ASSOCIATION FOR THE ADVANCEMENT OF INDUSTRIAL CROPS

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""Integrating technology with industrial crops and their products for a sustainable bioeconomy"

33rd Annual Meeting

October 9-12, 2022

Best Western Plus GranTree Inn

Bozeman, MT USA

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Conference Program

Sunday, October 09

7.30 AM - 5.00 PM	**Tour- Yellowstone National Park**
7.00 AM	Board bus – Hotel entrance
7.30 AM	Bus departs
12.30 PM	Lunch
5.00 PM	Arrive hotel

5:30 - 6:30 PM	AAIC Board Meeting	Aspen Room
5:30 - 6:30 PM	Registration	Foyer
6:30 - 9:00 PM	Opening Reception	Foyer

Monday, October 10

Plenary Session
Moderator: Dilpreet Bajwa
Room: Hyalite
Coffee with Light Snacks

8:00-10:00 AM	Registration Desk Open and Poster set up	
8:00 AM	Dilpreet Bajwa, Montana State University, Bozeman, MT, USA	Introduction
8:05 AM	Alison Harmon, Interim Vice President of Research and Economic Development, Montana State University, Bozeman, MT, USA	Welcome address
8:15 -8:45 AM	Cort Jensen, Montana Department of Agriculture, Helena, MT, USA	What your lawyer wishes you knew about growing energy and industrial crops
8:45-9:15 AM	Ron Colwell, Montana Renewables, Calumet, Great Falls, MT, USA	Montana Renewables: Pioneering seed to diesel
9:15-9:45 AM	Keith Horton, Sustainable Oils, Great Falls, MT, USA	Camelina: From farms to energy
9:45-10:00 AM	**Coffee Break**	
10:00-10:30 AM	Andrew Bishop, Ag Processing Solutions, Great Falls, MT, USA	Farming on dryland and value-added commodity processing in North

		Central, Montana
10.30 - 11:00 AM	Chaofu Lu, Montana State University, Bozeman, MT, USA	Developing camelina oilseed for sustainable production of biofuels and oleochemicals
11.00 - 11.30 AM	Marisol Berti, North Dakota State University, Fargo, ND, USA	Life cycle assessment and ecosystem services delivery of cropping systems that include industrial crops

Boxed Lunch 12.15 pm

POSTER SETUP

TECHNICAL SESSIONS
Concurrent Sessions

1. Fiber & Cellulosic Crops

Moderator: Efthymia Alexopoulou

Room: Hyalite

2:00 PM	***Keynote speaker:*** Dilpreet S. Bajwa	NATURAL FIBER- GROWTH, TRENDS AND FUTURE
2:30 PM	Burton L. Johnson, Darin J. Eisinger, and Mark E. Zarnstorff	STEM INJURY EFFECTS ON INDUSTRIAL HEMP GRAIN AND BIOMASS YIELD IN NORTH DAKOTA
2.50 PM	Saptaparni Chanda, Dilpreet S Bajwa, Nicole Stark, and Sreekala G. Bajwa	NANO BORON OXIDE AND NANO ZINC OXIDE INCORPORATION TO CELLULOSE NANOCRYSTALS TO IMPROVE THE THERMAL, MECHANICAL AND FLAMMABILITY PROPERTIES OF HIGH-DENSITY POLYETHYLENE POLYMER
3:10 PM	**Coffee Break**	
3:30 PM	Efthymia Alexopoulou, K. Iordanoglou, D. Kotoula, G. Tsipas, and E.G. Papazoglou	HOW IRRIGATION AND FERTILIZATION AFFECTS GROWTH AND YIELDS OF INDUSTRIAL HEMP GROWTH ON A MARGINAL AGRICULTURAL LAND IN GREECE

3:50 PM	Moritz Von Cossel, and Jablonowski, N.D.	ENERGY YIELD DECLINE OF SIDA (*SIDA HERMAPHRODITA* L. RUSBY) IN A SUMMER HARVEST REGIME FOR BIOGAS PRODUCTION
4:10 PM	Andrew Durado, D.S. Bajwa and Greta Gramig	BIODEGRADABLE COMPOSITE HYDROMULCHES FOR SUSTAINABLE ORGANIC HORTICULTURE
4:30 PM	Michele Pastore, João Pires, Leandro Gomes, Victor Gomes Lauriano Souza, Walter Zegada Lizarazu, Andrea Monti, and Ana Luisa Fernando	ENHANCING THE VALUE OF LIGNOCELLULOSIC BIOMASSES THROUGH THE PRODUCTION OF BIONANOCOMPOSITES
4:50-5:20 PM	**Fiber and Cellulosics Division Meeting- Division Chair: Efthymia Alexopoulou**	
5:00-6:00 PM	**Poster Session**	

2. Medicinal & Nutraceutical Plants

Moderator: Diana Jasso De Rodríguez, Ana Luisa Fernando

Room: Clark

2:00 PM	***Keynote Speaker:*** Ralph M. Paroli and R.J. Morgan	DEVELOPING NORMATIVE STANDARDS FOR THE CANNABIS/HEMP SECTOR
2.30 PM	Nirmal Joshee, Brajesh N Vaidya, and Samantha H Sherman	REPRODUCTIVE BIOLOGY OF MEDICINAL TREE, *PAULOWNIA*: POLLEN-STIGMA INTERACTION, EXTRAFLORAL NECTARIES AND TRICHOMES
2:50 PM	Diana Jasso de Rodríguez[1], Martín F. Rocha-Rivera, Homero Ramírez-Rodríguez, Raúl Rodríguez García, José A.Villarreal-Quintanilla, and Lourdes Díaz-Jiménez	SEMI-DESERT PLANT EXTRACTS AS BIOSTIMULANTS FOR GROWTH, YIELD AND FRUIT QUALITY IN BELL PEPPER (*Capsicum annuum* L.)

3:10-3:30 PM	**Coffee Break**	
3:30-4:00 PM	**Medicinal and Nutraceuticals Plants Division Meeting** **Division Chair: Diana Jasso de Rodriguez**	
4:00-5:00 PM	**Poster Session**	

Dinner on Your Own

Tuesday, October 11

TECHNICAL SESSIONS

Concurrent Sessions

3. General Crops & Products

Moderator: Ana Luisa Fernando

Room: Lewis and Clark

8:00 AM	***Keynote Speaker:*** Efthymia Alexopoulou	THE MAGIC PROJECT MARGINAL LANDS FOR GROWING INDUSTRIAL CROPS: TURNING A BURDEN INTO AN OPPORTUNITY
8:30 AM	Liv S. Severino	EXPLORING PLANT'S COGNITIVE ABILITIES AS A TOOL FOR MANAGEMENT OF INDUSTRIAL CROPS
8:50 AM	Ana Luisa Fernando, M.P. Duarte, M. Gonçalves, and E. Alexopoulou	OUT OF THE BOX: COMBATING CLIMATE CHANGE WITH PHYTOREMEDIATION. IS IT POSSIBLE?

9:10 AM	Alan Taylor, Y. Jiang, M. Amirkhani, E. Lewis, and L. Sosnoskie	IMAGING OF FLUORESCENT, SYSTEMIC SEED TREATMENT TRACERS IN HEMP FOR THE DEVELOPMENT OF A WEED MANAGEMENT SYTEM
9:30 AM	Emily Makowski, S. Kane, and C. Ryan	BIODEGRADABLE 3D-PRINTED RFID SENSOR FOR AGRICULTURAL PURPOSES
9:50 AM	**Coffee Break**	
10:10 AM	Steve F. Vaughn, S.X. Liu, M.A. Berhow, J.K. Winkler-Moser, S.C. Peterson, G.W. Selling, W.T. Hay, and C.D. Skory.	PRODUCTION OF AN ODOR-REDUCING, ANTIBACTERIAL CLUMPING CAT LITTER FROM SOYBEAN HULLS AND SOYBEAN HULL BIOCHAR
10:30-11:00 AM	**General Crops Division Meeting – Division Chair: Ana Luisa Fernando**	
11:00-12:00 PM	**Poster Session**	

TECHNICAL SESSIONS
Concurrent Sessions

4. Oilseeds (Tuesday, Oct 11)

Moderator: Hussein Abdel-Haleem

Room: Hyalite

8:00 AM	***Keynote Speaker:*** James V. Anderson, Brant Bigger, Kirk Howatt, Joseph Mettler, and Marisol T. Berti	AGRONOMIC TRAITS AND ECOSYSTEM BENEFITS OF FIELD GROWN SULFONYLUREA-RESISTANT *CAMELINA SATIVA* AND *BRASSICA NAPUS*
8:30 AM	Federica Zanetti, Barbara Alberghini, Richard P. Haslam, Susana Silvestre, Sylvain Prigent, Jean-Denis Faure, Anais Da Costa,	UNCOVERING MORPHO PHYSIOLOGICAL DIVERSITY IN CAMELINA (*CAMELINA SATIVA* L. CRANTZ)

	Javier Prieto, Yuri Herreras Yambanis, Andrea Monti, Yves Gibon, Dominik K. Grosskinsky, Bjorn Usadel, and Claudia Jonak	
8:50 AM	Barbara Alberghini, Federica Zanetti, Walter Zegada-Lizarazu, Federico Ferioli, Angela Vecchi, and Andrea Monti	WATER STRESS EFFECT ON MORPHOLOGICAL AND COMPOSITIONAL CHARACTERISTICS OF TWO CONTRASTING CAMELINA BIOTYPES
9:10 AM	Efthymia Alexopoulou, F. Zanetti, K. Kempapidis, Y. Yambanis, and A. Monti	CAMELINA: A CASH COVER CROP FOR GREECE
9:30 AM	Noemi Codina-Pascual, C. Cantero-Martínez, M. P. Romero, and A. Royo-Esnal	YIELD AND OIL CHARACTERISTICS OF 10 CAMELINA VARIETIES AS AFFECTED BY SOWING DATE IN A MEDITERRANEAN CLIMATE
9:50 AM	**Coffee break**	
10:10 AM	Chengci Chen, Charlemagne Lim, Shreya Gautam, Sooyoung Franck, and Chaofu Lu	CAMELINA RESPONSE TO NITROGEN FERTILIZER INPUT AND IDENTIFICATION OF HIGH NITROGEN USE EFFICIENCY GENOTYPES
10:30 AM-12:00 PM	**Poster Session**	

Lunch on Your Own

TOUR – MUSEUM OF ROCKIES

1:30-6:00 PM	**Tour- Museum of Rockies & Brewery Tour**
1:00 PM	Bus boards
1:30 PM	Bus departs
1:30-3:30 PM	Museum of Rockies
4:00-6:00 PM	MAP Brewery Tour

Dinner on Your Own

Wednesday, October 12

TECHNICAL SESSIONS
Concurrent Sessions

4. Oilseeds Division

Moderator: Hussein Abdel-Haleem

Room: Hyalite
Coffee with Light Snacks

8:00 AM	Racheal N. Upton, Fernando Henrique Correr, and Jennifer Lachowiec	DETERMINING *CAMELINA SATIVA* GERMINATION RATE VARIATION AND GENETIC CONTROL
8:20 AM	Fernando Henrique Correr, Racheal Upton, Anapaula Astorga, and Jennifer Lachowiec	OVEREXPRESSION OF *MIRNA167A* INCREASES GERMINATION RATES IN *CAMELINA SATIVA*
8:40 AM	Ana Luisa Fernando, L. Gomes, J. Moreira, B. Gomes, M. Abias, J. Costa, F. Zanetti, and A. Monti,	PROSPECTS OF OILSEED CROPS CULTIVATION IN HEAVY METAL CONTAMINATED SOILS - PRODUCING A RENEWABLE FEEDSTOCK USING ECOLOGICAL REMEDIATION
9:00 AM	Winthrop B. Phippen, John C. Sedbrook, and M. David Marks	ADVANCEMENTS IN BREEDING PENNYCRESS (*Thlaspi arvense* L.) AS A SUSTAINABLE FEED AND FUEL SOURCE
9:20 AM	Russ W. Gesch, Yesuf A. Mohammed, and Heather L. Matthees	RELAY-CROPPING PENNYCRESS AND SOYBEAN: SELECTING INTERSEEDING DATE AND SOYBEAN MATURITY
9:40 AM	Yesuf Assen Mohammed[1], Russ Gesch, Samantha Wells, Nicholas Heller, Alexander Lindsey, Alexander Hard and Bethany Wohrley	DOES CORN HYBRID SELECTION PRECEDING PENNYCRESS PLANTING AFFECT SEED YIELD AND QUALITY IN THE US CORN BELT?
10:00 AM	**Coffee Break**	

10:20 AM	Liv S. Severino, and Adriana P. Sales	STUDIES ON THE FACTORS CAUSING THE UNEVEN GERMINATION OF CASTOR SEED
10:40 AM	Mukhlesur Rahman, A. Rahman, M.Z. Alam, and M.G. Robbani	MODERN OILSEED BREEDING: FROM HIGH-THROUGHPUT PHENOTYPING TO GENOMIC SELECTION
11.00	L. Gomes, J. Moreira, B. Gomes, M. Abias, J. Costa, F. Zanetti, A. Monti, A.L. Fernando	PROSPECTS OF OILSEED CROPS CULTIVATION IN HEAVY METAL CONTAMINATED SOILS - PRODUCING A RENEWABLE FEEDSTOCK USING ECOLOGICAL REMEDIATION
11:25-12.00 PM	**Oilseeds Division Meeting- Division Chair: Hussein Abdel-Haleem**	

5. Natural Rubber and Resins Division

Moderator: Guangyao (Sam) Wang

Room: Lewis and Clark

8:00 AM	***Invited speaker:*** Colleen McMahan, Edward Baidoo, Chen Dong, Jackie Jarvis, Grisel Ponciano, Andrew Nelson, and F. Omar Holguin	CONSIDERING PRIMARY AND SECONDARY CARBON METABOLISM IN GUAYULE (*Parthenium argentatum* G.)
8:30 AM	Almudena Olivas del Rey, Horacio López-Córcoles, Francisco Miguel Jara, Jose Antonio Reche-Vilches, Amaya Zalacain, and Manuel Carmona	ARVENSE FLORA CONTROL IN TRANSPLANTED GUAYULE IN CASTILLA-LA MANCHA (SPAIN)
8:50 AM	Grace Q. Chen, Grisel Ponciano, Chen Dong, Niu Dong, Kumiko Johnson, Trinh Bolton, Tina Williams, Delilah F. Wood, Dante F. Placido, Colleen McMahan, and John M. Dyer	OVEREXPRESSING AN ARABIDOPSIS *SEIPIN1* AFFECTS RUBBER PRODUCTION IN GUAYULE

9:10 AM	Haruhiko Yamaguchi, Yukino Miyagi-Inoue, Ryo Kutsukawa, Riki Imaizumi, Miki Suenaga-Hiromori, Syuto Misawa, Toshiyuki Waki, Toru Nakayama, Satoshi Yamashita, and Seiji Takahashi	BIOSYNTHESIS OF NON-NATURAL POLYISOPRENOIDS BY FUNCTIONALLY MODIFIED *CIS*-PRENYLTRANSFERASES
9:30 AM	Katrina Cornish, David Ramirez-Cadavid, and Sarah Davis	A ROUTE TO SCALABILITY: GUAYULE LATEX RADIATION ATTENUATION GLOVES
9:50-10:20 AM	**Coffee Break**	
10:20 AM	Von Mark V. Cruz, Daniel Carver, Claire Heinitz, and Colin K. Khoury	PREDICTING GUAYULE GROWING AREAS AND COLD INJURY USING MAXIMUM ENTROPY (MAXENT) MODELING
10:40 AM	Serge Palu, A. Amor, and M. Dorget	TOWARDS ALTERNATIVE SOURCES OF NATURAL RUBBER
11:00 AM	Mostafa Dehghanizadeh, B. Silagy, J. Quinn, and Catherine E. Brewer	FEASIBILITY OF SUPERCRITICAL CO_2 EXTRACTION FOR GUAYULE RESIN AND RUBBER EXTRACTION
11:20 AM	Guayente Latorre, Sara Rodrigo-Gómez, Enrique Fernández-Carrillo, María Engracia Carrión, M. Mercedes García, Amaya Zalacain, Gonzalo Ortiz de Elguea-Culebras, and Manuel Carmona	REPELLENT AND ANTIFFEDANT ACTIVITY OF ESSENTIAL OILS AND GUAYULE RESIN AGAINST *Labidostomis lusitanica*
11:40 AM	Brooke Silagy, J. Quinn, M. Dehghanizadeh, C. Brewer, A. Smith, and K. Ogden	IMPROVING GUAYULE'S ECONOMIC COMPETITIVENESS -- A TECHNO-ECONOMIC EVALUATION OF TWO RESIN CO-PRODUCT PATHWAYS
12:00 PM-1:30 PM	**General Membership Luncheon Meeting Madison Room**	
1:40 PM	Francisco M. Jara, M. Engracia Carrión, Horacio López-Córcoles, M. Mercedes García-Martínez,	RESIN PRODUCTION VARIABILITY IN GUAYULE (*Parthenium argentatum* Gray) AND HYBRIDS IN CASTILLA-LA MANCHA (SPAIN)

	Jose Antonio Reche-Vilches, Almudena Olivas del Rey, Amaya Zalacain, and Manuel Carmona	
2:00 PM	M. Engracia Carrión, Guayente Latorre, M. Mercedes García-Martínez, Amaya Zalacain, and Manuel Carmona	GUAYULINS STABILITY IN GUAYULE (*Parthenium argentatum* Gray) HARVESTED STEMS AND RESIN
2:20 PM	Guangyao (Sam) Wang, Diaa Eldin M. Elshikha, Matthew E. Katterman, Theresa Sullivan, Stefan Dittmar, Von Mark V. Cruz, Douglas J. Hunsaker, Peter M. Waller, Dennis T. Ray, and David A. Dierig	DEFICIT IRRIGATION ON SEASONAL GROWTH AND RUBBER PRODUCTION OF DIRECT-SEEDED GUAYULE
2:40 PM	Von Mark V. Cruz, Colleen McMahan, Katrina Cornish, and Michel Dorget	REVIEW OF DIFFERENT ANALYTICAL METHODS FOR QUANTIFICATION OF GUAYULE RUBBER AND RESIN IN PLANT TISSUES
3:00-3:30 PM	**Rubber and Resins Division Meeting, Division Chair: Sam Wang**	

3:30-4:30 PM	**AAIC board meeting**
5:00-8:00 PM	**AAIC Awards Banquet Madison Room** **Guest Speaker**

Poster Presentations

Room: Foyer

GENERAL CROPS & PRODUCTS		
1	Efthymia Alexopoulou	BRIDGING THE GAP BETWEEN PHYTOREMEDIATION SOLUTIONS ON GROWING ENERGY CROPS ON CONTAMINATED LANDS AND CLEAN BIOFUEL PRODUCTION
2	Efthymia Alexopoulou	THE MAGIC PROJECT GROWING SELECTED PROMISING INDUSTRIAL CROPS ON MARGINAL LANDS
3	M.L. Flores-López, A.V. Charles-Rodríguez, O. Dionicio-Concepción, A.M. García-Munguía, V.M. Moo-Huchin, J.C. López-Romero, H. Torres-Moreno, J.L. Guía-García, A.A. Hench-Cabrera, and F.J. Camacho-Martínez	*RHUS MICROPHYLLA* LEAVES EXTRACTS USING OHMIC HEATING WITH INSECTICIDAL ACTIVITY
MEDICINAL AND NUTRACEUTICAL PLANTS		
4	Diana Jasso de Rodríguez, Dennise Anahí Carrillo-Lomelí, Victor Manuel Moo-Huchin, and José Ángel Villarreal-Quintanilla	CHARACTERIZATION OF MEXICAN WILD *OPUNTIA* SPECIES FOR DEVELOPMENT OF FILMOGENIC SOLUTIONS
NATURAL RUBBER AND RESINS		
5	O.J. Idowu, M. Omer, V.M. Cruz, and S. Wang	NITROGEN AND PHOSPHORUS FERTILIZER EFFECTS ON GUAYULE IN AN ARID SANDY SOIL
6	Ana Molina, Emilio J. González, M. Mercedes García-Martínez, M. Isabel Berruga, Guayente Latorre, Amaya Zalacain[2], and Manuel Carmona	FUNGISTATIC EFFECT OF GUAYULE RESIN AGAINST DAIRY PRODUCT FUNGI
7	M. Mercedes García-Martínez, Beatriz Gallego, Guayente Latorre, Jorge Hurtado de Mendoza, M. Engracia Carrión, Amaya Zalacain, and Manuel Carmona	CORRELATION OF THE ARGENTATINS QUANTITATION BY LC-HRMS AND FLOW INJECTION ANALYSIS (FIA-HRMS) IN THE GUAYULE RESIN

