for the harvested materials, as well as on their handling requirements is collected and fed in a model for optimizing biomass logistics, that has been developed in this project. This new comprehensive tool can handle multiple feedstock/source input into the supply chains as well as multiple output for the biorefiney (or other consumer of biomass) and takes into account losses throughout the supply chains, including losses during storage (depending on duration of storage). Results can be given as optimization of total costs or energy consumption or CO_2-emissions or any weighed combination of those 3 parameters.Yields performances of castor seed, safflower and crambe have shown a very good establishment and produce relatively high yields in Greece, with castor seed and sunflower having the leadership, whereas in Poland only crambe seem to be appropriate crop. Yields and oil properties from all field trials will be reported in the paper. In addition, the agronomic practices, harvesting and logistics of each crop will be discussed in order to indicate research gaps and provide recommendations. The cultivation of these oil crops at European level is not at a commercial scale at present, so for most of the crops yields are reported from USA mainly. For certain crops like castor seed and safflower there is already an established market and research going on in the Mediterranean area, thus it is highly likely that these crops could be candidate for larger-scale development in Europe. In the cold climate of Central Europe only crambe seems to have a potential to grow as it shows similar performances to rapeseed. The logistic tool has had the impact that very detailed calculations of costs, energy consumption and CO2-emissions for a number of different supply scenarios within the Value Chains have been evaluated.

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GROWTH AND YIELD OF OIL CROPS IRRIGATED WITH WASTEWATERS – THE EFFECT OF AMMONIUM ION AND NITRATES

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The European oleochemical industry currently relies on imported coconut and palm kernel oils, and castor oil as sources for medium-chain fatty acids and medium-chain polymer building blocks. These are used for the production of plastics, surfactants, detergents, lubricants, plasticisers and other products. Oil crops, such as crambe (*Crambe abyssinica*) and camelina (*Camelina sativa* Crantz) are being considered as new options as feedstock for the oleochemical industry. Although these oil crops are less water demanding then other oil crops (e.g. rapeseed), in countries where water resources are scarce, such as those of the Mediterranean, the water use needed for the cultivation may represent a constraint associated with their production. Therefore the aim of this work was to evaluate the growth responses, as well as the biomass productivity of crambe and camelina, irrigated with wastewaters presenting different nitrate and ammonium ion concentrations: 10, 20 and 40 mg/L (NH_4) and 50, 100 and 200 mg/L (NO_3). Two controls irrigated with tap water were used: one without any fertilization, and one with NPK fertilization. Throughout the experiment, in pots, percolated waters were analyzed in terms of ammonium and nitrate ions in order to evaluate if the "soil-biomass system" was capable to prevent contamination of the ground and surface waters. Results showed that irrigation with wastewaters did not affect the germination, growth and yields of both crambe and camelina. Germination of crambe was poor, ~35%. Contrarily, camelina germination reached an average of 80%. Yet, crambe was more productive than camelina. The average height of crambe was 0.68 m while camelina showed an average height of 0.54 m. Crambe showed a significant lower height when irrigated with wastewaters compared to control, but the yields did not showed a particular trend. In the case of camelina pots, the height was similar in controls and pots irrigated with wastewaters. An average seed yield of 0.49 g (dry matter)/pot was obtained with crambe, and camelina only produced 0.14 g (dry matter)/pot. Nevertheless, it will be mandatory to quantify and characterize the oil content obtained from the seeds to evaluate if wastewaters have an effect. Both oil crops showed capacity to trap the nitrogen in the wastewaters. Nitrates and ammonium ion analyzed monthly in the percolates showed that the "soil-biomass" system was able to remove more than 90% of the incoming pollutant. The characterization of the soil and of the biomass will allow to determinate the role of soil and biomass in the removal process.