8	Grisel Ponciano[1], Von Mark Cruz, David Dierig, Chen Dong, Andrew Nelson, Claire Heinitz, and Colleen McMahan	COMPARATIVE ANALYSIS OF RUBBER BIOSYNTHESIS IN GUAYULE (*Parthenium argentatum* Gray) AMONG DIFFERENT GROWING LOCATIONS IN THE US
OILSEEDS		
9	Jennifer Lachowiec, Anapaula Astorga Bedoya, and Racheal N. Upton	ANALYZING SUSTAINABLE NITROGEN NUTRITION FOR EFFICIENT CAMELINA PRODUCTION
10	S.C. Cermak, G. Biresaw, Y. Chen, L. Chen, H. Ngo, K. Wagner, and K.E. Vermillion	ISO-OLEIC ESTOLIDES WITH SUPERIOR COLD FLOW PROPERTIES
11	R. Evangelista, A. Parrish, D. Joos, P. Alberti, S. Cermak, M. Hojilla-Evangelista, and M. Berhow	INDUSTRIAL GRAIN HEMP VARIETY TRIAL IN ILLINOIS – 2021
12	Jennifer Lachowiec, Ian Mackay Oehler, Dakota Rygh, R N Upton, and Fernando Henrique Correr	NATURAL VARIATION IN BIOMASS ROBUSTNESS OF *CAMELINA SATIVA*
13	Mary E. Phippen, and Winthrop B. Phippen	DEVELOPMENT OF A RAPID ASSAY FOR TOTAL GLUCOSINOLATE CONTENT IN PENNYCRESS *(Thlaspi arvense* L.) SEED BY MEASUREMENT OF ENZYMATICALLY RELEASED GLUCOSE USING A BLOOD GLUCOSE METER AND TEST STRIPS
14	Federica Zanetti, Moritz von Cossel, Pietro Peroni, Elena Pagani, Michał Krzyżaniak, Mariusz J. Stolarski, Iris Lewandowski, Efi Alexopoulou, Andrea Monti	CAMELINA (CAMELINA SATIVA L. CRANTZ) ON MARGINAL SOILS IN EUROPE
15	Federica Zanetti, Lorenzo Samuil Mordos, Angela Vecchi, Agustina Sans, Rick Bennett, Christina Eynck, and Andrea Monti	CARINATA AS A COVER CROP FOR NORTHERN ITALY
FIBERS AND CELLULOSICS		
16	Saptaparni Chanda, Dilpreet S Bajwa, Mohiuddin Quadir, and Karan Bansal	AMINE COMPATIBILIZATION OF CELLULOSE NANOCRYSTALS TO IMPROVE DISPERSION AND PHYSICO-

		MECHANICAL PROPERTIES IN HIGH DENSITY POLYETHYLENE POLYMER
17	Ashton O. Chan, D.S. Bajwa, and K. Hartman	ENHANCING THE MECHANICAL PROPERTIES OF WOOD VIA CELLULOSE NANOCRYSTAL (CNC) IMPREGNATION
18	Daniel Blake, D.S. Bajwa and Adam Gladen	DEVEOPMENT OF NANOCELLULOSE BASED THERMAL ENERGY STORAGE MATERIAL

ABSTRACTS

FIBERS AND CELLULOSICS DIVISION

ORAL PRESENTATIONS

CHAIR

EFTHYMIA ALEXOPOULOU

CENTRE FOR RENEWABLE ENERGY SOURCES AND SAVING (CRES), PIKERMI, GREECE

NATURAL FIBERS – MARKET, TRENDS, AND FUTURE

Dilpreet.S. Bajwa

Montana State University, Bozeman, MT, USA

Natural fibers are thin, long and flexible thread-like structures that are obtained from animals, plants, or mineral sources. They are one of the sustainable and renewable resources that have recently attracted a lot of attention. Currently, the natural fibers market is valued at USD 4.46 billion in 2021 and is expected to reach USD 68.4 billion by 2029, registering a CAGR of 5.50 % during the forecast period of 2022 to 2029. Europe is predicted to remain as the largest market for natural fiber industrial products. Common natural fibers extracted from plants include bamboo (Bambusoideae), cotton (*Gossypium hirsutum*), sisal (*Agave sisalana* Perrine), kenaf (*Hibiscus cannabinus* L.), hemp (*Cannabis sativa* L.), and jute (*Corchorus capsularis*). Natural fibers have numerous benefits such as low density, high specific stiffness, strength, and are cost effective. Major industrial applications driving natural fiber usage include building composite materials, automotive composite parts, interiors of automobiles, panels for partition and false ceiling, particle boards, and insulation boards. Recent trends to use natural fibers in medical applications, cosmetics, electrical, electronics and sporting segments are gaining more traction. Physical pr.operties such as reduced skin irritation, thermal insulation, biodegradable and better surface finish to molded composite parts from natural sources are desirable. The demand for silk-based and wool-based products in medical and textile products respectively is expected to drive natural fibers to high end applications. Better thermal insulation, cost effective and low weight are key attributes to the textile industry. The rise in awareness of the damage to the environment by synthetic materials has led to the growth of environmentally sustainable materials. Some of the challenges associated with natural fibers from industry perspective include their affinity to moisture, variability in material properties, consistent and reliable supply, and the manufacturing and other functioning processes are cost intensive and energy intensive. Current agronomic and genetic efforts, chemical treatments, improved coupling agents for superior interfacial bonding between fiber and polymeric matrices are aimed at accelerating natural fiber use in commercial applications.

Contact: Dilpreet Bajwa, Department of Mechanical and Industrial Engineering, Montana State University, Bozeman, MT, USA E-mail: Dilpreet.bajwa@montana.edu

STEM INJURY EFFECTS ON INDUSTRIAL HEMP GRAIN AND BIOMASS YIELD IN NORTH DAKOTA

Darin J. Eisinger[1], Mark E. Zarnstorff[2], and Burton L. Johnson[1]

[1]North Dakota State University, Fargo, ND, USA
[2]National Crop Insurance Services, Overland Park, KS, USA

Crop plant injury from weather related events such as hail storms and wind can cause broken or cut off stem damage that reduces crop grain and biomass yields. Studies were initiated to quantify stem damage effects on industrial hemp (*Cannabis sativa* L.) grain and fiber yield in collaboration with the National Crop Insurance Services. Experiments were conducted at the North Dakota State University Prosper off-station research site located approximately 24 km NW of Fargo, ND, USA, in the 2021 and 2022 growing seasons. Studies were a RCBD with a factorial treatment arrangement with 4 replicates and experimental units consisting of 6-rows spaced, 30 cm apart, and 4 m in length. Treatments involved three factors (i.) cultivars, (ii.) growth stage (13, 55, and 67), and (iii.) stem injury (non-injured control, cutoff, and broken-over). Hemp cultivars Katani and Canda are diecious and monecious, respectively. Traits determined were grain and fiber yield and stem injury response categorized as straight (non damaged), gooseneck, and branched. The growth stage (GS) by stem injury (SI) interaction indicated grain yield reduction increased as growth stage advanced with the greatest grain yield reduction for the stem cutoff treatment and less yield reduction for the broken-over treatment when compared with the control. Greater grain and fiber yield reduction for the cutoff compared with broken-over stem injury treatment was related to cutoff plants having to regrow stems (branches) from leaf node axillary buds whereas broken-over stems either straightened or developed a gooseneck. As treatments were applied at later growth stages the level of straightened stems decreased and goosenecks increased. For the stem cutoff treatment branching from lower stem nodes was more common at earlier stages and branching at higher leaf nodes was more common at the later growth stages. The GS main effect and GS x SI interaction were not significant for fiber yield, but the main effect of SI indicated a 12 and 33 percent reduction in fiber yield for the broken-over and cut off stem treatments, respectively, when compared with the control. These studies are ongoing and provide the base information for formulating stem damage loss charts for industrial hemp crop loss procedures.

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NANO BORON OXIDE AND NANO ZINC OXIDE INCORPORATION TO CELLULOSE NANOCRYSTALS TO IMPROVE THE THERMAL, MECHANICAL AND FLAMMABILITY PROPERTIES OF HIGH DENSITY POLYETHYLENE POLYMER

Saptaparni Chanda[1], Dilpreet S Bajwa[1], Nicole Stark[2], and Sreekala G Bajwa[3]

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Recent development in nanotechnology opens up a new era in the polymer composites industry. For the production of functional composites, bio-based sustainable nanofiller like cellulose nanocrystal (CNC) is used. Poor fire retardancy (FR) of polymers influenced the search for nanoscale based FRs for the production of FR polymer composites. Nano inorganic oxides can improve the fire behavior of polymers by modifying their degradation pathway. Boron and Zinc-based compounds are well known for their superior flame retardancy, low toxicity and eco-friendly nature. In this research, hybrid systems of nano B_2O_3/CNC and nano ZnO/CNC were prepared and incorporated in the HDPE matrix to improve physico-mechanical and FR properties. Nano B_2O_3 was produced by ultrasonication of B_2O_3 powder. ZnO nanoparticles were prepared using zinc acetate and sodium hydroxide in aqueous dispersion. Both inorganic oxides were coated onto CNC separately in different concentrations. These hybrid systems of B_2O_3/CNC and ZnO/CNC were added to HDPE separately for the production of composites via melt blending extrusion process. The composite properties were evaluated using Fourier Transform Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray (EDX), Thermo-Gravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and Dynamic Mechanical Analysis (DMA) and tensile testing. SEM micrographs and EDX images confirmed the fibrillar morphology of the composite cross-section and presence of Boron and Zinc in the system. The composites containing CNC: ZnO (1:2) and CNC: B_2O_3 (1:1) showed higher crystallinity, higher thermal stability, better mechanical properties, and lowest reduction in weight loss (%) compared to the other systems. The ZnO/CNC and B_2O_3/CNC complexes provided an insulating and shielding effect to the polymer composites, improving the thermal stability. ZnO incorporation improved the storage modulus of the system for 89% and B_2O_3 improved for 69% compared to neat HDPE. There is a reduction in weight loss (%) for 18% with the incorporation of nano oxides in the composites. Incorporation of more ZnO and B_2O_3 to the system accelerated the degradation of the polymer at higher temperatures. The declining trend of mechanical and thermal properties can be attributed to this reason. The LOI test and cone calorimetry test are in progress.

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HOW IRRIGATION AND FERTILIZATION AFFECTS GROWTH AND YIELDS OF INDUSTRIAL HEMP GROWTH ON A MARGINAL AGRICULTURAL LAND IN GREECE

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Industrial hemp (*Cannabis sativa* L.) is a short-day bast-fiber crop with a rapid growth that can reach a height of 4 m in 100 days. It is considered a good crop ahead of cereal cultivation. Hemp absorbs heavy metals (such as Cd, Pb, Zn, and Cu) and contributes to the phytoremediation of contaminated soils. Although it is traditionally considered as fiber crop currently it is characterized as a multi-purpose crop since a wide range of biobased products and bioenergy can be produced from all parts of the plant (www.fibrafp7.net, www.multihemp.eu) such as biocomposites, insulation mats, textiles and construction materials from its stems, CBD from its panicles, oil and proteins from its seeds (www.eiha.org). At European level the area of industrial hemp cultivation remains for a long period (more than 20 years) between 10,000 and 15,000 euros and from 2013 starting to increase. In 2017, the cultivation of industrial hemp was 42,500 ha. The main producer in Europe is France providing more than half of the total production. The main reason for this increase in the cultivation area was the increasing demand for biocomposites and CBD. The aim of this research work was to evaluate the effect of irrigation (I3: fully irrigated, I2: 50% of I3 and I1: 25 % of I3) and fertilization (N0: zero top fertilization, N1: 30 kg/ha and N2: 60 kg N/ha) on two hemp varieties (Futura 75 & Futura 83). The field trial was established in spring 2021 in a marginal area in central Greece. The soil was sandy with low organic matter. A drip irrigation system was used for irrigation and top nitrogen fertilization. During the growing period the following measurements had been carried out: a) phenological observations (date of sowing/establishment, emergence date, flowering time and harvesting time), b) growth data (plant height, plant density, and stem diameter), c) yields data (1 m^2 per plot was harvested for yields estimations) and d) laboratory analyses (dry matter content, proximate and elemental analysis, gross and net calorific value). The total dry matter yields (t/ha), averaged overall treatments, was 27.6 t/ha (the dry stem yields were 16.2 t/ha). Between the two tested varieties the most productive was Future 83 with dry matter yields of 30.4 t/ha, while for Future 75 was 24.8 t/ha. Irrigation affected the biomass hemp yields and thus the highest yields were recorded in the fully irrigated plots with dry yields of 33.8 t/ha. The plots with medium irrigation gave a lower productivity (26.1 t/ha), while the plots that received ¼ of the full irrigation gave 22.80 t/ha. The corresponding values for dry stems yields were 18.2 t/ha (I3), 14.5 t/ha (I2) and 12.8 t/ha (I1). Nitrogen affected less hemp yields compared with irrigation. The plots that didn't receive nitrogen fertilization produced 26.5 t/ha dry biomass (14.7 t/ha dry stem yields). The plots that fertilized with 30 kg N/ha produced 27 t/ha (15 t/ha dry stem yields). The highly fertilized plots reached the highest dry matter yields and were 29 t/ha (16 t/ha dry stem yields). The data collected from both field and lab are still analyzed and the final outcomes will be presented in the full article of this abstract.

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ENERGY YIELD DECLINE OF SIDA (*SIDA HERMAPHRODITA* L. RUSBY) IN A SUMMER HARVEST REGIME FOR BIOGAS PRODUCTION

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In Germany, the interest in perennial cropping systems for bioenergy feedstock production has increased significantly over the past decade. For example, the area under the cup plant (*Silphium perfoliatum* L.) has increased from 500 to 10,000 ha since 2015. The reasons for this are primarily the environmental and societal ecosystem services that are more pronounced in cup plants compared with silage maize (*Zea mays* L.), such as biodiversity enhancement, and erosion mitigation. To promote the diversification of energy supply even more sustainably through another equally promising perennial flowering bioenergy crop, *Sida hermaphrodita* L. Rusby (hereafter referred to as *Sida*), also known as Virginia mallow, was investigated in field trials at University of Hohenheim (southwest Germany). Up to now, *Sida* has been widely considered as a solid biofuel in research and practice. For this use, the dead aboveground *Sida* biomass is harvested in spring before the plants' regrowth. Consequently, the research question of this study was, in how far *Sida* performs as a biogas crop in comparison with cup plant and silage maize, which is commonly used for commercial biogas production. Therefore, the vegetative biomass of *Sida* was harvested in the vegetative stage, i.e. green biomass in summer, to evaluate its methane yield employing batch tests. Due to the perennial nature of *Sida*, regular summer harvests were conducted over a longer period (2014-2018) to clearly evaluate the overall plant performance. A comparison of the average dry matter yields (DMY) showed that *Sida* performed considerably weaker (12.3 t/ha) than cup plant (22.4 t/ha) and maize (20.1 t/ha) when harvested in summer. Moreover, there was a clear trend of a gradual decline in DMY for *Sida* from 18.2 t/ha in 2015 to 9.2 t/ha in 2018. Against this, cup plant and maize showed relatively stable DMY throughout the observation period (i.e. for cup plant from 2015-2018). The average substrate-specific methane yield (SMY) of *Sida* (278.4 l_N CH_4/kg_{VS}) was similar to cup plant (264.3 l_N CH_4/kg_{VS}), while maize yielded highest (335.2 l_N CH_4/kg_{VS}), as was expected for this positive control. However, for *Sida* a minor increase in SMY (circa 10 l_N CH_4/kg_{VS}) was observed from 2016 to 2017, which might be due to the change in *Sida* biomass composition. Based on these results, the methane yield per hectare (MYH) was calculated (MYH = DMY × SMY). Here, for *Sida*, the large decrease in DMY was shown to have a stronger impact on MYH than SMY, as MYH also decreased by 45.4% from 4643.2 m^3 CH_4/ha or 167.2 GJ/ha (1 m^3 CH_4 equals 36 MJ) in 2015, to 2537.3 m^3 CH_4/ha or 91.3 GJ/ha in 2018. In contrast, the MYHs of cup plant and maize showed stable MYHs of 5261.4 and 6610.6 m^3 CH_4/ha, respectively. We suggest that the steady decrease in DMY, which can be considered as the main reason for the energy yield decline of *Sida*, is a consequence of the early harvest of the *Sida* biomass in summer. Such yield declines were not observed for *Sida* biomass harvests in winter. In this case, *Sida* can translocate nutrients and assimilates back to the root system allowing for a stronger regrowth in spring. It can be concluded that *Sida* is rather not suitable for biogas production due to cutting intolerance in a continuous summer harvest regime.

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BIODEGRADABLE COMPOSITE HYDROMULCHES FOR SUSTAINABLE ORGANIC HORTICULTURE

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In agriculture, mulch helps retain soil moisture and soil temperature while preventing weed growth. Currently, the most common material used for commercial mulching is polyethylene. At the end of the growing season, this plastic is typically buried or burned, creating a large impact on the environment. Another issue with this type of mulch is it cannot be used for organic farming. The goal of this research is to develop an alternative to polyethylene mulch that is organic and biodegradable while still providing the same benefits. The hydromulch treatments being tested contain a mixture of either paper pulp, wood fiber, or hemp (*Cannabis sativa* L.) hurds in combination with a tackifier. The tackifiers being used are guar gum, psyllium husk, and camelina meal, which are being tested at various concentrations. These treatments have been tested for tensile and puncture strengths using a universal testing device. The treatments were also compared to control samples containing no tackifier to determine if the addition of tackifier at increased concentration resulted in enhanced mechanical properties. The results have shown that the samples containing tackifiers performed better in both tests than the control samples that didn't contain any, and the mulches containing paper were far superior to those containing wood or hemp hurds. It has also been observed that increased tackifiers improve mechanical properties and that guar gum was clearly the best tackifier. Due to the high costs of guar gum, in an attempt to cut overall costs of the hydromulch, guar gum was combined with camelina meal. This was done at a rate of 75%, 50% and 25% by weight and then combined with paper like before. The results showed that the interaction of the two tackifiers caused a substantial decrease in mechanical properties eliminating these tackifier blends as potential candidates. In addition to the strength testing, rain fastness is being done. In this test, water is dripped onto a sample of hydromulch at a rate of 0.6 inches over a span of 15 min. The sample is at an angle of 10 degrees to allow for excess water and material to run off. The sample is then dried and reweighed and the rain fastness index (RFI) is calculated (final weight/initial weight of dry ingredients). This test is ongoing, but results are indicating that paper is far superior to wood in the rain fastness test and no trends have yet to be seen between type of tackifier, tackifier concentration, and RFI. Further testing is being conducted to test other properties including soil adhesion. When all lab tests are complete, the best performing formulations will be studied outdoors in a large-scale field study.

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ENHANCING THE VALUE OF LIGNOCELLULOSIC BIOMASSES THROUGH THE PRODUCTION OF BIONANOCOMPOSITES

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The need for more ecological and biodegradable materials, and of renewable origin represents nowadays a key focus of the scientific community to combat the massive use of non-renewable and non-biodegradable resources that are contributing to severe levels of pollution. Lignocellulosic crops are rich in cellulose, hemicellulose, and lignin, representing, therefore, an important feedstock to multiple value-added products, capable of substituting the fossil feedstocks. Nanocellulose (NC) is a suitable example that has applications in many different areas, ranging from automotive manufacturing, medicine, food industry, and extending to the energetic field. In the food industry, the change from traditional petroleum-based plastics to biodegradable polymer materials is causing some constraints, namely the pauper mechanical, thermal, and barrier properties are restricting the opening of biopolymers to the markets. The insertion of homogeneously scattered nanoparticles, like nanocellulose, as a reinforcement agent, into the biopolymer matrix is seen as a promising possibility to surpass these shortcomings, generating bionanocomposites. Therefore, the aim of the work was to optimize the extraction of NC from different lignocellulosic biomasses (sorghum, (*Sorghum bicolor* (L.) Moench) and sunnhemp, (*Crotalaria juncea* L.)) and to evaluate its application as a reinforcing agent in chitosan biofilms. The nanocellulose was obtained via alkaline pretreatments with NaOH, followed by a bleaching and acid hydrolysis. In the alkali pretreatment process optimization, some parameters were tested, namely time of reaction and temperature, and taking into consideration a scale up of the process, the time of 2 h 30 min and temperature of 60ºC were chosen as optimum. Comparing the two biomasses, nanocellulose extracted from sunnhemp was easier to process mechanically and presented a better nanocellulose/micro cellulose ratio. From sorghum, two different NC were prepared, from inner and outer layer, as the original stems were divided in these two parts which have been processed separately after chopping and grinding. These NC were incorporated in chitosan at 2.5% w/w over the mass of chitosan and the bionanocomposites were characterized: FT-IR, mechanical properties, thickness, optical properties, surface color, permeability (oxygen and water vapor), solubility, swelling degree, and contact angle. A biofilm made with pristine chitosan was used as the control. The results confirmed that the nanoparticles improved the mechanical properties of the chitosan biopolymer as planned. At the rate of 2.5% NC, it was possible to achieve near 30-40% increment in Tensile Strength (TS), 50-60% in Elastic Modulus (EM) and reduction of Elongation at break (% EAB) by 60-70%, compared with pristine chitosan films. Further, bionanocomposites are slightly more saturated and showed greater ultraviolet light block than the pristine chitosan films, in particular Sunnhemp NC. Sunnhemp films also showed a slightly higher thickness than sorghum films and pristine chitosan films. Hence, results indicate that those lignocellulosic crops may afford a source of NC for the production of bionanocomposites.

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ABSTRACTS

MEDICINAL AND NUTRACEUTICAL PLANTS DIVISION

ORAL PRESENTATIONS

CHAIR

DIANA JASSO DE RODRÍGUEZ AND ANA LUÍSA FERNANDO

UNIVERSIDAD AUTÓNOMA AGRARIA ANTONIO NARRO, SALTILLO, COAHUILA, MÉXICO

DEVELOPING NORMATIVE STANDARDS FOR THE CANNABIS/HEMP SECTOR

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ASTM International was created in 1898 and has become one of the world's largest international standards developing organizations (SDO). Defined and set by members who are volunteers, ASTM standards improve the daily lives of millions of people around the world. There are over 30,000 members from around the world with stakeholders from industry, governments and individuals and these members collaborate openly/transparently in technical committees, to deliver standards which combine market relevance with the highest technical quality. As a result, ASTM standards are used and accepted worldwide and cover areas such as metals, paints, plastics, textiles, petroleum, construction, energy, the environment, consumer products, medical services, devices and electronics, advanced materials, cannabis/hemp, etc. These standards enhance performance and help everyone have confidence in the things they buy and use - from the toy in a child's hand to the aircraft overhead. Everyone works together with one overarching objective - *helping our world work better*. The principles are simple; the standards process must be open, transparent, relevant, forward looking, global in reach and collaborative. The global cannabis/hemp sector is growing at a rapid pace. Standards that help build confidence in this field help this industry blossom. Since 2017, a diverse group of globally recognized industry leaders from 30 countries work together to help develop standards that promote safety and quality in various branches of the industry under ASTM Committee D37 on Cannabis (*Cannabis sativa* L.) (astmcannabis.org). The committee considers diversity, equality and inclusion as well as sustainability when developing standards in the area of horticulture, quality management, laboratory analysis, processing/packaging, security/transportation, credentialing, hemp, devices and sustainability. This presentation will describe the way the committee was established and how it grew from ~60 people in February 2017 to over 1000 members to develop market relevant standards. This will include a description of the standard development process and how standards in subcommittee D37.01 on *Indoor and Outdoor Horticulture and Agriculture* such as the Practice for Good Medicinal Cannabis Cultivation are progressing at ASTM D37.

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REPRODUCTIVE BIOLOGY OF MEDICINAL TREE, *PAULOWNIA*: POLLEN-STIGMA INTERACTION, EXTRAFLORAL NECTARIES AND TRICHOMES

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Plants have always been a valuable source of life saving drugs and bioactive compounds. Recently, SARS-CoV-2 infection has brought plants back into the focus for the search of antiviral compounds. *Paulownia* is a multipurpose, fast -growing tree that has been domesticated in over 50 countries and present in the US landscape for over 180 years. Phytochemical studies suggest the presence of many bioactive compounds that are present in the leaves, fruits, flowers, bark, and wood. Aqueous extracts of *P. elongata* leaves and silage have shown *in vitro* antimicrobial activity against many gram-negative bacteria. *P. tomentosa* leaf extracts inhibit the protein tyrosine phosphatase 1β and α-glucosidase, which are important therapy targets of obesity and diabetes treatment, suppress the production of IL-6 and TNF-α in LPS-stimulated RAW 264.7 macrophages, and treat airway inflammation. *Paulownia* genus is placed in a monogeneric family Paulowniaceae with its nine natural species and many natural and man- made hybrids. To develop hybrids with desirable traits, reproductive biology was studied. In middle Georgia conditions, trees flower in March and continue producing flowers for 3-4 weeks. *Paulownia* buds were collected at different developmental stages to study floral biology, pollination and fertilization employing light, fluorescent, and scanning electron microscopy from the 5 acre '*Paulownia* Demonstration Plot' established at Fort Valley State University. For preparing paraffin sections to score histological events using light microscopy, flower buds were fixed in Histochoice for 24-48 hours, dehydrated in ethanol series, transferred into the infiltration medium and embedded in paraplast. The paraffin blocks were cut with a rotary microtome at a thickness of 8-10 micron, and the microtome sections were then stained with safranin or toluidine blue. For samples studied using SEM techniques, the buds were fixed in glutaraldehyde and osmium tetroxide, dehydrated in ethanol series, critical-point dried using liquid CO_2, mounted onto aluminum stubs on carbon coated disc, and sputter-coated with gold prior to scans. Pollination can be assisted by insects or wind and is highly efficient. Fertilization results in the formation of hundreds of seeds housed in two locules of ovary. Seeds are winged that aids in its dispersal. An interesting find was the presence of extra floral nectaries on *Paulownia* leaves and their possible function is a part of ongoing research. Further, leaves, flowers and fruits possess many types of glandular and non-glandular trichomes that can be important for secondary metabolite synthesis, plant defense, and anti-feedant compounds. Flavonoid analysis of different plant parts revealed high concentrations in the leaves, seeds, and flower buds. Research conducted in all these aspects will be presented and their possible interactive roles will be discussed.

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SEMI-DESERT PLANT EXTRACTS AS BIOSTIMULANTS FOR GROWTH, YIELD AND FRUIT QUALITY IN BELL PEPPER (*Capsicum annuum* L.)

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Species with a high content of polyphenols and antioxidant activity have been identified in the semi-arid areas of northeast Mexico, which can be used as biostimulants that promote physiological effects similar to bioregulators as well as growth and production in bell pepper. The objective of the research was to evaluate the effect of four semi-desert plant extracts: *Rhus muelleri*, *R. virens*, *Flourensia microphylla* and *F. retinophylla*, as biostimulants for growth, yield and fruit quality of bell pepper, Cannon variety. The experiment was carried out in a greenhouse, under a completely randomized design with eight treatments: four extracts of the plants mentioned above and three bioregulators as controls (gibberellic acid, indole acetic acid, and 6 benzyl aminopurine), and a control without extract or bioregulator, with 14 repetitions per treatment. The applied dose of extracts and bioregulators was 75 mg L^{-1}, with five foliar applications of extracts (transplant, at 17, 33, 46 and 94 days after transplant) and three foliar applications of bioregulators (in transplant, at 33 and 46 days after transplant). In general, the extract of *F. retinophylla* stimulated a higher fruit weight (212.9 g), number of fruits (7.4) and fruit yield (1.57 kg/plant), it also stimulated a greater equatorial diameter. The extract of *F. microphylla* promoted a higher content of *vitamin C*, and that of *R. muelleri* the content of total soluble solids. It is concluded that the extract of *F. retinophylla* may represent an alternative for the formulation of a semi-desert plant biostimulant.

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ABSTRACTS

GENERAL CROPS AND PRODUCTS DIVISION

ORAL PRESENTATIONS

CHAIR

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THE MAGIC PROJECT MARGINAL LANDS FOR GROWING INDUSTRIAL CROPS: TURNING A BURDEN INTO AN OPPORTUNITY

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Industrial crops can provide abundant renewable biomass feedstocks for the production of high added-value bio-based commodities (i.e. bio-plastics, bio-lubricants, bio-chemicals, pharmaceuticals, bio-composites, etc.) and bioenergy. They can be broadly categorized as oil, lignocellulosic, carbohydrate or specialty crops. Most of them are multipurpose crops offering the opportunity to follow a cascade bio refinery concept to produce a number of value-added bioproducts and bioenergy, thus feeding the bio-based economy. Prospectively, industrial crops can increase and diversify farmers' income through access to novel bio-based markets (i.e. bulk and fine chemical, biomaterial or bioenergy industries, amongst others), and the possibility to exploit marginal land with limited value for conventional agriculture. In recent years, a debate has emerged regarding food security and land use for bioenergy/industrial non-food crops. Cultivating industrial crops on marginal land unsuitable for food production is consistently proposed as a viable alternative to minimize land-use competition for food production, and its adverse effects (direct or indirect) on food security, land based GHG emissions and biodiversity loss. The MAGIC research project (H2020, www.magic-h2020.eu, that ended in December 2021) aimed to promote the sustainable development of resource-efficient and economically profitable industrial crops grown on marginal lands. To achieve the objectives of the project different work packages were designed: WP1) an up-to-date database of existing resource-efficient industrial crops was developed with information on their agronomic characteristics, input requirements, yield performance and quality traits for end-use applications; WP2) development and validation of a Decision Support System (DSS) with the active involvement of farmers and end users. Mapping of current and future marginal lands in Europe facing natural constraints, characterized, and analyzed to provide a spatially explicit classification that will serve as a basis for developing sustainable best-practice options for industrial crops; WP3) Identification of the most promising crop species taking advantage of the profound experience of the consortium and in a multi-actor approach with stakeholders. Further investigation actions include the creation of new breeding tools and strategies towards better crop varieties; WP4) identification and optimization of appropriate agronomic practices with limited input requirements; WP5) development of suitable harvesting strategies and logistics to optimize the biomass supply-chains; WP6) maximization of the impact of MAGIC by integrating sustainability aspects (covering environment, society and economy) of the value chains; WP7) analysis of success stories of industrial crops in EU regions addressing technical, environmental, economic and social issues to produce policy recommendations and best-practice guidelines for their promotion at local/regional level; WP8) dissemination to increase farmers' awareness and establish strong links with EIP AGRI. An overview of the main results achieved through the MAGIC project will be presented.

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EXPLORING PLANT'S COGNITIVE ABILITIES AS A TOOL FOR MANAGEMENT OF INDUSTRIAL CROPS

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The recognition that plants have cognitive abilities is proposed as an avenue to apply the complex knowledge from the discipline of Plant Physiology in the crop management of industrial crops. Plants have the ability to sense many cues from the surrounding environment and assess their internal condition, and they process that information, make decisions, and take actions driven by those decisions. The plant's cognition has limited acceptance in the scientific community because it is mistakenly compared with the animal's cognition that requires a nervous system and a central organ (a brain) to perform the thinking activity. Plants do not have neurons or brains, but they develop different mechanisms to operate their intelligence. The process of sensing the cues and responding to stimuli are traditionally investigated with the mechanistic approach that aims to identify and measure the biochemical sensors, the genes that are up or down regulated, the enzymes that are involved, and so on. These mechanisms are very complex and difficult to understand. For that reason, the knowledge from Plant Physiology is hardly applied in crop management. It is proposed that the recognition that the plants collect the relevant information, process it, and make smart decisions, is a bridge that can provide comprehensible information in the management of industrial crops. The decisions that plants make always have a rational fundament that could be explored as the explanation to the effect of treatments. For instance, some industrial crops are cultivated aiming to extract an active compound that is highly influenced by the environment. The factors that drive the accumulation of that compound could be investigated following the question why the plant decides to increase or decrease its content. Plant's decisions are coherent with rational frameworks such as the analysis of benefit / cost, when it considers the amount of resources employed compared with the benefits resulting from each decision. The reasoning can also be guided by a strategic analysis. For example, a germinating seed has limited reserves, which needs to be strategically balanced between using them in short time for a fast growth or conservatively to endure a long time under stressful environment. The plant's decisions can also be the optimization of very intricate processes. For instance, photosynthesis is influenced by a long list of factors from environment and internal condition (CO_2, light intensity and quality, air temperature and relative humidity, water availability in the soil, nutrients, hormones, source-sink balance). The photosynthesis regulation can be investigated as a mechanism able to integrate all the relevant variables to make instantaneous decisions that optimize the main output which is carbon assimilation. In conclusion, the cognitive ability of plants could be explored as an option to facilitate understanding the plant's response to treatments and how to manage crops in order to achieve the objectives of agriculture.

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OUT OF THE BOX: COMBATING CLIMATE CHANGE WITH PHYTOREMEDIATION. IS IT POSSIBLE?

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Among the various impacts caused by man to the environment, soil contamination deserves attention. This gives rise to a number of environmental problems such as desertification, contamination of water resources and contamination of food crops, which can lead to serious health problems for humans directly or indirectly. To avoid these situations, it is necessary to decontaminate the soils, which can occur through various techniques (physical, chemical and biological methods). The use of plants for the decontamination of soils (phytoremediation), and specifically the use of energy crops, is an interesting alternative. Most of the energy crops are considered tolerant to contaminated soils and along with the decontamination action, the biomass produced may provide an additional income, when used for bioenergy or biomaterials. In addition, its production, either for bioenergy or biomaterials, offers environmental advantages, by contributing to the reduction of greenhouse gases and energy savings, helping to combat climate change, and social benefits, especially in rural areas. Moreover, the establishment of dedicated energy crops on contaminated land, avoids land-use conflicts due to competition for food and feed. Among the various species which can be grown to generate energy or biomaterials, the perennial crops miscanthus *Miscanthus* spp), and switchgrass (*Panicum virgatum* L.), and the annual crops biomass sorghum (*Sorghum bicolor* (L.) Moench) and industrial hemp (*Cannabis sativa* L.) are promising because of their high productivity, energy content and biomass composition. Yet, yields and biomass quality can be affected by the soil marginality, reducing the environmental savings and compromising its economic exploitation. In this context, studies on the production of these crops in heavy metal contaminated soils are reviewed, taking into account environmental, economic and socio-economic aspects as also the technological obstacles associated with biomass characteristics. In the end, a critical assessment of the literature is made, and opportunities and risks are pointed out.

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IMAGING OF FLUORESCENT, SYSTEMIC SEED TREATMENT TRACERS IN HEMP FOR THE DEVELOPMENT OF A WEED MANAGEMENT SYSTEM

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New tools are needed for weed management especially during the Critical Weed Free Period (CWFP) of crop development. The CWFP is the time where interspecific competition must be reduced to maximize yield production, usually the first few weeks following crop emergence. One approach is to develop imaging technologies to recognize and differentiate between crop and weed seedlings to facilitate precision weed management. Hemp (*Cannabis sativa* L.) was chosen as the model crop as weed control options, particularly herbicide availability, are limited in the US. Our approach was to use fluorescent tracers, applied as either seed or soil treatments, which are taken up by hemp seedlings. Rhodamine compounds have a desired optical property that both absorbs light and fluoresces in the visible range, so conventional illumination sources and imaging sensors can be used to excite and detect the unique fluorescence in the lab and field. A prototype fluorescence imaging system with needed algorithms and graphic user interface (GUI) was developed at Cornell AgriTech for data acquisition and analysis for lab testing. Excellent spatial resolution was found to detect fluorescence in hemp seedlings. The selectivity of rhodamine, fluorescent tracers was tested in a crop/weed competition study in growth chamber studies. Rhodamine was applied as a seed treatment or soil applied at time of planting. Velvetleaf (*Abutilon theorphrasti* Medic.) was used as the model weed. Velvetleaf was selected for use in this study as it is a common weed throughout many hemp growing regions of the US. Velvetleaf seeds were planted 2.5 cm from the treated hemp seed. Fluorescence was detected only in the crop seedlings when rhodamine was applied as a seed treatment; conversely, some fluorescence was observed in the velvetleaf seedlings from a soil application. Therefore, the best differentiation between crop and neighboring weeds was from rhodamine seed treatment. The long-term goal is to apply the fluorescent tracer as a seed treatment and integrate the seed treatment with the developed sensing and computing technologies for the development of an enhanced precision weed management system.

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BIO-DEGRADABLE 3D-PRINTED RFID SENSOR FOR AGRICULTURAL PURPOSES

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Conventional plastics are a crucial material across many industries, from packaging to high-end electronic sensors, due to their low cost, unique material properties, and resistance to degradation. Despite their benefits, plastic production and disposal pose large environmental problems. Annually, 34 million tons of plastics are produced, 93% of which wind up in landfills or oceans. Due to its inability to biodegrade, these plastics continue to accumulate. Approximately one million tons of plastic debris per year reach aquatic environments. Further, plastic production is highly dependent on fossil fuels and releases large amounts of CO_2 into the atmosphere, contributing to global warming. Sustainable alternatives to oil-based plastics are needed to help mitigate these environmental issues, while maintaining plastics' unique material properties. Bioplastics are a solution to this dilemma since they provide an environmentally-friendly option. Although bioplastics provide a sustainable alternative, their drawbacks include high production costs and limited mechanical properties relative to conventional plastics. Due to these drawbacks, research has been focused on bio-based and biodegradable plastics using renewable resources such as starch, cellulose, wood, and consumer waste. With an enormous amount of animal and consumer waste that is created in a variety of industries, bioplastics created with these wastes provide a solution that is practical for application. Recent studies have found that lignin-based biochar can replace petroleum-based powders in polymer composites as well as in energy storage applications. The biochar provides a renewable alternative with comparable electrical conductivity to petroleum-derived carbon materials. The objective of this work is to combine this biochar with bioplastics to produce a biodegradable and electrically conductive polymer composite that will be 3D-printed to create an agricultural sensor. We hypothesized that a bioplastic material that has comparable electrical and 3D-printing capability to conventional, electrically conductive composites will be attainable. The research began with the conversion of lignin into biochar through pyrolysis at 1100°C. Samples were created with varying amounts of either carbon black or biochar with a blend of common bioplastics poly(hydroxybutyrate-co-hydroxybutyrate) (PHBV) and polylactic acid (PLA). The resistivities of the various samples to determine their electrical conductivity and percolation threshold. A high electrical conductivity biochar composite was chosen for the electrically conductive polymer for the RFID sensor. Using a Lulzbot Taz 3D-printer, the RFID antenna was printed with a PLA substrate base and with the characterized biochar material atop. Polymer degradation tests were conducted within the lab. Lastly, the sensor was sent to the MSU Agricultural Research and Teaching Farm (Bozeman, MT, USA) to be tested for performance. This research provided insight on biochar and how it can be further improved, so that it can someday take over the role of petroleum-derived carbon materials to produce biodegradable and environmentally friendly electrically conductive polymer composites.