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EVALUATION OF THE GERMINATION RATE OF PENNYCRESS *(Thalspi arvense* L.) IN DIFFERENT CONDITIONS OF STORAGE AND TEMPERATURE

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Biofuel is defined as an alternative fuel whose energy is obtained through a process of biological carbon fixation. Biofuels are produced from renewable sources and emit fewer pollutants than petroleum products. Field pennycress (*Thlaspi arvense* L.) is a plant that is considered a weed in most parts of the United States; however, it has become a viable option for biofuel production in North America. Pennycress seeds have high oil content which is rich in erucic and linoleic acids. Plant breeding programs are rapidly developing new varieties of pennycress with improved stand establishment and early flowering. As seed production becomes established, a reliable seed storage protocol is needed to ensure maximum seed viability for the next generations. The objective of this experiment was to evaluate the germination rate of seeds that have been stored over an 8 week period. Pennycress variety 'Spring 32' seed was stored in air tight microfuge tubes and breathable envelopes at temperatures of 17°C, -2.2°C, 22°C and 33°C. Each week, triplicate samples were pulled from each container type and temperature regime. All samples were germinated in plastic boxes containing a layer of grid paper and one layer of filter paper moistened with distilled water. The germination boxes were placed in a seed germinator at 22°C for 10 days. By week 3, all seed stored in all conditions began to decline in germination rates. Paired t-tests determined both storage containers and temperatures provide statistical differences in germination rates. Seed stored at 33°C had the highest seed germination rate in the envelopes, obtaining 50% germination rate, while other temperatures obtained less than 25% germination rates. Overall, 'Spring 32' demonstrated poor storage ability over all conditions regardless of container type during the 8 week period. As breeders develop new varieties for fast germination, seed coat and storage ability characteristics need to be considered.

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LIFE CYCLE ASSESSMENT OF BIODIESEL PRODUCTION FROM *Jatropha curcas* L.

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A life cycle assessment (LCA) of biodiesel production from *Jatropha curcas* L. suitable as transportation fuel was carried out in 2014. Environmental impacts were calculated according to the CML 2001 method, in the `Chain Management by Life Cycle Assessment` (CMLCA) software. The goal of the study was to conduct a comprehensive LCA and assess methodological choices which apply in biofuel assessments and also give preliminary results on jatropha biodiesel performance. The system is evaluated for small scale, rural applications. Primary data for cultivation were provided by the European Union funded project JatroMed (www.jatromed.aua.gr, demonstration field in Essaouira, Morocco), while the rest of data was obtained by Ecoinvent v.2.2, literature review and questions to experts. Fruit yield was determined to 3500 kg of dry dehulled seeds (kernel) per ha, based on primary and bibliographic yield performances from several case studies. Two cultivation treatment scenarios were evaluated; treatment A of 170kg/ha urea and 925 m^3/ha irrigation and treatment B of 170kg/ha NPK (20-20-20) and 473m^3/ha irrigation. Two different scenarios of crop residues (i.e. jatropha fruit shells) treatment were also evaluated, with the first being the fermentation of residues to biogas and digestate applied to the field and the second of direct residue application to the field as soil amendment. Both market economic values and energy content were used to allocate impacts between by-products.

Treatment B combined with the application of crop residues directly to the field yields the lowest environmental impact for all impact categories under study. In all scenarios the energy allocation triggers lower impacts than economic allocation. Carbon footprint of the product system was calculated to 1.11 kg $CO_{2eq.}$ (62% due to use phase). Compared to Ecoinvent v2.2 for conventional diesel, global warming potential is slightly lower for jatropha biodiesel and abiotic depletion of fossil fuels is three times lower for the latter, as well. However, there is an increase in acidification (5%) and eutrophication (84%) from the jatropha system relative to the fossil case. IPCC 2006 methodology was used to calculate soil organic carbon storage (SOC) assuming land conversion from subtropical steppe to jatropha plantation. Annual carbon sequestration was calculated to be 1.29 ton CO_2/ha, due to increased biomass growth.

Major system improvement options are the optimization of: agronomical practices, by-products use and nutrients cycling. Access to more primary data of biodiesel processing, local energy mix use and accurate seed yields are recommended for future LCA research. This work was conducted within the JatroMed project, which is funded by the European Commission (EuropeAid/128320/C/ACT/Multi, Contract nr.: 2011/221-037).

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