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PRODUCTION OF AN ODOR-REDUCING, ANTIBACTERIAL CLUMPING CAT LITTER FROM SOYBEAN HULLS AND SOYBEAN HULL BIOCHAR

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Soybean (*Glycine max* (L.) Merr.) hulls (SH) are a coproduct of soybean processing and are used as a supplement in animal feeds. The hulls currently have a market value of approximately $150 USD per metric ton as animal feed, so finding higher value uses for the hulls would benefit U.S. soybean growers. Biochars from a variety of feedstocks have been found to absorb liquids and odors, including several biochars as components of biobased commercial cat litters. Soybean hull biochar (SHB) was produced from soybean hull pellets in a Top-Lit Updraft design gasifier kiln which reached a maximum temperature of 735ºC during pyrolysis. Copper sulfate ($CuSO_4 \cdot 5H_2O$), which is antimicrobial and has also been previously found to reduce headspace concentrations of the cat-urine compound 3-mercapto-2-butanol (3M2B), and an antimicrobial amylose inclusion complex (AIC) produced by our research group were also examined as litter components. To prepare litter formulations for testing, all components were mixed with 0.5 %w/w guar gum and water to form a dough which was then passed through a pellet mill, dried, ground in a flour mill and sieved to reach a final particle size distribution of 0.5-2.0 mm. Nine litter formulations were produced to determine water absorption (termed hydration capacity) and 3M2B absorption. These formulations were as follows (all in %w/w): (1) SH only; (2) SH + 1% SHB; (3) SH + 10% SHB; (4) SH + 250 ppm copper sulfate; (5) SH + 1 % SHB + 250 ppm copper sulfate; (6) SH + 10 % biochar + 250 ppm copper sulfate; (7) SH + 3.56% AIC; (8) SH + 1% SHB + 3.56% AIC; (9) SH + 10 % SHB + 3.56% AIC. All nine formulations had acceptable hydration capacities, while formulations 3, 4, 5, 6 and 9 greatly lowered 3M2B headspace concentrations. Because the use of copper sulfate has some toxicity concerns if cats were to ingest the litter, formulation 9 was selected for further tests. Additional guar gum was tested as a clumping agent at 1, 2, 3, 4, 5, 7 and 10 %w/w, with the 4% formulation being the lowest amount of guar needed for optimal clumping. Mineral oil was added as an anti-dust agent at 0.5, 1, 2, 3, and 4 %w/w, with the 2% rate being the lowest for optimal dust control as determined by a particle counter. The final formulation treated with simulated cat urine significantly reduced the growth of three pathogenic bacteria. A patent application was filed in 2021 and our research group is collaborating with a commercial cat litter company on the development of a commercial product based on this research.

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ABSTRACTS

OILSEEDS DIVISION

ORAL PRESENTATIONS

CHAIR

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AGRONOMIC TRAITS AND ECOSYSTEM BENEFITS OF FIELD GROWN SULFONYLUREA-RESISTANT *CAMELINA SATIVA* AND *BRASSICA NAPUS*

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New industrial oilseed crops such as camelina [*Camelina sativa* (L.) Crantz] do not have approved herbicides for weed control, which limits its expansion as a commercial crop. The objectives of this field study were to evaluate agronomic traits and ecosystem services provided by sulfonylurea-resistant camelina and canola (*Brassica napus* L.). Field plots near Fargo, ND were set up in a randomized complete block design including four blocks of camelina, canola, and fallow per location (NDSU and NW22). Camelina and canola were seeded (18 May) at 4.9 and 2.9 kg ha^{-1}, respectively, using 19-cm row spacing. Data was collected mid- and late-season (29 June and 22 July, respectively) for crop and weed stem count (no. m^{-2}), biomass dry matter (kg m^{-2}), and nutrient (N, P, K, S) content (kg m^{-2}), as well as final season (7 August) seed yield (kg ha^{-1}) and fatty acid profile for camelina and canola treated with and without sulfonylurea. Using Prefer 90 (NIS) at 0.25% v/v, camelina was treated with thifensulfuron at 6.3 g a.i. ha^{-1}, and canola was treated with thifensulfuron at 10.5 g a.i. ha^{-1} and tribenuron at 5.3 g a.i. ha^{-1}. Compared with fallow, both camelina and canola reduced mid- and late-season weed pressure (stem count and/or biomass). Although weed stem counts in camelina and canola plots were not significantly different ($P \leq 0.05$) from fallow at NW22, biomass of weeds was reduced by both camelina and canola. The herbicide treatment had an additive effect on reducing weed stem counts and biomass in camelina and canola plots at NDSU, but not at NW22. Canola tended to retain greater nutrient content compared with camelina at both locations and camelina and canola biomass, nutrient content, and seed yield were all greater at NW22 than at NDSU. Although seed fatty acid profiles were significantly different between camelina and canola, overall profiles were similar at each location. In this study, the sulfonylurea herbicide treatment was not a significant variable for crop stem counts, biomass yield, nutrient content, or seed yield and fatty acid profiles. Thus, the results indicate that sulfonylurea-resistant camelina and canola could be good rotational cropping options for enhancing weed suppression in agriculture settings.

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UNCOVERING MORPHO-PHYSIOLOGICAL DIVERSITY IN CAMELINA (*CAMELINA SATIVA* (L.) CRANTZ)

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Camelina [*Camelina sativa* (L.) Crantz] is an oilseed crop with recognized potential to become a staple crop in the coming years. Camelina is a climate-resilient crop that meets the diverse needs of end-users across the world and has the potential to propel the expanding bioeconomy sector. Despite being already characterized as a resilient crop, camelina genetic diversity and morpho-physiological plasticity remain relatively poorly characterized. Within the EU project UNTWIST (Uncover and promote tolerance to temperature and water stress in *Camelina sativa*), funded by the H2020 framework research programme, a set of 54 spring camelina genotypes, derived from different sources (i.e. genebanks, private collections, commercial material and private company breeding materials), has been selected to study the plasticity of the crop in response to different climatic conditions. To achieve this, four field trials were established in diverse locations across Europe during the 2020/21 growing season. The test locations included Bologna (Italy), Harpenden (UK), Versailles (France), and Alcalá de Henares (Spain). At each location replicated plots (≈ 1 m^2) with a consistent seed rate (500 seeds m^{-2}) were adopted. Trial sowing dates were specific to the local conditions e.g., end of October in Italy, mid-November in Spain, end of March in France, and beginning of April in UK. To further examine camelina plasticity across the collection, the same set of genotypes were grown in a controlled environment glasshouse experiment to test the effect of temperature elevation and drought stress at an early development stage (BBCH 15-19). The complete dataset from both open field and glasshouse experiments have been analyzed to quantify the individual environmental response of each line, characterizing the diverse capacity of camelina to respond to drought and temperature elevation, and also combined stress in open field conditions. In the open field trials in Spain and Italy, camelina were subjected to environmental extremes typified by the Filomena storm and atypical seasonal drought stress respectively, whilst in UK and France the growing season was average for recent years. In the field, plants were surveyed for phenologic, morphologic, production and seed quality traits. Additionally, on the most stressful site (Italy) stable carbon isotope discrimination was determined for harvested seeds. In the glasshouse, plants were surveyed for phenologic and morphologic traits, alongside collection of samples were collected for targeted and untargeted metabolomic profiling and total antioxidant capacity. Finally, to ensure the collection represented the full diversity of known camelina germplasm, the 54 camelina lines were fully sequenced using Next Generation Sequencing approaches. Multivariate statistical analysis and hierarchical clustering approaches were used to explore the combined data sets. As result the lines have been ranked according to their responses in the field and glasshouse experiments. The results showed unexpected variability across tested genotypes and therefore it was possible to cluster the lines based on their diversity/similarity. This study enabled the identification of camelina lines optimized for specific environmental conditions. The metabolic signatures identified in these lines open the way for future breeding and modeling efforts in camelina.

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WATER STRESS EFFECT ON MORPHOLOGICAL AND COMPOSITIONAL CHARACTERISTICS OF TWO CONTRASTING CAMELINA BIOTYPES

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Water scarcity is becoming one of the main constraints for agricultural production worldwide. Specifically, the shortage of water available during reproductive stages of plant development impairs assimilate allocation in seeds. This results in severe reductions in seed yields and seed quality. Camelina (*Camelina sativa* L. Crantz) is an oilseed crop which has shown better tolerance to drought with respect to other *Brassicaceae* such as canola. Oil composition of camelina makes it useful for several food, feed, and industrial applications. The aim of this work was to evaluate the effect of drought during reproductive stages on two different camelina biotypes, namely a spring and winter cultivar. The experiment was carried out in a semi-controlled environment between November 2020 and May 2021. Plants were grown under a transparent plastic shed at the experimental farm of Bologna University at Cadriano (Italy, 44°30' N, 11°21' E, 32 m a.s.l.), to control water supply. Pots were filled with a silty-clay-loam soil (55% sand, 13% clay, 32% silt) soil. The camelina cultivars Joelle (winter) and Cypress (spring, provided by Smart Earth Camelina, Saskatoon, Canada) were seeded in November 2021. Irrigation was applied at a rate of 17% pot capacity during winter, and at a rate of 21% pot capacity from early spring until full maturity, in the control pots. Water shortage was applied in two growth periods (water treatment), from full flowering to maturity (D1), and from the end of flowering to maturity (D2). Stressed pots received water at a rate of 12% pot capacity. During the growth cycle, plant height was weekly measured until reaching the maximum value. At harvest, the number of siliques on the main stem, stem and seed dry weight per plant were assessed. Seed oil content, fatty acid and tocopherol composition were determined on the seeds of each pot. Two-way ANOVA was conducted, using "water treatment" and "cultivar" as main factors. Factor "cultivar" was significant for the number of siliques, stem dry weight, C18:1 content, and n-3:n-6 ratio. The analysis revealed that water shortage significantly ($P \leq 0.05$) affected all variables, except α-tocopherol. Interaction "treatment x cultivar" resulted significant ($P \leq 0.05$) for seed production. Cultivar Joelle had significantly more siliques on the main stem (42.9) compared with Cypress (29.0). However, Cypress stems were heavier (2.19 g) than the ones of Joelle (1.96 g). Plants from D1 were the smallest (45.4 cm), with less siliques (32.5 siliques per plant) and lighter stems (1.65 g DM/plant), compared with both D2 and control plants. Plants of D2 produced significantly less seed (0.67 g/plant) than the ones in D1 treatment (0.78 g/plant), and the control ones (1.62 g/plant). Cypress produced much more seed than Joelle under control conditions (1.92 g/plant and 1.31 g/plant, respectively). However, seed production of Cypress and Joelle under stressful conditions was not significantly different, thus Cypress yield was more severely affected by drought stress (64.7% reduction) than Joelle (41.1% reduction). Regarding oil quality, Joelle had the highest C18:1 content (12.2% compared with 11.4 in Cypress), and the highest n-3:n-6 ratio (2.10 compared with 1.56 in Cypress). Seeds from D1 plants had a higher seed oil content (30.6%, not significantly different from 32.1% oil content of control plants), than D2 seeds (24.1%). Plants in D1 had a n-3:n-6 ratio significantly higher than D2 plants (2.1 and 1.6, respectively), but not different than the one of control plants (1.9). Both D1 and D2 treatments decreased C18:1 content of seeds (11.1% and 11.8%, respectively) when compared to seeds from control plants (12.6%). Seeds from plants of D2 treatment showed the highest γ-tocopherol content (1071.9 mg kg^{-1} oil), while D1 and control plants showed remarkably lower γ-tocopherol content (616.7 mg kg^{-1} oil and 622.6 mg kg^{-1} oil, respectively). The experiment confirmed that drought stress at reproductive stages modifies plant morphology and decreases seed production in camelina.

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CAMELINA: A CASH COVER CROP FOR GREECE

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Camelina [*Camelina sativa* (L.) Crantz] is a novel oilseed crop for the European biobased industry. It has a short growing cycle (<120 days, 90 to 120 days), it can be grown in most climatic zones of Europe and in the Mediterranean region can be grown both as a winter and spring crop. Due to its short growing cycle and its cold resistance, it can be grown as a cash cover crop in dry areas of South Europe. In recent years, it has been studied in several EU research projects. Currently, in the light of the 4CE-MED project (www.4cemed.eu) camelina is being studied as a cash cover crop for the Mediterranean region (Italy, Greece, Spain, France, Morocco, Tunisia, and Algeria) in effective double cropping agricultural systems. In the framework of 4CE-MED two field trials had been carried out in a dry area of central Greece (Aliartos-Kopaida) for a period of two subsequent years. The *first trial* compared seven camelina varieties (CCE26, CCE27, CCE29, CCE34, CCE40, CCE42, and Alba) developed and provided by Camelina Company (CCE, https://camelinacompany.es/en) in four blocks. In both years the sowing took place in the beginning of December. In the *second trial* three cultural practices [two sowing times (early and late November), two plant densities (low: 500 plants/m^2 and high: 800 plants/m^2), two tillage systems (tillage, no-tillage)] compared in four blocks, while the variety used was Alba. In both trials a basic fertilization was applied a few days prior to sowing at a rate of 300 kg of fertilizer/ha (NPK: 11-15-15). The camelina flowering started in the beginning of March of 2021 and the final harvest for both trials carried out in the 2nd half of May 2021 and in the first half of June 2021. At the final harvest in each plot the total biomass from an area of 2m^2 was harvested and the seeds separated from the straw and weighted, and samples were taken for dry matter determinations. The most productive variety in 2021 was ALBA (1.5 t/ha) and in 2022 was CCE26 (1.5 t/ha). The mean seed yields of the two years varied from 1.41 t/ha (CCE29) to 1.48 (CCE27 and ALBA). In the second trial, it was found that camelina (variety Alba) was slighter more productive when it was sown later in the season (1.32 t/ha vs 1.28 t/ha seeds) but if the results of the same variety were compared with the seed yields in the first trial it can be said that a later sowing resulted in higher seed yields (1.5 t/ha). Regarding the two plant densities it was found that the high density gave 20% higher seed yields compared to the low one (1.42 vs 1.18 t/ha). Between the two tillage systems it was found a slight superiority of the conventional tillage system over the no tillage one.

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YIELD AND OIL CHARACTERISTICS OF TEN CAMELINA VARIETIES AS AFFECTED BY SOWING DATE IN A MEDITERRANEAN CLIMATE

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Winter cereals are the most important crops in dryland fields, which are usually grown in monocrop systems. In contrast, crop rotation presents a broad range of long-term ecosystem benefits, like soil organic matter and fertility improvement, among other advantages. In addition, it is a useful tool to keep pest populations (weeds, pests, and pathogens) below threshold levels. However, in the sub-humid Mediterranean climates of Lleida, where annual rainfall is about 500 mm, the availability of productive and competitive crops to be rotated with cereals is limited. In this context, *Camelina sativa* (L.) Crantz can be a suitable choice to integrate in crop rotation systems. On one hand, its short life cycle, and tolerance to cold temperatures and droughts, make it a promising crop for these Mediterranean conditions. On the other hand, camelina seeds are rich in oil and protein, with a unique fatty acid (FA) composition that contain high omega-3 and omega-6 levels, and antioxidants, and can be of interest for both humans and animal diets. However, camelina's low yield (1.500 kg/ha) and the current market in Spain (biodiesel production) complicate its integration as a rotation crop with cereals. Also, there is a lack of information on the different performance of the available plant material. The aim of this experiment was to assess the productivity and oil quality (omega-3) of ten camelina varieties in two sowing dates under sub-humid Mediterranean conditions. The camelina varieties (nine summer biotypes + one winter biotype) were sown under no-tillage in Montargull, Lleida, Spain, on 18 November 2020 (first sowing date, SD1) and 2 February 2021 (second sowing date, SD2) with a conventional seeder in 3 x 30 m^2 plots with three replications. The plant density was 500 plants m^{-2} for each variety. In February 2021, Cletodim was applied to control monocotyledonous weeds. Before harvest, three 1 m^2 quadrats were collected from each plot for estimating the harvest index (HI). Harvest was done on 3 June 2021 (SD1) and 30 June 2021 (SD2). After cleaning and drying, seeds were cold-pressed, and the resulting oil was analyzed for fatty acid profile by gas chromatography as fatty acid methyl esters. In general, there were significant yield differences between SD1 (2460 kg ha^{-1} - 1451 kg ha^{-1}) and SD2 (1624 kg ha^{-1} – 925 kg ha^{-1}), being *Omega* (2460 kg ha^{-1}) and *Selone* (2247 kg ha^{-1}) the most productive varieties in SD1, and *Calena* (1624 kg ha^{-1}) and *Sonny* (1604 kg ha^{-1}) in SD2. In contrast, the least productive varieties were *Alba* (1565 and 1039 kg ha^{-1}) and *Joelle* (1451 and 925 kg ha^{-1}, respectively) in both sowing dates. Similarly, the overall HI value was always higher in SD1 (0.217 on average) than in SD2 (0.187 on average). Regarding the oil quality, omega-3 (C18:3) content represents, on average for SD1, 34.8% of the total FA profile, while its percentage is decreased to 33.0% in SD2. *Vera* and *CO46* were the varieties with the highest (>36%) omega-3 content in SD1, while *Vera* and *Joelle* showed the highest percentages in SD2 (35 and 34%, respectively). In terms of productivity and oil quality, *CO46* resulted in the most interesting variety in SD1 in 2020-21, while in SD2 the result is not as clear as the highest yield varieties showed the lowest omega-3 percentage and vice versa.

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CAMELINA RESPONSE TO NITROGEN FERTILIZER INPUT AND IDENTIFICATION OF HIGH NITROGEN USE EFFICIENCY GENOTYPES

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Camelina sativa [*Camelina sativa* (L.) Crantz] is a non-food oilseed biofuel feedstock, and nitrogen fertilizer is the largest energy input and production cost for camelina production. A series of field studies were carried out in eastern Montana in 2021 and 2022 to investigate the response of camelina genotypes to nitrogen input and identify high nitrogen use efficiency (NUE) genotypes. Results showed that camelina requires nitrogen fertilizer to produce an optimal biomass and oil yield. However, different genotypes responded differently to nitrogen inputs. Among the 212 camelina accessions we studied, seed yield ranged from 5 to 32 g plant^{-1} and oil concentration varied from 26 to 38%. Nitrogen concentration in seed and plant tissue also varied among the accessions. Several genotypes have been identified to have higher seed yield and oil concentration than the checked varieties under the low nitrogen regime. The traits that contributed to higher yield and NUE are under analysis.

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DETERMINING *CAMELINA SATIVA* GERMINATION RATE VARIATION AND GENETIC CONTROL

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Germination is the first step in successful plant growth and a key component to developing promising crops for commercial production. *Camelina sativa* is a promising oilseed crop and an alternative biofuel energy source. *Camelina sativa* germination rates and variability remain poorly understood, and greater insight into germination rate variance and genetic controls would assist in developing this novel crop. We studied the variability and genetic control of germination rates in over 200 sequenced camelina accessions from around the world. We determined daily germination and rate for all accessions over two weeks. We found five distinct patterns of camelina germination across accessions. Greater germination rate variability was highly predictive of a lack of successful complete germination. Germination rate and number during the first four days of the study were highly variable between accessions and determined the overall germination success of each individual accession. Germination slope was found to be independent of individual germination day counts, and higher slopes during the first week of the study were correlated to greater overall success of individual accessions. To further investigate the genetic controls of germination in *C. sativa* we examined the heritability of germination metrics and used a genome-wide association study approach to determine candidate loci controlling germination rate. Our genetic analysis combined with the physiological measurements has provided promising avenues to identify influences on camelina germination rate for future breeding programs and mechanistic understanding.

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OVEREXPRESSION OF *MIRNA167A* INCREASES GERMINATION RATES IN *CAMELINA SATIVA*

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Camelina [*Camelina sativa* (L.) Crantz] is an oilseed crop rich in linoleic and α-linolenic acids, used in human and animal nutrition. It also has potential to become a sustainable crop for second generation biofuels production. Efforts have been made in increasing the size of seeds and their oil content by studying the phenotypic variation among accessions and identifying genes associated with those traits. Although the pathway for oil content has been studied, there is a lack of knowledge in processes driving the development of seeds and their viability. We therefore aimed to identify co-expressed genes responsible for differences in seed size through a weighted network analysis. To accomplish this objective, we evaluated published data of the gene expression profiles of two camelina genotypes – the cultivar Suneson and miR167OE, a Suneson transgenic line overexpressing *miRNA167Aa* – at 8, 10 and 12 days after fertilization (DAF). miRNA167 regulates plant reproduction in other species, such as Arabidopsis (*Arabidopsis thaliana*). In Camelina, its overexpression results in larger seeds and lower levels of α-linolenic acid, the latter due to the suppression of the fatty acid desaturase 3 genes. We hypothesized that a group of genes would be responsible for the faster development of seeds in miR167OE. Indeed, the expression profiles revealed that miRNA167OE-induced changes occur especially in the earliest time point, as the late stages – 10 and 12 DAF - in miR167OE are more like Suneson at 8 DAF. We identified two major patterns—with opposite trends—where gene expression at 8 DAF differs from the late stages and the genotypes are characterized by different magnitudes of expression. One of the groups of co-expressed genes shows increasing expression from 8 to 10-12DAF in miR167OE, with 10-12 DAF time points being most similar to Suneson at 8 DAF. In this group we found significant enrichment of genes responsive to auxin, seed oil body biogenesis, seed maturation and seed germination. The lower expression of genes related with auxin in miR167OE was expected, as the *miRNA167A* represses the expression of the auxin responsive factors (ARF) 6 and 8. In addition to genes found in the enrichment analysis, we also identified other candidates involved with seed germination: *DELAY OF GERMINATION 1* (*DOG1*), *ABA-HYPERSENSITIVE GERMINATION 1* (*AHG1*) and *FIE2*. The expression profiles of those genes indicated profound differences at 8 DAF in miRNA167OE compared to all the other samples. Based on the patterns of expression in these genes, we hypothesized earlier germination in miRNA167OE compared to Suneson. This was confirmed by a germination assay to evaluate the germination rate of both genotypes for two weeks, where the transgenic genotype at 22 ºC indeed germinated earlier. These outcomes provide evidence that besides increasing the oil content on seeds, *miRNA167A* also accelerates development and maturation, resulting in faster germination rates in the mutant genotype.

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PROSPECTS OF OILSEED CROPS CULTIVATION IN HEAVY METAL CONTAMINATED SOILS -PRODUCING A RENEWABLE FEEDSTOCK USING ECOLOGICAL REMEDIATION

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Recent human activities can lead to several environmental problems. Among them, soil contamination deserves attention. The implications of soil contamination are desertification, water resources, and/or contamination of food crops. Through food and feed crops contamination, the contaminants enter the food chain and accumulate in plants and animals, causing several health issues. To prevent these problems, soil decontamination becomes essential to guarantee the safety of food production in the future. Phytoremediation, a bioremediation process that promotes soil decontamination through the uptake of contaminants by plants that allow to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater, becomes an option to tackle this problem. However, once the plant takes up the contaminants, the utilization of its biomass becomes a critical part of the process, considering that the biomass is contaminated. In this way, the utilization of energy crops such as oilseed crops can promote the soil decontamination and, at the same time, produce a renewable and sustainable feedstock for bioenergy, biofuels, and biomaterials, generating an income for farmers in contaminated soil at the same time that contributes to reduce the dependence on fossil and non-renewable feedstocks and to alleviate the soil contamination. Therefore, this work aimed to study the effects of different heavy metals (Zn, Pb, Cd, Ni) on the productivity and ash content of different oilseed crops (*Camelina sativa* (L.) Crantz, *Crambe abyssinica* Hochst, *Brassica carinata* A. Braun, *Thlaspi arvense* L., and *Carthamus tinctorius* L.). The soils were artificially contaminated, and the established concentrations were the double the limits established by the Decree-Law 276 of 2009 (Portuguese regulation that establishes the regime for the use of sewage sludge in agricultural soils) - Zn: 900 $mg.kg^{-1}$; Pb: 900 $mg.kg^{-1}$; Cd: 8 $mg.kg^{-1}$; Ni: 220 $mg.kg^{-1}$. The results indicated that camelina was the most affected crop, showing a significant reduction in yield for all tested heavy metals, being critically affected by Ni with a yield reduction of 76%. Regarding the ash content, on average, the crops cultivated in contaminated soils presented a higher value in both below and aboveground biomass, compared to control. However, the ash content in the seeds was not affected by the contamination. In contrast, the oil content was reduced in the seeds collected from contaminated pots, which may hinder the industrial exploitation of these crops, when cultivated in soils contaminated with heavy metals.

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ADVANCEMENTS IN BREEDING PENNYCRESS (*Thlaspi arvense* L.) AS A SUSTAINABLE FEED AND FUEL SOURCE

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The availability of oilseed feedstocks in the US is limited. To address this, we are developing the cash cover-crop pennycress (*Thlaspi arvense* L.) to be grown as a winter annual industrial crop throughout the U.S. Midwest Corn Belt. Off-season integration of pennycress into existing corn and soybean acres would extend the growing season on established croplands and avoid displacement of food crops or ecosystems while yielding up to an additional 2 billion gallons of oil annually. Through the advances in plant breeding and gene editing, we have converted wild pennycress into a commercial seed product named CoverCress[tm]. The conversion of pennycress involved not only improvements in yield and maturity through traditional breeding but also improvements in the composition of the oil and protein. Mutations in the *tt8* gene have led to a thinner seed coat with a golden color and dramatically improved germination rates of greater than 95% for freshly harvested seed. The improved germination has substantially increased yield by allowing for a more reliable and consistent stand establishment in the fall and subsequently earlier harvest in the spring. Reduced seed dormancy has also alleviated concerns of wild pennycress returning as a weed in subsequent years. Crude protein in the seed meal has increased from 25% to 30%, acid detergent fiber decreased from 40% to 15%, and total oil content improved from 30% to 34%. Multi-state field trials were conducted over the last 3 years confirming the stability of these traits. A CoverCress[tm] crop is unique among winter cover crops in that it can generate income as an oilseed crop thereby providing incentive for adoption by producers and stakeholders.

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RELAY-CROPPING PENNYCRESS AND SOYBEAN: SELECTING INTERSEEDING DATE AND SOYBEAN MATURITY

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Pennycress (*Thlaspi arvense* L.) is a new winter annual oilseed being developed as feedstock for biofuels and bioproducts. Pennycress relay-cropped with soybean [*Glycine max* (L.) Merr.] is a way to keep continuous living cover on the landscape while providing new economic opportunities and ecosystem services. A multi-season study was conducted in west central Minnesota on a Barnes Loam soil to evaluate the effects of soybean interseeding date and cultivar maturity on the overall productivity of a pennycress-soybean relay system. Interseeding date was based on pennycress growth stage; SD1 (rosette), SD2 (bolting), and SD3 (initial flowering). For soybean maturity, three different maturity group (MG) cultivars were evaluated, an MG0.2 (early), MG1.1 (standard for the region), and a MG1.7 (late). In one out of two seasons, relay interseeding of soybean reduced pennycress seed yield, but the reduction (23%) was least for SD2. Pennycress seed oil content was consistently greater in relayed treatments (337 g kg^{-1}) than a monocrop control (328 g kg^{-1}), likely due to N competition during overlap of the two crops. Soybean cultivar maturity impacted seed yields in the relay system. Average relayed soybean yields for the MG0.2, MG1.1, and MG1.7 were 2589, 3196, and 3445 kg ha^{-1}, respectively. Generally, relayed soybean yields were lower than a monocrop MG1.1 soybean control, but for the MG1.7 interseeded at SD2 the difference was not significant. Results indicate that relay interseeding a longer maturity soybean (MG1.7) for the region at the time pennycress is bolting (SD2) optimized productivity of the relay system. More research is warranted to improve soybean genotype selection and crop management regionally for this unique relay system.

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DOES CORN HYBRID SELECTION PRECEDING PENNYCRESS PLANTING AFFECT SEED YIELD AND QUALITY IN THE US CORN BELT?

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Pennycress (*Thlaspi arvense* L.) is a winter oilseed being developed as a cash cover crop to provide feedstock for biofuel and bioproducts. However, pennycress establishment following corn grain harvest in the northern US Corn Belt is limited due to the short duration between corn harvest and winter freeze. A study was conducted for two growing (2020/21 and 2021/2022) seasons in which corn hybrids (varying in maturity and harvest date) were grown preceding pennycress planting. Pennycress was planted as early as feasible following corn harvest, and pennycress seed yield and quality were quantified. The corn hybrids ranged from 95 to 113 days at Hoytville (Ohio) and Lexington (Illinois) locations, and from 76 to 95 days at Morris (Minnesota) and Rosemount (Minnesota) locations. In 2021 (during the 32nd annual meeting of AAIC), we presented results focused on corn (*Zea mays* L.) grain yield and pennycress establishment (emergence and green cover). Here, we present on pennycress performance of seed yield and oil content as affected by corn hybrids at different locations. Results varied across locations and for the corn hybrids. For instance, in 2021, pennycress seed yield at Hoytville ranged from 492 kg ha^{-1} to 1387 kg ha^{-1} and oil content ranging from 326 g kg^{-1} to 343 g kg^{-1}. At Morris, seed yield ranged from 322 kg ha^{-1} to 685 kg ha^{-1} with oil content ranging from 309 g kg^{-1} to 332 g kg^{-1}. Pennycress seed yield at Morris in 2021 was low likely due to drought. Cumulative rainfall received in May and June of 2021 at Morris was 132 mm less than the long-term average (185 mm). The amount and distribution of rainfall received during these months at Morris are very critical for pennycress growth and seed development. This presentation will report data from the two growing seasons at four locations and present the findings on pennycress seed yield and oil content as affected by corn hybrids varied in maturity days.

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STUDIES ON THE FACTORS CAUSING THE UNEVEN GERMINATION OF CASTOR SEED

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Castor (*Ricinus communis* L.) is cultivated for the oil extracted from its seed. After sowing, the germination of castor seed and the emergence of the seedlings are highly uneven. The poor and irregular initial stand reduces castor seed yield and creates a problem for weed management and reduces the efficiency of mechanized harvest. The factors influencing the uneven germination of castor seeds were investigated in a series of studies under controlled conditions. It was found that the germination of castor seed is influenced by many factors, but the temperature was the most important of them. The optimal temperature for germination is approximately 31 °C, which is higher than the soil temperatures usually observed at sowing time. The seed imbibition was not influenced by temperature, and seed hydration did not limit germination. However, a small puncture in the seed coat in the region below the caruncle caused the germination to occur significantly faster. The effect of the puncture was not related to an easy entrance of water into the seed. Instead, it was found that the seed coat exerts a mechanical resistance to the radicle growth, which delays the germination. The puncture in the seed coat creates a fracture that reduces the mechanical resistance and facilitates the germination. It was also observed that castor seed has a strong post-harvest dormancy that reduces after some months of storing. The post-harvest dormancy is influenced by the germinating temperatures, and it was more intense at sub-optimal temperature (22 °C) than at near-optimal temperature (28 °C). Morphological characteristics of the seed (weight, volume, density, seed coat thickness) have a weak correlation with the time for germination. Thus, selecting seeds according to morphological traits is not an efficient practice to improve the uneven emergence of castor crop. It was found that selecting castor genotypes with fast germination and reduced post-harvest dormancy is possible, and significant progress on those traits can be observed in a few generations. The intended selection for fast germination under sub-optimal temperature resulted in the unintended selection of genotypes that germinate fast in response to sodium hypochlorite, which was used for seed disinfection. Although there was a progress in the germination behavior of the selected plants under regular conditions, the intended fast germination under sub-optimal temperature was achieved more intensely when the germination was induced by the seed treatment with the disinfection agent. Further studies will evaluate if castor seed can be pre-germinated in order to improve uneven emergence and to measure the performance of fast-germinating genotypes at field conditions.

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MODERN OILSEED BREEDING: FROM HIGH-THROUGHPUT PHENOTYPING TO GENOMIC SELECTION

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North Dakota led the nation in the production of canola (*Brassica napus* L.) and flax (*Linum usitatisimum* L.) with over 85% and 92% of the U.S. production, respectively. North Dakota State University (NDSU) initiated the canola breeding program in 2006 from scratch. The NDSU flax program is the only breeding program in the U.S. and is one of only two in North America, which is a 133-year-old program. Both programs are giving emphasis to increase the genetic diversity in the crops and to release adaptive cultivars for North Dakota and the USA. The purpose of this research is to utilize high-throughput phenotyping and genomic selection technologies in the oilseed breeding program. Currently, we are using unmanned aerial vehicles (DJI Drone with multispectral and RGB cameras) and small plot autonomous ROBOT for high-throughput phenotyping (HTP) in the program. The HTP offers the opportunity to eliminate time and high labor cost involved in phenotyping and helps to generate in-depth and large-scale phenotyping data using minimum labor intensity and cost. The oilseed breeding program is also developing Multi-parent Advanced Generation Inter Crosses (MAGIC) populations to increase the genetic diversity in the oilseed crops. Four MAGIC populations of canola and two MAGIC populations of flax are in progress to develop. Genomic selection (GS) has emerged as a promising genomics-assisted technique that uses genome-wide SNPs data and phenotypic data of the training population to select the best statistical model, which is used to estimate the genomic estimated breeding values of unknown breeding populations. In the MAGIC populations, we are in progress in genotyping and phenotyping the training populations to identify the best GS models. Based on the GS models, we will select the desired breeding lines based on only genotyping information of breeding populations for further field evaluation. The incorporation of HTP and GS in the breeding program will be effective, economic, eco-friendly, and will boost genetic gain in the oilseed breeding program.

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PROSPECTS OF OILSEED CROPS CULTIVATION IN HEAVY METAL CONTAMINATED SOILS PRODUCING A RENEWABLE FEEDSTOCK USING ECOLOGICAL REMEDIATION

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Recent human activities can lead to several environmental problems. Among them, soil contamination deserves attention. The implications of soil contamination are desertification, water resources, and/or contamination of food crops. Through food and feed crops contamination, the contaminants enter the food chain and accumulate in plants and animals, causing several health issues. To prevent these problems, soil decontamination becomes essential to guarantee the safety of food production in the future. Phytoremediation, a bioremediation process that promotes soil decontamination through the uptake of contaminants by plants that allow to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater, becomes an option to tackle this problem. However, once the plant up took the contaminants, the utilization of its biomass becomes a critical part of the process, considering that the biomass is contaminated. In this way, the utilization of energy crops such as oilseed crops can promote the soil decontamination and, at the same time, produce a renewable and sustainable feedstock for bioenergy, biofuels, and biomaterials, generating an income for farmers in contaminated soil while contributing to reduce the dependence on fossil and non-renewable feedstocks and alleviating the soil contamination.
Therefore, this work aimed to study the effects of different heavy metals (Zn, Pb, Cd, Ni) on the productivity and ash content of different oilseed crops (*Camelina sativa* (L.) Crantz, *Crambe abyssinica* Hochst, *Brassica carinata* A. Braun, *Thlaspi arvense* L., and *Carthamus tinctorius* L.). The soils were artificially contaminated, and the established concentrations were double the limits established by the Decree-Law 276 of 2009 (Portuguese regulation that establishes the regime for the use of sewage sludge in agricultural soils) - Zn: 900 $mg.kg^{-1}$; Pb: 900 $mg.kg^{-1}$; Cd: 8 $mg.kg^{-1}$; Ni: 220 $mg.kg^{-1}$. The results indicated that camelina was the most affected crop, showing a significant reduction in yield for all tested heavy metals, being critically affected by Ni with a yield reduction of 76%. Regarding the ash content, in average, the crops cultivated in contaminated soils presented a higher value in both below and aboveground biomass, compared to control. However, the ash content in the seeds was not affected by the contamination. In contrast, the oil content was reduced in the seeds collected from contaminated pots, which may hinder the industrial exploitation of these crops, when cultivated in soils contaminated with heavy metals.

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ABSTRACTS

NATURAL RUBBER AND RESINS DIVISION

ORAL PRESENTATIONS

CHAIR

GUANGYAO (SAM) WANG

BRIDGESTONE AMERICAS, INC., ELOY, AZ, USA

CONSIDERING PRIMARY AND SECONDARY CARBON METABOLISM IN GUAYULE (*Parthenium argentatum* G.)

Colleen McMahan[1], Edward Baidoo[2], Chen Dong[1], Jackie Jarvis[3], Grisel Ponciano[1], Andrew Nelson[4], and F. Omar Holguin[3]

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The arid-adapted guayule plant sequesters remarkable quantities of carbon, which are converted perennially into biomass as well as secondary metabolites of economic importance. The most significant of these metabolites is natural rubber, i.e., *cis*-1,4-polyisoprene, a Critical Agricultural Material of strategic importance to US defense, medicine, and transportation. Carbon metabolism in guayule is complex, especially so since rubber production is linked to abiotic stress such as cold, under conditions which also trigger changes in photosynthetic rates and in carbohydrate metabolism. Field, greenhouse, and *in vitro* experiments have begun to reveal a better understanding of carbon metabolism in guayule. Here, we first summarize early studies tracing carbon metabolism through the plant to the natural rubber product. Next, we interpret guayule functional genomics in the context of overall plant metabolism. These investigations, along with a growing body of transcriptomics analyses, have underscored the importance of environment, specifically abiotic stress, in rubber production in guayule. Metabolomics tools such as LC/MS are now being applied to better characterize and understand isoprenoid carbon metabolism in guayule. In growth chamber plants, mevalonate pathway metabolites, especially acetyl-Co-A, HMG-CoA, and mevalonate, were more concentrated in guayule stem tissues compared with leaf and root tissues. Interestingly, leaf tissue presented the highest concentrations of the rubber biosynthesis initiator FPP, and monomer, IPP/DMAPP. Dozens of downstream isoprenoids (C24-C60+) were detected using LC/MS, including the important triterpene guayulins and argentatins. To close, we identify the key questions that might be addressed through broader metabolomics studies.

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ARVENSE FLORA CONTROL IN TRANSPLANTED GUAYULE IN CASTILLA-LA MANCHA (SPAIN)

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The guayule plant (*Parthenium argentatum* A. Gray) is a potential alternative to replace the current production of rubber (*Hevea brasiliensis*). There are two approaches for the industrial exploitation of guayule: direct-seeding or transplanting. Each of them presents different challenges for the control of arvense flora. The aim of this work was to study ten different control treatments for transplanted guayule in Castilla-La Mancha (39º 58' 11.07"N, 3º 8' 58.83" W). These control systems included a chemical approach (glyphosate (1), metribuzin (2), pendimethalin (3), and 2,4-dichlorophenoxyacetic acid (2,4-D) (4); two mechanical methods such as plowing (5) and weeding (6); two other preventive methods such as the use of black polyethylene sheeting (7) and weed control netting (8); and a thermal treatment characterized by the use of butane gas (9). A control plot without any control system was used for comparison (10). The experimental design of this trial consisted of a randomized block statistical design, with three replicates, using the guayule accession AZ-5, and implemented in elementary plots of 63.0 m^2. The best chemical control was achieved with metribuzin (before planting) and pendimethalin (after planting); glyphosate showed good results although it is not the most recommendable method due to the accumulation of residues. Finally, 2,4-D was characterized by a complicated application and slowed down the crop growth, so the treatment was repeated with the residues that this action entails. Regarding the preventive methods (plastic and anti-weed netting), both systems were effective, and no significant differences were observed between them. Regarding the results of the mechanical methods, weeding was difficult to apply in the early stages of cultivation and it was concluded that it would have a complicated adaptation to agricultural scale. Plowing was considered an effective mechanical method, but the use of a suitable specialized utility would be necessary. Finally, the thermal method was characterized by its complicated application in the early stages of the crop, and therefore, good results were not obtained between plants. In conclusion, the best control system was the chemical one using metribuzin and/or pendimethalin.

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OVEREXPRESSING AN ARABIDOPSIS *SEIPIN1* AFFECTS RUBBER PRODUCTION IN GUAYULE

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Natural Rubber (NR) is a vital raw material for numerous products. Current commercial source of NR is from Hevea (*Hevea. brasiliensis*). Hevea is cultivated only in Southeast Asian countries and is vulnerable to leaf blight diseases. To secure NR production, guayule (*Parthenium argentatum Gray)* has been developed as an alternative crop which can be grown in most agricultural regions. Various efforts have been made to increase guayule NR production, including germplasms selection, breeding, and genetic engineering. NR consists mainly of *cis*-1,4-polyisoprene synthesized in/on rubber particles (RPs). RPs are analogous to the lipid droplets (LDs) generated from the endoplasmic reticulum (ER), although the major components enclosed in the phospholipid monolayer structure of LDs are triacylglycerols, not polyisoprene. A prominent LD protein is SEIPIN conserved across eukaryotes and plays an important role in LD biogenesis. Arabidopsis (*Arabidopsis thaliana*) contains three SEIPIN genes. Overexpression of *AtSEIPIN1* in Arabidopsis results in increased numbers of large LDs in leaves, as well as in seeds, and increased seed oil content by up to 10% over wild-type seeds. This finding prompts us to investigate the effects of *AtSEIPIN1* in guayule NR production. We have generated three independent transgenic guayule lines expressing *AtSEIPIN1*. These lines did not display any abnormal growth phenotype. We found small decreases of average rubber contents by 22–33% in tissue cultured plantlets and by 20–36% in stembark tissue of mature plants grown in a greenhouse. Rubber qualities were assessed by measuring molecular weight of the highest peak (Mp) and weight average of molecular weight (Mw) of extracts from the stembark tissue. Compared with wild-type (WT), the average Mp and Mw values decreased slightly by 12% and 23% in two lines and remained unchanged in one line. It is possible that *AtSEIPIN1* affects rubber production in guayule on both quantity and quality. To investigate if *AtSEIPIN1* changes RP size, we examined the RP images and measured the RP sizes. Compared with WT, we observed less and smaller RPs per section of scanning electron microscope. Average diameter of RP of transgenics ranged from 0.7–0.9 μM which was significantly smaller than that of WT at 1.1 μM. Comparison of the frequency distributions of rubber particle size between WT and transgenic lines revealed a shift of RP population toward smaller sizes in transgenic lines. *In vitro* assay of rubber synthesis showed lower rubber transferase activities in samples from transgenic lines compared to WT. The mechanisms of *AtSEIPIN1* on influencing NR production in guayule are discussed.

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BIOSYNTHESIS OF NON-NATURAL POLYISOPRENOIDS BY FUNCTIONALLY MODIFIED *CIS*-PRENYLTRANSFERASES

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Natural rubber (NR) is a natural polymer used for industrial rubber products, such as tires. NR mainly consists of *cis*-1,4-polyisoprene with a few *trans*-isoprene units at their ω-end. NR biosynthesis is believed to proceed by enzyme which is a member of the *cis*-prenyltransferase (cPT) family from the Para rubber tree (*Hevea brasiliensis*), using primer substrate such as geranyl diphosphate (GPP, C_{10}), (*E*,*E*)-farnesyl diphosphate (FPP, C_{15}), and all-(*E*)-geranylgeranyl diphosphate (GGPP, C_{20}). On the other hand, some *Solanum* species have cPTs that primarily use DMAPP as a primer to synthesize all-*cis*-oligoprenyl diphosphates, such as neryl diphosphate (NPP, C_{10}). In this study, we investigated critical residues for the primer substrate preference through comparison of these cPTs. Neryl diphosphate synthase (NDPS1) from tomato (*Solanum lycopersicum*) has Ile and Phe in helix-2 which is the primer substrate-binding region. These residues are substituted for Gly and Trp, respectively, in the *Hevea* Rubber Transferase 1(HRT1). An NDPS1 mutant with I106G/F276W substitutions preferred not only DMAPP but also all-*trans*-oligoprenyl diphosphates. Furthermore, one of the helix domains (helix-3) that constitutes the hydrophobic cleft for accommodating elongating prenyl chains was demonstrated to be critical in primer substrate preference. An NDPS1 I106G/F276W mutant with a chimeric helix-3 domain swapped with that of HRT1 synthesized longer products than WT. These NDPS1 mutations could be used in the enzymatic synthesis of non-natural all-*cis*-polyisoprenoids.

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A ROUTE TO SCALABILITY: GUAYULE LATEX RADIATION ATTENUATION GLOVES

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Disruptions of the global supply chains are making domestic natural rubber production vital to national security and defense. A major scalability challenge remains in that commodity markets, which require low prices and huge supplies cannot be entered by rubber or latex produced at pilot scale from small acreages of alternative rubber crops. Thus, premium markets with high profit margins must be identified and addressed to support commercialization on the small scale at which these crops will be initially introduced. Radiation attenuation gloves (RAG) are one such market. RAG protect and shield health care workers (HCW) from occupational exposure to ionizing radiation. Natural latex RAG are classified as personal protective equipment because the high load of attenuation filler required reduces their mechanical properties to below Food and Drug Administration (FDA) medical glove physical performance requirements and so may not provide a sufficient barrier against potentially infectious materials; therefore, double gloving RAG with medical gloves - examination or surgical - is required to fully protect health care workers. However, RAG are often not regularly worn by health specialists since they are thicker and heavier than regular medical gloves, and so decrease tactile sensation, hand dexterity, and fine motor control in the fingers especially when double-gloving is used. Guayule (*Parthenium argentatum* G.) natural rubber latex (GNRL) is an alternative circumallergenic natural elastomer. GNRL's low protein, relatively high fatty acid and resin content and linear polymers make it softer and more elastic than Hevea rubber, and at the same time, enable a high filler loading while maintaining outstanding physical properties. The objective of this study was to investigate the radiation attenuation and mechanical properties of GNRL films prepared with a radio-opaque material filler, micro-sized Bi_2O_3. GNRL/Bi_2O_3 films were produced with Bi_2O_3 loads ranging from 50 to 300 parts per hundred of rubber (PHR) and film thicknesses from 0.2 to 0.3 mm. The films were subjected to 60, 80, 100, and 120 KeV ionization energies and tensile measurements (ASTM D412). Attenuation efficiencies of GNRL/Bi_2O_3 films with 150 PHR Bi_2O_3 loading at 0.2 mm thickness produced by optimized curing conditions were above the ASTM attenuation requirements and met the tensile requirements for natural latex examination and surgical gloves. Medical RAG produced by GNRL would eliminate the need for double-gloving during radiation-assisted procedures and ensure the safety and security of HCW. Entry of GNRL into specialty markets of this type can pave the way to guayule expansion.

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PREDICTING GUAYULE GROWING AREAS AND COLD INJURY USING MAXIMUM ENTROPY (MAXENT) MODELING

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Guayule (*Parthenium argentatum* Gray) is a rubber-bearing shrub in the Asteraceae family being developed as an alternative source of natural rubber in the United States, Europe, and Australia. The utilization of guayule dates to the pre-Columbian times, though its major commercial use happened in the early 1900's when Mexico established rubber extraction plants supplied with feedstock harvested from wild populations. The harvesting from wild stands may have resulted in many populations of guayule to be lost as suggested by the limited diversity existing in current germplasm collections. To determine possible new germplasm collection areas, we used MaxEnt models to simulate the suitable habitats of guayule in North and Central America using published botanical collection sites. The same methodology was used to predict suitable growing areas of guayule in the United States as well as regions where cold injury is likely to occur using historical data from indicator plot locations during the Emergency Rubber Project and recent research reports. A total of 138 occurrences in Mexico and the United States were used in the modeling. The top five environmental factors among 26 ecogeographic predictors from WorldClim-Global Climate Data v.2 and Shuttle Radar Topography Mission (SRTM) that influence the distribution of guayule wild populations were isothermality, temperature seasonality, maximum temperature of warmest month, altitude, and annual precipitation. For cultivation areas that did not show cold injury, the top five factors were mean temperature of driest quarter, altitude, precipitation of coldest quarter, precipitation of driest month, and maximum temperature of driest month. The final MaxEnt models did not use correlated environmental factors resulting in 13 factors used for predicting wild habitat and 22 for cold injury. The change in guayule distribution and suitable growing areas under future climate scenarios and limited agricultural water availability in the US Southwest remains to be determined.

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TOWARDS ALTERNATIVE SOURCES OF NATURAL RUBBER

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Natural and synthetic rubber, whose world share distribution is 40/60%, are necessary for the rubber industry (tires, industrial goods, latex gloves). Hevea (*Hevea brasiliensis*) rubber (HNR) is the only commodity of NR and 90% is produced in Southeast Asia. Furthermore, an increase of production is limited. The present geopolitical context (Covid pandemic, war in Ukraine, energy supply, climatic change, deforestation, and sustainability approach) shows that the supply is not guaranteed. This situation reminds us of WWII (GRS, ERP) and the 1970's oil crisis. It is thus necessary to provide for the implementation of industrial alternative sources of NR. R&D efforts for over half a century in the USA (Firestone, Goodyear, universities, USDA-ARS, Yulex, Bridgestone, Cooper Tire) and in Europe (Continental, Nokian Tire, ETRMA, universities, CIRAD, GuaTecs, and EU projects) have promoted guayule (*Parthenium argentatum* A. Gray) and Kazakh dandelion (*Taraxacum kok-saghyz*) as the best opportunities to fill the gap of shortage of HNR if the two sources are developed around the world. It is a great challenge which needs a massive investment from all sectors (governments, financial institutions, farmers, manufacturers, users, other bio-refinery producers) under a collective approach as has been the case for Hevea for more than a century. This situation favors increasing collaborative projects and eliminating the competition between actors, since the goal is to allow various sectors to continue their activities and to have access to a rubber supply for first ranked uses (military, transport, health, energy, etc). A global approach will show advantages and disadvantages of each technical option in order to reach the collective target. The primary interest of GuaTecs is latex production, such as for glove applications and for the valorization of resin and bagasse. We started in 2019 with a lab process, patented by CIRAD & CTTM (TRL 4). Thanks to funding from Fr-ADEME and others we developed, in 2021, a pilot unit (TRL5), presently used in a batch mode. It is being improved with the aim of operating in a continuous mode and of adding steps for processing by-products (TRL6). Several extraction processes (based on solvents or water) have been developed and patented by the guayule stakeholder community. Potential rubber users will soon have access to new grades of TSR and latex, probably showing differing properties. An ASTM standard for guayule (D1076) already exists for latex. A new ASTM standard has been proposed to measure rubber and resin content in guayule biomass. GuaTecs is in favor of building a consortium of laboratories and suppliers to qualify latex or rubber (TSR) from alternative sources of NR (guayule and K. dandelion) and differing extraction processes (for example direct water-based extraction, solvent-based extraction followed by an emulsification process; dry rubber extracted with solvents, dry rubber produced by coagulating water-extracted latex). At the end, after the formulation and vulcanization stage, various types of raw material will be qualified and compared to current marketed formulations. This collaborative work will contribute to finding suitable uses for each type of newly-developed latex and rubber.

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FEASIBILITY OF SUPERCRITICAL CO_2 EXTRACTION FOR GUAYULE RESIN AND RUBBER EXTRACTION

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Guayule (*Parthenium argentatum*) is a woody shrub native to the southwestern US that produces rubber in its stems. In the production of guayule hard rubber for tires, two residue streams are produced: a liquid resin and a fine, dry, woody bagasse. Value-added use of these residues can substantially impact rubber production costs. Since resin contains a wide range of secondary metabolites, the separation, fractionation, and purification of resin are critical if there are to be value-added uses of this complex mixture. Conventional fractionation techniques have the challenges of thermolabile compound decomposition and large volumes of organic solvents, which decrease the feasibility of these techniques for large-scale applications. In this study, supercritical CO_2 extraction has been investigated for guayule resin and rubber extraction with the initial target products of hard rubber, a low-molecular weight rubber and sesquiterpenoid/triterpenoid fraction for adhesive applications, and a terpene/terpenoid fraction for bio-based insect repellents and other applications.

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REPELLENT AND ANTIFFEDANT ACTIVITY OF ESSENTIAL OILS AND GUAYULE RESIN AGAINST *Labidostomis lusitanica*

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In recent years, pistachio (*Pistacia vera* L.) cultivation has undergone a major expansion in Spain, especially in Castilla-La Mancha (approximately 75% of the national total). So far, the incidence of pistachio pests in Spain is lower than in other growing areas. However, the huge growth of pistachio crops may lead to the emergence of new pests, or to the spread of existing ones. The leaf beetle *Labidostomis lusitanica* is an example of a pest with the potential to become a serious problem for pistachio in Spain as it has been reported to be a voracious leaf feeder that can completely defoliate young trees in a few hours. At the moment, there are not many alternatives for the treatment of this pest, and none of them are compatible with ecological production. Therefore, it is necessary to look for effective alternative treatments that are in line with ecological farming. For this purpose, a choice feeding assay with ten replicates was designed to test the repellent and antifeedant activity of the treatment of pistachio leaves with three essential oils [(thyme (*Thymus vulgaris*), savory (*Satureja hortensis*), and oregano (*Origanum vulgare* L.), 5 µg/µl)] and guayule (*Parthenium argentatum* A. Gray) extract (20% p/v) in comparison with untreated leaves and acetone-treated leaves as controls. In four-armed plastic olfactometers, 10 males and 10 females of *L. lusitanica* freshly collected were left to move and eat freely for 24 hours. After that, the attracted insects and the number of egg laying were counted for each treatment, as well as the percentage of foliar areas consumed, and the repellency indexes calculated. In terms of the number of individuals, no treatment showed significant differences compared to the controls, but it is noteworthy that thyme and savory showed significantly more individuals than oregano. As for egg laying, the treatments did not affect it either, as none of the treatments showed significant differences with the controls or with each other. Lastly, with respect to the percentage of foliar areas consumed, guayule-treated leaves were significantly less eaten than thyme and savory-treated leaves and controls, while they showed no significant differences with oregano-treated leaves. Regarding repellency indexes, with respect to untreated leaves, there were no significant differences between guayule, thyme, savory-treated leaves, and controls, while oregano-treated leaves had a lower repellency index. In view of these results, none of the tested products could be considered as a repellent, as they all had a neutral effect. However, guayule may well be postulated as a potential antifeedant treatment.

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IMPROVING GUAYULE'S ECONOMIC COMPETITIVENESS - A TECHNO-ECONOMIC EVALUATION OF TWO RESIN CO-PRODUCT PATHWAYS

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Guayule (*Parthenium argentatum)* is a woody, perennial shrub native to the southwestern U.S. and northern Mexico. It is drought tolerant and contains roughly 8-12% natural rubber. Most natural rubber production is solely sourced from the Hevea tree (*Hevea brasiliensis*) in Southeast Asia. The increasing demand for natural rubber increases the need for finding an alternative source. While guayule is a promising alternative source to *Hevea* rubber, attempts to commercialize guayule have failed due to economic factors. Barriers to guayule commercialization include the low cost of *Hevea* rubber (approximately 1.30-2.50 USD/kg in 2020); low rubber yield; significant costs of cultivation, harvesting, and processing; and no efficient value-added use of the co-products (resin and bagasse). A techno-economic analysis of guayule rubber production puts the baseline minimum rubber selling price (MRSP) at 3.05 USD/kg. Guayule resin currently contributes little to the economic feasibility of guayule as an industrial crop. Improving the resin value can reduce the minimum selling price of guayule rubber, but there is limited information on efficient utilization of the guayule resin as a value-added coproduct to enhance guayule's economic competitiveness. The two objectives of this study are: 1) define efficient large-scale separation methods for two promising natural resin co-products; cockroach insecticide and essential oil extract, without compromising their physical properties, and 2) evaluate the techno-economic and life cycle analysis for these two resin co-product extractions. In this research, a multicomponent vacuum distillation was designed in ASPEN PLUS® process simulator for essential oil extracts to carry out the separation of alpha-pinene, beta-pinene, and d-limonene from guayule resin, to obtain purities of 98%, 97%, and 99% respectively. Data obtained from ASPEN PLUS® was then used to inform the trace elemental analysis (TEA) and life cycle analysis (LCA) analyses. An additional co-product separation for cockroach repellant was designed in Microsoft Excel from laboratory experimental data that tracked equipment, material, and energy requirements to inform TEA and LCA analyses. TEA results showed that to meet the MRSP of 3.05 USD/kg, which assumes a resin co-product revenue of 1.00 USD/kg, 14% of the cockroach insecticide produced would need to be sold or, the essential oil would need to be sold at 28.16 USD/kg. LCA results showed the essential oil pathway had a greater environmental impact than the cockroach repellant pathway due to a greater number of distillation columns, although both contribute little to the overall impact of a rubber processing facility. These outcomes suggest that both pathways have potential to meet the resin co-product revenue assumption of 1.00 USD/kg. To see cost competitive MRSP, the total resin revenue must be 2.75 USD/kg.

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RESIN PRODUCTION VARIABILITY IN GUAYULE (*Parthenium argentatum* Gray) AND HYBRIDS IN CASTILLA-LA MANCHA (SPAIN)

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Guayule resin is a relevant co-product biosynthesized in greater quantities than the natural rubber, which is the raw material for which the plant is cultivated, representing about 10–15% of the dry weight of the plant. Although many applications have been proposed in recent years for this resin, such as asphalt binder, biocomposite, adhesives, antifungal, insect antifeedant or anti-termite protector, it currently contributes little to the economic feasibility of guayule as an industrial crop. While some authors found differences related to cultivation site, harvest date, shrub strain or shrub age, other authors assured that, contrary to individual resin compounds' synthesis, resin content is not affected by the environment. The objective of this study was to understand how the resin production changes to the genetics of the plant along the vegetative cycle, under the agro-climatic conditions of Castilla-La Mancha. For this purpose, resin production of four pure accessions (N565, AZ-1, AZ-5, and AZ-6) and seven improved hybrids (three Mariola hybrids: R100, R1101 and R1103; and the four non-Mariola hybrids: CAL-1, CAL-2, AZ-2 and AZ-3) was compared, in terms of resin percentage in the plant and yield per hectare, throughout the vegetative cycle (three sampling dates from 12 to 24 months). The 11 accessions (USDA-ARS National Plant Germplasm System) were germinated and transplanted at three months of age in May 2017 in a randomized design with three replications per accession and 33,333 plants ha^{-1}. Results showed that pure accessions had significantly higher average resin percentage than the hybrids. However, when the average resin yield was calculated based on biomass production, the hybrids were comparable and even improved pure accessions. For instance, the case of AZ-3 which produced 517.7 kg ha^{-1}, versus the pure accessions AZ-6 and N-565, which produced 265.0 and 285.7 kg ha^{-1} respectively. The pattern of production of resin throughout the vegetative cycle was similar for all the hybrids and two of the pure accessions which biosynthesized resin during the Summer, reaching the maximum yield before the Winter and maintaining it in Spring. On the contrary, the pure accessions AZ-1 and AZ-6 showed a strange behavior since the yield decreased in Spring. In the case of these two accessions, the optimum harvesting time would be the Winter while Spring is proposed for the rest of accessions and hybrids.

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GUAYULINS STABILITY IN GUAYULE (*Parthenium argentatum* Gray) HARVESTED STEMS AND RESIN

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The profitability of guayule (*Parthenium argentatum* Gray) cultivation will depend on the establishment of an industrial chain from cultivation to the marketing of its products. One of these products are the guayulins, sesquiterpenoid compounds contained in the resin with interesting potential applications as biopesticides. As immediate processing of guayule shrub on a commercial scale is not feasible, the objective of this study was to evaluate the stability of guayulins in harvested guayule stems, and in the already extracted resin as a first industrial step. The stability of guayulins in guayule stems stored at room temperature was assessed by periodic sequential resin extractions in an ASE E-914 extractor followed by HPLC-DAD analysis for six months in three guayule accessions (CAL-1, AZ-2 and R1040), also checking the influence in their preservation of the agronomic conditions (irrigation and fertilization) in AZ-2. On the other hand, the stability of guayulins in the first extracted resin was assessed by periodic analysis by HPLC-DAD for three months within AZ-5 resin stored at different temperatures (4, 20 or 40ºC). In guayule stems, a decrease of guayulins A and B content over time was observed, whereas guayulins C and D increased, regardless of growing conditions and accession. However, the variation percentages did depend on the accession and growing conditions. Total guayulins varied significantly in all accessions from 42 days after harvesting. However, individual guayulins were more unstable in AZ-2, showing significant variations at 14 days after harvesting. While irrigation affected guayulins A and B preservation, fertilization only affected slightly guayulin A. Attending to the extracted resin, differences were observed as a function of storage temperature. At 4ºC, each guayulin and total guayulins remained constant throughout the three months. At 20ºC, total guayulins also remained constant, but after 60 days onwards, a small decrease of guayulin A and a small increase of guayulins C and D was observed. Finally, at 40ºC, starting on day 5, a progressive decrease of guayulins A and B was observed, accompanied by a progressive increase of guayulins C and D, which was more evident as time went on. However, total guayulins remained constant until day 90, when guayulins C and D decreased. Therefore, it could be concluded that guayulin content is quite stable in the extracted resin, especially at lower temperatures, whereas these compounds were not so stable within the harvested stems.

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DEFICIT IRRIGATION ON SEASONAL GROWTH AND RUBBER PRODUCTION OF DIRECT-SEEDED GUAYULE

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Understanding guayule's (*Parthenium argentatum* A. Gray) response to deficit irrigation is critical for irrigation management under water shortage to maximize rubber and resin accumulation throughout the growing seasons. A study was conducted at a clay soil at Eloy, AZ to compare plant growth and rubber accumulation among different irrigation treatments during the two-year growing season (April 2020 to March 2022). Six irrigation treatments were included: 1) Full irrigation: Irrigate with 75% ETo as determined by the model developed in a previous project; 2) Stress before harvest: Full irrigation for the first 16 months, then stop irrigation; 3) Minimum Year2: Year 1 irrigate as determined by the model, and Year 2 irrigate three times (March, April/May, and September); 4) Half Irrigation: Irrigate every other irrigation as determined by the model; 5) Minimum irrigation: Irrigate three times a year (March, April/May, and September); 6) One irrigation: one irrigation after establishment in the first year, one irrigation in year 2. Two guayule genotypes, AZ-2 and AZ-6 were included in each plot. Aboveground biomass, rubber/resin content, and rubber/resin yield were measured every other month from establishment to final harvest. Guayule plants in the treatment 5 and 6 survived the hottest and driest summer in 2020 in Arizona history without irrigation from July to September. However, biomass and rubber/resin yield were significantly reduced in the treatments with less irrigation. At the final harvest, guayule rubber yield in the Stress before harvest (treatment 2), Minimum year 2 (treatment 3), Half (treatment 4), Minimum (treatment 5), and One irrigation (treatment 6) treatments were 91.2%, 79.6%, 91.3%, 75.6%, and 57.1% of the full irrigation treatment for AZ-2, and 90.7%, 69.2%, 79.0%, 69.8%, 46.5% of the full irrigation treatment for AZ-6. The positive relationship between biomass, rubber/resin yield and irrigation water amount was linear. This study indicates that guayule plants could survive severe drought in Arizona summer. While rubber/resin and biomass yield were positively correlated with irrigation amount, deficit irrigation under water shortage situations could still produce significant yield.

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REVIEW OF DIFFERENT ANALYTICAL METHODS FOR QUANTIFICATION OF GUAYULE RUBBER AND RESIN IN PLANT TISSUES

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Multiple stakeholders are currently conducting research and development activities on guayule (*Parthenium argentatum* Gray). This new crop was successfully utilized as an alternative source of natural rubber in the early 1900's by harvesting wild stands in Mexico for processing in industrial facilities. It was also cultivated in large acreages in the United States during the 1940's when the country's rubber supply chain was disrupted during the war. Publications on guayule from earlier and modern times report a wide range of rubber and resin content, depending on factors such as germplasm type, shrub age and morphology, harvest season, extraction method, and laboratory equipment. The various options for quantifying rubber and resin content in guayule present a challenge to researchers that aim to cross validate and compare results. Standardized analytical methods will be useful guides for guayule especially as the crop is commercialized. In 2020, the American Society for Testing and Materials (ASTM) formed a Guayule Natural Rubber (GNR) Task Group (D11.21.01) to develop standards on guayule so the research community, companies, government agencies, and laboratories working on the crop can have harmonized methodologies. The GNR Task Group has compiled past and current methods for quantifying guayule rubber and resin content. These methods include wet chemistry (Soxhlet extraction, accelerated solvent extraction, gel permeation chromatography, and latex quantification) as well as spectroscopic methods such as near infrared (NIR), Fourier transform infrared (FTIR), and nuclear magnetic resonance (NMR). In addition to the analytical methods, some attention will be given to biomass sampling and preparation. The advantages of each method and sampling procedure will be presented with the goal to solicit comments from the AAIC membership on the best path forward and gather information for focusing the standards development.

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ABSTRACTS

POSTER PRESENTATIONS

1. BRIDGING THE GAP BETWEEN PHYTOREMEDIATION SOLUTIONS ON GROWING ENERGY CROPS ON CONTAMINATED LANDS AND CLEAN BIOFUEL PRODUCTION

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GOLD is a European research project including international collaboration started in May 2021 aiming to produce clean low indirect land use change biofuels by growing selected high-yielding lignocellulosic crops on contaminated land, and, in long-term, to return the polluted lands back to agricultural production. This research project is mainly built on three pillars. On the *first pillar* the optimization of selected high-yielding lignocellulosic energy crops (miscanthus (*Miscanthus* spp), switchgrass (*Panicum virgatum* L.), biomass sorghum (*Sorghum bicolor* (L.) Moench) and industrial hemp (*Cannabis sativa* L.)) for phytoremediation purposes is being addressed in two continents: in Europe (Greece, Italy, France, Poland) and in Asia (India and China). The optimization targets are a) increasing the potential remediation performance of the selected energy crops by improving their biomass production and, thus, their final bioaccumulation and b) reducing the soil contaminants levels either via uptake (inorganic contaminants) or degradation (organic contaminants) by proposing appropriate management practices (plant-associated microorganisms and a variety of bio-stimulants). Pilot small-scale field trials have been established having dual-fold purposes: the application of the best-performing management practices for phytoremediation, and the feedstock production that will feed the conversion processes. The use of biomass harvested from existing contaminated sites -and not artificially contaminated- is crucial for gaining reliable results from the conversion methods. On the *second pillar*, the biofuel production will be accomplished by two thermochemical conversion routes. In the first route, the contaminated feedstock will be pre-treated (by Torwash, torrefaction or low-temperature pyrolysis) and gasified at high temperatures securing the ash heavy metals in a condensed vitrified slag. The produced syngas, after cleaning, will subsequently be fermented to final liquid biofuels. The second route consists of a pyrolysis-based solution with the subsequent upgrade of the pyrolysis products to refinery-compatible intermediates and Fischer-Tropsch-fuels. In both routes the produced liquid biofuels will be clean and the contaminants will be collected in concentrated form. In the *third pillar*, an integrated sustainability assessment is being carried out and a specific model will be developed for selected value-chains, to bridge the gap between phytoremediation strategies and clean biofuel production. Mapping in details the contaminated sites and analyzing the decontamination strategies in terms of further replication at EU level. Spatially explicit models will be applied and combined with spatial data for soil contamination from LUCAS, GEMAS and FORESG surveys to estimate the potentials, at EU level, of the contaminated areas that could be remediated, the feedstock quantities that could be produced, as well as the relevant quantities of biofuel production. The mapping will be presented online with an open access tool, available on the project website. Furthermore, best practices and recommendations for combining phytoremediation with clean low ILUC biofuels will be developed, taking into consideration both environmental and socio-economic gains and bringing GOLD closer to its ambition and reaching the Sustainable Development Goals (SDGs).

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2. THE MAGIC PROJECT: GROWING SELECTED PROMISING INDUSTRIAL CROPS ON MARGINAL LANDS

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Industrial crops can provide abundant renewable biomass feedstocks for the production of high added-value bio-based commodities (i.e. bio-plastics, bio-lubricants, bio-chemicals, pharmaceuticals, bio-composites, etc.) and bioenergy. They can be broadly categorised as oil, lignocellulosic, carbohydrate or specialty crops. Most of them are multipurpose crops offering the opportunity to follow a cascade bio refinery concept to produce several value-added bio products and bioenergy, thus feeding the bio-based economy. Cultivating industrial crops on marginal land unsuitable for food production is consistently proposed as a viable alternative to minimize land-use competition for food production, and its adverse effects (direct or indirect) on food security, land based GHG emissions and biodiversity loss. In the framework of MAGIC research project (H2020, www.magic-h2020.eu, that ended in December 2021) twenty industrial crops have been selected to be grown on marginal land facing natural constrains throughout Europe (including Ukraine) as well as on contaminated lands with heavy metals. The crops that have been selected are: miscanthus *(Miscanthus spp),* switchgrass (*Panicum virgatum* L.), giant reed (*Arundo donax* L.), tall wheatgrass (*Thinopyrum ponticum*), cardoon (*Cynara cardunculus*), willow (*Salix alba* L.), poplar (*Populus tremula* L.), Black locust (*Robinia pseudoacacia*), Siberian Elm (*Ulmus pumila*), Eucalyptus (*Eucalyptus obliqua* L'Hér.), camelina (*Camelina sativa* (L). Crantz), crambe (*Crambe abyssinica*), castor (*Ricinus communis*), safflower (*Carthamus tinctorius* L.), lupin (*Lupinus albus*), sorghum (*Sorghum bicolor* (L.), industrial hemp (*Cannabis sativa* L.), pennycress (*Thlaspi arvense* L.), Ethiopian mustard (*Brassica carinata* A. Braun) and wild sugarcane (*Saccharum spontaneum*). Most of the perennial industrial crops had been grown on long-term field trials (started in previous research projects) that brought to MAGIC datasets more than 20 years (miscanthus, switchgrass, willow and poplar). At the same time most of the crops have been tested on field trials established for the purposes of MAGIC under low inputs management. In the newly established fields improved varieties/genotypes for marginal lands for selected industrial crops had tested for camelina, crambe, miscanthus and industrial hemp throughout Europe and thus sound data had been collected for the yields of these crops on marginal lands. In MAGIC four tools have been developed, available online, which a)https://docs.google.com/spreadsheets/d/19L3l0SuwthUbkox1pR0iltdHolIm7uHhSzS8hYbppMY/edit#gid=2065080458), b) a decision support system for the relevant stakeholders – MAGIC DSS (https://iiasa-spatial.maps.arcgis.com/apps/webappviewer/index.html?id=a813940c9ac14c298238c1742dd9dd3c) and c) maps presenting the marginal lands facing natural constraints in Europe – MAGIC MAPS (https://iiasaspatial.maps.arcgis.com/apps/webappviewer/index.html?id=270aa7d778c245228fe82dc826cbd703) and d) Bio2Match tool (initially developed for S2BIOM project and it was improved in order to include also oilseeds and specialty crops; https://magicmatch.wenr.wur.nl). A total number of ten value chains have been developed for the purposes of MAGIC including the following crops: camelina, castor, safflower, industrial hemp, sorghum, lupin, willow, poplar, switchgrass and miscanthus. For these selected value chains an integrated sustainability assessment is being developed. Success stories of industrial crops in EU regions have been analyzed addressing technical, environmental, economic and social issues to produce policy recommendations and best-practice guidelines for their promotion at local/regional level. The project results, database, maps and the DSS tool are being used as dissemination tools to increase farmers' awareness.

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3. *RHUS MICROPHYLLA* LEAVES EXTRACTS USING OHMIC HEATING WITH INSECTICIDAL ACTIVITY

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Plants from arid and semi-arid regions of Mexico have been used in traditional medicine to treat illness and wounds. In the trend of developing natural-based pesticides in agriculture, they have also been studied for their potential to control crop pests. In this regard, agrito (*Rhus microphylla* Engelm. ex A. Gray), a shrub distributed in Mexico and the southeastern United States, has evidenced interesting antioxidant and antimicrobial activities; however, studies of its composition and bioactivity as natural pesticides are still limited. The objective of the present study was to evaluate the insecticidal activity of extracts from *R. microphylla* leaves obtained by ohmic heating on *Musa domestica* L. and *Plutella xylostella* L. Four extracts (A5, A10, H5, and H10) were obtained using two extraction times (5 and 10 min) and two solvents (water (A) and hydroalcohol solution (H) -50:50) at 70 V using a laboratory-built ohmic heating system. The insecticidal activity was evaluated at different concentrations (0.1, 0.5, 1.0, 2.5, and 3.0 g/L) under a block design with four replications, where the experimental unit consisted of four Petri dishes with 10 larvae each. An absolute control (water) and commercial insecticides based on neonicotinoids (1 mL/L) and *Bacillus thuringiensis* Berliner (2 g/L) were included for *M. domestica* and *P. xylostella*, respectively. Mortality was measured at 0, 2, 4, 6, 8, 12, 24, and 48 h after treatment applications, in which the insects were considered dead if the appendages did not respond after being touched with a camel hairbrush. At the end of the test for *M. domestica*, there were differences ($p<0.05$) with respect to the absolute control and between some treatments, observing that the best insecticidal activity was detected with the H5 treatment at doses of 2.5 and 3.0 g/L, as it showed lower values of 90% lethal dose (LD_{90} = 3.0 g/L). In the case of *P. xylostella*, a better insecticidal effect was also observed with the H5 treatment in the dose range of 1.0, 2.5, and 3.0 g/L with values of LD_{90} of 3.9 g/L. These results can be related with the content of phenolic compounds present in the *R. microphylla* leaves extracts, mainly gallic acid and catechin; however, further studies are required to elucidate the mechanism of action and the relationship between bioactive compounds of the extracts and their insecticidal activity. This research reveals for the first time the potential of the *R. microphylla* leaves extracts as a novel natural-based and environmentally friendly insecticide agent.

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4. CHARACTERIZATION OF MEXICAN WILD *OPUNTIA* SPECIES FOR DEVELOPMENT OF FILMOGENIC SOLUTIONS

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In the semi-arid areas of the southeast of the state of Coahuila, a great variety of wild species of *Opuntia* grow, which have been used as fodder and for human consumption. These species produce viscous materials known as mucilage, which is a mixture that mainly contains polysaccharides. These types of polymers have been reported as a material to formulate edible coatings and films that can be used in the agri-food chain. However, there is a lack of information on its morphology and physicochemical characteristics, which is imperative in development of film-forming solutions. Thus, the aim of this study was to determine the morphology and physicochemical characteristics of cladodes and fruits from the wild species *O. stenopetala, O. imbricata* and *O. microdasys*, as possible materials to formulate filmogenic solutions. Samples of cladodes and fruits from *Opuntia* spp. mentioned above, were collected at the Southeast of Coahuila in the ejido of Guadalupe Victoria. The samples were disinfected, weighted (g), and measured; and then, were cut and dried at 50 ºC for 72 h, then dry materials were ground in a mill. Subsequently, crude protein, fat and fiber were analyzed. The polysaccharides extractions were performed by agitation method and yield was obtained; then, particle size, degrees of methylation and esterification, as well as viscosity were performed. Results showed that O. *stenopetala* presented the highest yield with 26.21%. Moreover, the percent of degree of esterification for *O. stenopetala*, *O. imbricata* and *O. microdasys* were 76.92%, 78.26% and 81.82%, respectively, these results define the functionality of the *Opuntia* spp. and are related with a greater solubility and faster gelation rate. Therefore, the characteristics that the three species of *Opuntia* present, allow them to be utilized as a great natural source, to form filmogenic solutions for the development of edible coatings for agri-food products.

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5. NITROGEN AND PHOSPHORUS FERTILIZER EFFECTS ON GUAYULE IN AN ARID SANDY SOIL

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Guayule (*Parthenium argentatum*) is a desert-adapted shrub that can serve as a domestic source of natural rubber in the southwestern United States. Since guayule is a new cultivated crop in the desert southwest, its optimal crop management practices and fertilization requirements in different growing regions are yet to be established. Understanding the response of guayule to nitrogen and phosphorus fertilization will help farmers to optimize their resources. Therefore, a field study was conducted at New Mexico State University (NMSU) Leyendecker Plant Science Research Center in Las Cruces, New Mexico, to evaluate the effects of nitrogen (N) and phosphorus (P_2O_5) rates on guayule (cultivar AZ-2) growth and yields in a sandy loam soil with furrow irrigation. The nitrogen rates applied were 0, 100, and 200 kg N/ha while the phosphorus rates were 0 and 100 kg P_2O_5/ ha. Guayule was transplanted in the field in May 2021, after the seedlings were raised in the greenhouse for 4 months. Fertilizer application occurred about three months after transplanting. Plant growth measurements assessed included plant height, canopy width, stem diameter, and plant leaf chlorophyll. Harvest measurements included plant dry biomass, resin, and rubber content. Results of samples collected after one year (May 2022) of growth in the field showed no statistical significance of treatment effects on all the measured growth and yield parameters. Although no significant differences were observed between the treatments, the plant dry matter, canopy width, and plant leaf chlorophyll index were slightly higher in treatment with the highest nitrogen and phosphorus levels. On the other hand, the average resin and rubber contents were slightly lower in the treatments with high levels of nitrogen though not statistically different from other treatments. The trial will continue until the final harvest when plants are two years old to assess the effect of fertilizer treatments on guayule growth and yields.

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6. FUNGISTATIC EFFECT OF GUAYULE RESIN AGAINST DAIRY PRODUCT FUNGI

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Defects caused by undesirable molds may appear during the cheese-making process. To avoid this, the cheese industry currently uses authorized synthetic compounds to control them, but consumers are increasingly inclined towards foods made up of more natural ingredients and are rejecting those that contain chemical compounds in their formulation. In this work, different guayule (*Parthenium argentatum*) resin fractions were assayed against two molds, *Penicillium verrucosum* and *Aspergillus flavus*, that cause alterations in the dairy industry which entail serious economic losses and could produce mycotoxins. Reverse phase-flash chromatography technique (Biotage Sfär C18D-Duo 100A- 30 µm cartridge, flow 50 ml/min, 60:40 acetonitrile:water to 100% acetonitrile in 25 min) was used to fractionate the guayule resin in three different fractions. The most polar one (F1_gCD) was mainly composed of polar guayulins C and D, fraction F2_aA by argentatin A and, finally, fraction F3_gAB by apolar guayulins A and B. PDA plates containing the different fractions at 5 and 10 mg/ml concentration, previously diluted with acetone, were produced. The two molds (10 µl of a suspension between 1 to $5 \cdot 10^5$ conidia/mL) were inoculated in a 1 cm diameter disk filter previously placed in the center of the fortified plates. Plates of PDA medium with acetone and plates with the inoculum alone were used as controls. After an incubation period of 9 days (25 ºC), the results of each plate were analyzed with the Countermat flash equipment (IUL S.A., Barcelona, Spain) to obtain a precise image of each one. The diameter of the growth zones was determined using ImageJ v1.52a software. Contrary to what was expected, guayulins C and D showed fungistatic activity, an activity that was not shown by guayulins A and B, nor by argentatin A. After 9 days of incubation, fraction F1_gCD had reduced between 40-50% the molds growth in comparison with the controls. Less resistance to guayulins effect was observed in the genus *Penicillium* than in the genus *Aspergillus*. Results were more visible at concentrations of 10 mg/mL. Tests should be carried out with the isolated pure compounds to determine their potential industrial application since the activity shown as an enriched fraction was moderate.

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7. CORRELATION OF THE ARGENTATINS QUANTITATION BY LC-HRMS AND FLOW INJECTION ANALYSIS (FIA-HRMS) IN THE GUAYULE RESIN

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Argentatins, tetracyclic-type triterpenoids, are the most abundant compounds in guayule (*Parthenium argentatum*) resin. Recently, these compounds have attracted researchers' attention due to their anti-inflammatory and antitumorigenic activity. Previously, the analysis of argentatin compounds has been carried out by liquid chromatography combined with mass spectrometry, or by derivatization before analyzing them with a UV detector, as they showed a weak absorption in the UV region. While such techniques provide extensive coverage and characterization of the metabolome, the chromatographic step is time-consuming (e.g. 30 min per sample for LC-MS). There are other techniques with the absence of chromatographic separation, such as Flow Injection Analysis (FIA) which let the simultaneous introduction of all the analytes into the mass spectrometer allowing successful sample classification and quantification in some cases. A precise and accurate method for the quantification of argentatins A and B by FIA has been developed with the support of standards. Afterwards, the quantification of these two argentatins was carried out in 135 different guayule resin samples by LC and FIA. The spectrometer used in both methods was a Q Exactive orbitrap (HRMS) technology. In the case of argentatin A, the recovery offered by FIA-HRMS was 82.4% compared to LC-HRMS with a CV of 16.4%. Mean data resulted equal and the dispersion of the variances was not significantly different when both analytical methods were compared. Therefore, the data populations in case of argentatin A were considered similar, and FIA-HRMS method comparable to the LC-HRMS. For argentatin B, on the contrary, there was a recovery of 384.2% with the FIA-HRMS method and a CV of 29.7%. This overestimation reflected that there were several compounds apart from argentatin B with the *m/z* signal 457.3676 $[M+H]^+$, such as argentatin H and different fragments generated during analysis, for instance from argentatin C. In this case, the data populations were significantly different, although the factor between the results provided by both techniques was constant. For this reason, this test method could be considered, at least, as a predictive method by using this correction factor.

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8. COMPARATIVE ANALYSIS OF RUBBER BIOSYNTHESIS IN GUAYULE (*Parthenium argentatum* Gray) AMONG DIFFERENT GROWING LOCATIONS IN THE US

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The perennial shrub guayule (*Parthenium argentatum*), indigenous to the Chihuahuan desert of Mexico and the Southwestern US, is currently being cultivated as a source of domestic natural rubber (NR) in the US and elsewhere. NR is a *cis*-1,4-polyisoprene polymer of wide range industrial importance. In guayule, as in all rubber-producing plants (and some fungi), NR is biosynthesized by an enzymatic complex known as rubber transferase (RuT). The RuT is presumed to be localized on the surface of a cellular organelle known as rubber particle. Extracted washed rubber particles (WRP) from guayule stem tissue retain RuT activity. The concentration of NR in guayule tissues is dependent upon the shrub's genetic background, the growing environment (such as soil type, water input, and climate), and the interaction between genetics and environment. It is well established that rubber biosynthesis, aka RuT activity, increases dramatically upon cold stress triggered by low temperatures during the winter months of the growing season. Understanding the molecular basis of this unique cold-inducible mechanism and how the environment influences it is invaluable for breeding high rubber-producing guayule varieties. A field study is underway at three US locations (Eloy, AZ, Parlier, CA, and Salinas, CA) all planted with the guayule AZ-6 line. We harvested stem tissues of one-year-old plants at three different time points: pre-cold induction, cold-induction, and post-cold induction and extracted WRP from plant stem tissue. Harvest dates varied among locations and were carefully determined by monitoring day and night temperatures. First harvest was in October 2021 and the last one in January 2022. Rubber biosynthesis was quantified by testing the RuT activity of the extracted WRPs. Comparative analysis of the interactions between NR biosynthesis levels and location and harvest time will be presented.

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9. ANALYZING SUSTAINABLE NITROGEN NUTRITION FOR EFFICIENT CAMELINA PRODUCTION

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Nitrogen is the most abundant fertilizer used globally, with over 100 million tons per year applied worldwide. Nitrogen fertilization is necessary to increase crop production to meet the rising demand for food security and plant-based products as the worldwide population continues to grow. However, nitrogen fertilization has many negative impacts on soil and the environment. Overuse of nitrogen fertilization can lead to decreases in soil organic matter and nitrogen availability, greater water contamination from runoff, and contributes to increased greenhouse gases. *Camelina sativa*, an oilseed plant with multiple potential uses including biofuel production, oil and soap production, and livestock feed. Our study aims to determine the phenotypic response of multiple camelina accessions to high (1X) and low (0.1X) nitrogen fertilization concentrations. We used hydroponic systems to evaluate three different camelina accessions grown in modified Hoagland solutions. To determine the impact of nitrogen availability on camelina development we assessed end point growth patterns and germination rates. We evaluated 3 storage times for camelina germination success. In low nitrogen conditions, camelina height decreased by over 20%, branch numbers decreased by more than 50% and successful germination was reduced, compared to optimal nitrogen conditions. Overall, nitrogen conditions had a greater impact on camelina growth than genotype. Germination assays showed an interactive impact of maternal nutrient conditions and genotype and an impact of storage time. Our study directly contributes to decision making for most advantageous management practices needed to promote camelina productivity. Determining the optimal nitrogen conditions for camelina will contribute to further the industrialization of this developing crop while minimizing the harmful damage to the environment. By evaluating development benchmarks, we can increase our predictive power for determining successful camelina production.

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10. ISO-OLEIC ESTOLIDES WITH SUPERIOR COLD FLOW PROPERTIES

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One of the drawbacks of using vegetable oils directly as lubricants is their poor performance at low temperature [pour points (PP) and cloud points (CP)]. Various approaches have been used over the years to overcome this disadvantage including the use of expensive pour point depressant (PPD) additives. Chemical modification of vegetable oils has also been used to lower PP and CP. However, such products still require blending PPD additives to meet PP and CP specifications for some high-volume applications, such as engine oils, gear oils, and hydraulics. These and other problems continue to depress the global market share of bio-based lubricants to under 1%. Oleic estolides were developed to improve these properties as well as increase the oxidative stability and improve the low temperature properties of these new oils. Estolides are biobased synthetic esters obtained from the reaction of a fatty acid with a double bond (e.g., oleic acid), hydroxyl group (e.g., ricinoleic acid), or epoxide on its chain, with a second fatty acid of similar or different structure, in the presence of a catalyst. A new series of iso-oleic estolide free acids and 2-ethylhexyl (2-EH) esters capped with various fatty acids had superior physical properties and cold flow properties, compared to traditional oleic based estolides. The average pour point of the iso-oleic estolide 2-EH esters was -41ºC, compared to -23ºC of iso-oleic estolide free acids. The iso-oleic-octanoic and iso-oleic-decanoic estolide 2-EH esters had excellent pour points of -60ºC. The cold flow properties of iso-oleic estolides decrease with increasing the carbon number of the saturated capping fatty acid, while the viscosity index and oxidation stability were only slightly improved. Therefore, saturated mid-chain fatty acids are more suitable as the capping fatty acid for iso-oleic acid based estolides. Iso-oleic-coconut estolide 2-EH esters exhibited good physical properties, with pour points as low as -45ºC. The iso-oleic estolide free acids and 2-EH esters are a new kind of low-cost materials for bio-lubricants with excellent cold flow properties.

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11. INDUSTRIAL GRAIN HEMP VARIETY TRIAL IN ILLINOIS – 2021

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Industrial hemp (*Cannabis sativa* L.) field trials consisting of two grain varieties (Henola and USO 31) and four multi-purpose varieties (NWG 2463, 2730, 4000, and 4113) were conducted to evaluate their suitability for commercial production in Illinois. Overall agronomic performance and grain quality traits were evaluated. The experimental plot was of Flanagan silt loam type with 2% slope. The field was fertilized with liquid urea ammonium nitrate (UAN) at 112 kg/ha. An alpha-lattice experimental design with four replicates and plots of six 19 cm rows x 4.9 m in length were employed. Target seeding rates were 160 and 270 pure live seeds/m^2 and planting depth was 2.0-2.5 cm. Vegetative samples taken from all varieties tested below the legal limit of 0.3% THC. Harvested grains were dried for 48 hours at 60 ^oC, cleaned, and then weighed to determine grain yields. Grains were analyzed for oil, crude protein, ash, and total carbohydrates contents. The fatty acid composition of the oils was also determined. Conditions in Illinois were ideal during the entire 2021 industrial hemp growing season. Emergence started to occur four days after planting (DAP) but no variety achieved the target population after two weeks. Ninety percent flowering was attained 48 DAP. Hemp was able to outcompete most weeds observed which had relatively low abundance in the plots used for compiling yield data. Weed pressure increased as plants senesced, and canopies opened or in plots with poor emergence. USO 31 and Henola plants were shorter at 129 and 139 cm, respectively, compared with the 160-180 cm height of NWG varieties. Grain yields from Henola and NWG lines varied from 140 to 166 g/m^2 while that of USO 31 was much lower (38-50 g/m^2) due to late harvest. USO 31 had the largest grain (15.7 g/1000 seeds) and NWG 2730 had the smallest grain (12.5 g/1000 seeds). However, the true density of the grains of all varieties were the same (1.13 g/cc). The grain's oil content varied from 28.4 to 32.3% while the crude protein content was the same (24.8 ± 0.3%). Fatty acid composition of the oil is typical of hemp, with the major fatty acids being linoleic (55.6 ± 1.0 %), α-linolenic (16.2 ± 1.2%), oleic (12.9 ± 0.5%), and palmitic (7.6 ± 0.3%). Seed quality parameters (germination, emergence, vigor, etc.) are highly variable across and within hemp varieties/cultivars and germplasm sources and must be accounted for to ensure good stand establishment and development. The varieties evaluated were able to be planted and harvested using conventional field equipment common to Midwestern crop production systems. However, more research will be needed to determine which cultivars are best suited to Illinois conditions to produce a grain of high yield and quality.

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12. NATURAL VARIATION IN BIOMASS ROBUSTNESS OF *CAMELINA SATIVA*

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Individual plants grow differently under identical conditions, which is a hindrance to producers. Ideal plants predictably produce yields that producers can rely upon. *Camelina sativa* is an oilseed plant that can be utilized for renewable biofuel and cosmetics. Camelina is adapted to many different environments and is favored for its cold hardiness and relatively short growing season. Camelina is under development as an oilseed crop, requiring improvement to yield and quality. Camelina accessions provide variation in critical traits for improvement, including oil content, speed of growth, number of leaves, and nitrogen requirements. Across these traits, an accession's ability to maintain consistent characteristics under identical conditions in isogenic individuals is known as robustness. We hypothesized that some accessions would be more robust than others. Our research addresses the robustness of these accessions through measuring the aboveground biomass of young plants. In this experiment, we examined 72 accessions with 40 replicates of each, resulting in a sample size that enables highly accurate estimates of robustness. We observed a large degree of variability in dry mass across individual plants. Robustness was estimated using the statistical CV (coefficient of variation) for each accession. We then explored the genetic control of biomass robustness, through the approach of a genome-wide association study, given that the accessions examined have been sequenced. Understanding the robustness of this crop is important for determining which accessions may be most viable for commercial use.

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13. DEVELOPMENT OF A RAPID ASSAY FOR TOTAL GLUCOSINOLATE CONTENT IN PENNYCRESS (*Thlaspi arvense* L.) SEED BY MEASUREMENT OF ENZYMATICALLY RELEASED GLUCOSE USING A BLOOD GLUCOSE METER AND TEST STRIPS

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Field pennycress, *Thlaspi arvense* L., is a new oil seed cover crop being commercialized as a source of biofuel in the United States. Along the path to commercialization, pennycress seed and meal will be marketed as animal feed. As a member of the Brassicaceae family, pennycress seed is abundant in glucosinolates which are anti-nutritional factors that make the seed and meal less palatable to animals. As work continues to develop varieties low in glucosinolates, a rapid assay is needed to determine the total glucosinolates in pennycress seed. A rapid assay to determine the total glucosinolate content in pennycress seed was developed using a blood glucose meter and test strips. Pennycress seeds were ground in a potassium phosphate buffer. The addition of myrosinase to ground seeds in the buffer catalyzed the enzymatic hydrolysis of glucosinolates to equimolar amounts of glucose. Glucose content was determined using a blood glucose meter and test strips. From the molar concentration of glucose, the molar concentration of glucosinolates was known and glucosinolate level in seeds was calculated in µmol/g. The results were confirmed by LC/MS analysis. This rapid and inexpensive assay will allow breeders to efficiently screen materials for improved seed meal characteristics for livestock feed.

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14. CAMELINA (CAMELINA SATIVA L. CRANTZ) ON MARGINAL SOILS IN EUROPE

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Camelina (*Camelina sativa* L. Crantz) is an annual multi-purpose oilseed crop, belonging to the *Brassicaceae* family, native of Europe. Camelina is highly suitable to different pedo-climates, and the availability of both winter and spring types further expands its cultivation basin to whole Europe. Additionally, the low agricultural input requirement, the very short growing cycle, and the tolerance against many biotic and abiotic stresses have made camelina a good candidate for areas characterized by marginal soils. At this scope, in the framework of the MAGIC project (GA 727698), several field trials were established across Europe, under different marginality conditions, to test the feasibility of camelina, being this oilseed identified as the industrial crop with the widest environmental adaptability matched with relevant annual species. The aim of the present study is therefore to provide and analyze the results of field trials carried out at four different European locations, characterized by different marginality constraints, namely adverse terrain conditions (steep slope >12%) in Italy; low soil fertility (pH < 4.5) and adverse terrain conditions (steep slope >12%) in Greece; limitations in rooting (rooting depth < 30 cm, stoniness > 15% of the texture) in Germany and in Poland (sand > 40% and clay > 50% of the texture). The trails were performed either as replicated plots or in large strips (≈1000 m^2) to evaluate not only the suitability of camelina to the different test environments but also the technical feasibility of the crop on marginal soils. All trials were performed for two or three growing seasons from 2018 to 2021. The best camelina genotype available at each trial site was used, namely Cypress (Smart Earth Camelina, Canada) in Italy, Luna and Omega (Poznan University, Poland) in Greece and Poland, respectively, and WURZ (Wageningen Research, The Netherlands) in Germany. In details, in Italy and Greece, camelina was grown with an autumn cycle, while in Poland and Germany with a spring cycle. Camelina confirmed its good suitability to marginal soils, even if, as expected seed yield was significantly reduced, but the crop never failed completely. Depending on the trial site and the level of marginality faced seed yield reductions ranged between 50 to 75%, for example in Italy under mild-marginal conditions camelina yielded about 2 Mg DM ha^{-1}, which dropped down to 0.5 Mg DM ha^{-1} when it was grown under very steep slope at 25%. Nevertheless, seed quality (i.e. 1000-seed weight, seed oil content, etc.) seemed not only maintained stable also on marginal soils but to some extent even improved. In fact, again in Italy, seed oil content was 37.5% under mild-marginal condition and 40% under very marginal condition ($P \leq 0.05$). This type of long-term multi-location trials finally permitted to define the real suitability of camelina to European marginal soils, thus allowing the future scale-up of the crop also in such areas, which may represent a potential basin of growth of several million of hectares.

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15. CARINATA AS A COVER CROP FOR NORTHERN ITALY

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Carinata (*Brassica carinata*) is receiving renewed interest worldwide in relation to its suitability to different environmental conditions and cropping systems (i.e., cover cropping, double and relay-cropping, etc.). Carinata is an oilseed crop belonging to the *Brassicaceae* family, and it's well known for its plasticity and low input requirements. In recent years, the development of new genetic material suitable for different environments and management types, allowed not only to further expand the growing area of the crop but also the certification as a low iLUC (Indirect Land Use Change) feedstock to produce liquid biofuel from carinata oil. In this context, a preliminary screening trial has been established at the experimental farm of Bologna University at Cadriano (44°32'58" N, 11° 24'32" E) to test the suitability of new improved carinata genotypes as a summer cover crop in that area. The possibility to establish carinata after the harvest of a winter cereal would represent a new opportunity for this promising non-food oilseed crop. The screening trial has been carried out from June to September 2021, and comparing nine different carinata cultivars: six from the breeding program of Nuseed – cv.1 DH-129.B036, Cv. 2 HYB062, Cv. 3 HYB079, Cv. 4 HYB094, Cv. 5 HYB096, Cv. 6 HYB097-, and three from the breeding program of AAFC (Canada) – Cv.7 GIP 6634, Cv. 8 GID 6091, Cv. 9 GID 6084. The growing season was extremely dry with less than 30 mm of precipitation from sowing to harvest compared with a 20-year mean five times higher, thus external irrigation was needed at least for the first two months to allow carinata to establish well. This exceptional drought was also associated with high pest pressure, in particular flea beetles (*Altica oleracea*) which are endemic in the region, needed to be chemically controlled several times after emergence until the end of July. Some differences among cultivars emerged significantly concerning growing cycle duration and the suitability to be grown as a summer cover crop. In particular, generally all the hybrid materials were able to reach maturity by the end of September, while the inbred cultivars were significantly slower, and Cv. 9 never reached maturity. Seed yield resulted also significantly affected by cultivar choice, and in particular all the Nuseed genotypes were significantly more productive than the ones from AAFC. The seed yield ranged between 1.25 g DM plant^{-1} in Cv. 5 and 0.10 g DM plant^{-1} in Cv. 8. Thousand seed weight was higher than in previous studies and the grain mean exceeded 4.5 g, and differences among genotypes were negligible. The present study permitted to highlight the feasibility of carinata as a summer cover crop for the northern Mediterranean environment but great attention should be paid to cultivar choice, pests and irrigation needs which might significantly reduce the future acceptability of this crop by local farmers.

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16. AMINE COMPATIBILIZATION OF CELLULOSE NANOCRYSTALS TO IMPROVE DISPERSION AND PHYSICO-MECHANICAL PROPERTIES IN HIGH DENSITY POLYETHYLENE POLYMER

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Cellulose nanocrystals (CNC) can be used as potential reinforcements in polymer composites because of their easy accessibility, biodegradability, light weight, and superior mechanical properties. The central challenge faced to produce polymer composites is to disperse CNC uniformly in the polymer matrix. In this research, amine treatment was used to functionalize the surface hydroxyl groups of CNC. Nanoscale in-situ fabrication of ZnO on CNC scaffold was also studied. At first, the surface hydroxyl groups of CNC were epoxy functionalized using epichlorohydrin (10 mmols) and then the epoxy groups were opened with 15 mL of 30% ammonium hydroxide solution to introduce primary amino groups. ZnO nanoparticles were prepared using zinc acetate and sodium hydroxide in aqueous dispersion of CNC. These nanoparticles were deposited on both modified and unmodified CNC scaffolds in different concentrations by controlling the stoichiometry of zinc salt to CNC in the system. These scaffolds containing ZnO nanoparticles were incorporated in the high-density polyethylene polymer (HDPE) matrix to prepare composites via melt-blending extrusion process. The composite properties were evaluated using FT-IR, SEM, EDX, DMA and tensile testing. FT-IR spectrographs confirmed grafting of amine onto CNC. SEM micrographs demonstrated highly fibrillar morphology of the composite cross-section. EDX images confirmed the presence of ZnO in the system. A decrease in storage modulus and increase in tan δ of the composites was observed with the increase in amount of ZnO in the system. This can be attributed to the degradation of ZnO at higher temperatures and lowering of molecular weight. The TGA, DSC, horizontal burning test and LOI test are yet to be conducted.

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17. ENHANCING THE MECHANICAL PROPERTIES OF WOOD VIA CELLULOSE NANOCRYSTAL (CNC) IMPREGNATION

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A major challenge in the lumber industry today is the shortage of trees aged for harvest, resulting in builders resorting to the use of alternative and expensive building materials as the price of lumber has increased over 300% from November 2021 to May 2022. As a result, cellulose nanocrystals (CNCs) have excellent potential to be used as a reinforcement in wood because of their inherent biodegradability, universal accessibility, and exceptional mechanical properties. The objective of this research project is to design a method to impregnate cellulose nanocrystals into softwood to enhance its mechanical properties to allow for a sustainable method to use younger trees as construction material. In this research, southern yellow pine (SYP) wood underwent sodium hydroxide treatment to remove lignin obstructing the wood's pores. Then, SYP samples were submerged in CNC/benzoic acid solution. The solution was then subjected to ultrasonication treatment for CNC penetration. This was followed by a vacuum pressure treatment for air pocket removal and CNC impregnation. After treatment, the wood was dried and underwent mechanical testing. It was found that vacuum pressure treatment combined with surface functionalization via benzoic acid increased modulus of rupture (MOR) by 22% and modulus of elasticity (MOE) by 32%. Additionally, Hertzian maps were generated under an atomic force microscope upon running a cantilever beam across a 1 μm^2 area of the sample. This data produced force curves, which allowed for the mapping of the elasticity modulus of a CNC treated sample. It was found that the areas with a CNC presence have a significantly greater elasticity modulus (>3.37 GPa) compared to the rest of the area consisting of SYP (0.63-3 GPa). The results support a novel methodology to improve the mechanical properties of wood.

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18. DEVEOPMENT OF NANOCELLULOSE BASED THERMAL ENERGY STORAGE MATERIAL

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The energy sector is going through massive transformation. It has become faced with challenges in recent years, some of which are the needs to reduce cost and improve lifetime of energy storage devices. In harnessing the latent heat of crystallization, cellulose nanocrystals (CNCs) have shown promise in their ability to enhance the nucleation of crystal growth in subsequent cycles of energy storage/release. The work presented here attempts to develop a salt-based CNC composite material for efficient and sustainable heating as well as dehumidification. The following anhydrous salts have been employed in the study: $CaCl_2$, $MgSO_4$, $MgCl_2$, $SrCl_2$, and LiOH as well as several composite combinations of the species ($MgSO_4$:$SrCl_2$; $SrCl_2$:$CaCl_2$; $CaCl_2$:$MgCl_2$). The objective of our research is to develop the most-promising salt and CNC composite material for effective heat output and potential dehumidification over a period of extended cycling; especially while maintaining the quality of the material. The initial goal of the experimentation and data collection presented here is to develop the design of experiment for the production of sub-micron CNC-impregnated hygroscopic salt particles. Aforementioned anhydrous salts were dissolved in deionized (DI) water to dissolve/disperse particles. Hielscher UIP1000 ultrasound producing device was employed to effectively fragment larger salt particles (>1um) and lower the particle size distribution (PSD). CNC-salt systems were observed using transmission electron microscopy (TEM) for visual evidence of PSD and to verify formation of the composite material. The results have shown the ability of CNCs to nucleate crystal growth of the given salt as well as impregnation of sizable pores that have formed during growth of the salt crystals. The images provide evidence toward the improvement in recyclability of a salt-based thermal energy storage system by the addition of CNC.

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